

STEM IS INSPIRING FUTURE CAREERS

Project no 2021-1-ES01-KA220-SCH-000031524

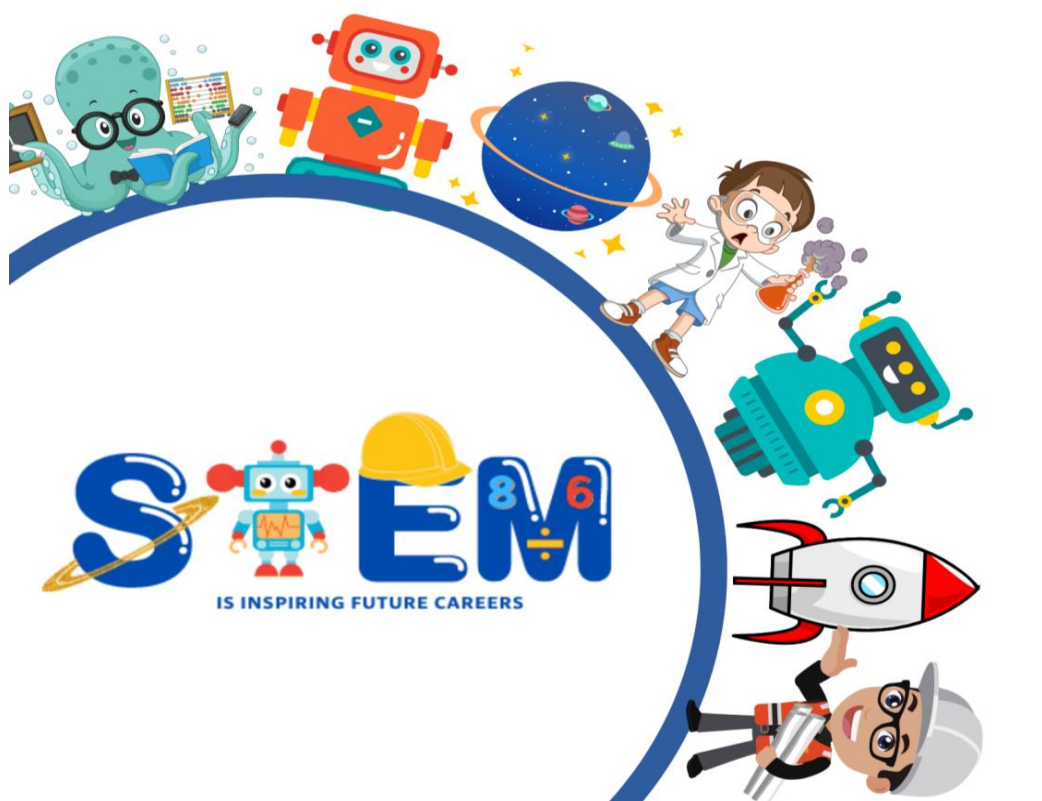
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Coordinated by UNIVERSITY OF A CORUÑA

2023

ENGLISH

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General Index

DOCUMENT 1 – STEM GUIDEBOOK FOR TEACHERS

DOCUMENT 2 – DESK RESEARCH - GUIDELINES



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Developed by UNIVERSITY OF A CORUÑA

2023

ENGLISH



Editors

Almudena Filgueira-Vizoso
Laura Castro-Santos



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Contents

1. OBJECTIVES	1
2. CHAPTER 1. TEACHING STEM THROUGH PROBLEM-BASED AND REAL-LIFE CASE SCENARIOS	3
2.1. A THEORETICAL FRAMEWORK OF STEM EDUCATION	3
2.2. INTEGRATION OF DISCIPLINES AND INTEGRATED STEM EDUCATION	5
2.3. STEM EDUCATION MODELS, STEM LITERACY AND THINKING SKILLS IN STEM EDUCATION	7
3. CHAPTER 2. ENHANCE STUDENT’S SCIENTIFIC BASIC SKILLS THROUGH THEIR ACTIVE INVOLVEMENT IN THE LEARNING PROCESS	13
3.1. DESIGNING A STEM UNIT/LESSON PLAN	13
3.1.1. INTRODUCTION	13
3.1.2. STEPS OF LESSON PLANS	14
3.1.3. STEP 1: PLANNING A STEM LESSON	15
3.1.4. STEP 2: IMPLEMENTING A STEM LESSON	20
3.1.5. STEP 3: EVALUATING A STEM LESSON	21
4. CHAPTER 3. EFFECTIVE USE OF NEW TECHNOLOGIES TO PROMOTE THE STEM KNOWLEDGE	23
4.1. INNOVATIVE ASSESSMENT METHODS IN STEM EDUCATION	23
4.2. GYMKHANA	51
5. CHAPTER 4. TRANSNATIONAL COOPERATION TO PROMOTE STEM KNOWLEDGE IN SCHOOL EDUCATION	99
6. ACKNOWLEDGMENTS	104
7. REFERENCES	106
8. THE PARTNERSHIP	115



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Index of Figures

Figure 1. Theoretical frameworks in STEM. _____	4
Figure 2. STEM Education model considering the four basic colors. _____	6
Figure 3. STEM as an acronym. _____	8
Figure 4. Real-World Problem Solving as Context. _____	9
Figure 5. Science as Context. _____	9
Figure 6. Science, Technology, Engineering and Mathematics as Unconnected Disciplines. _____	10
Figure 7. Integrated Disciplines. _____	10
Figure 8. Engineering Design Process as Context. _____	11
Figure 9. Science and Engineering Design Process as Context. _____	11
Figure 10. Engineering as Context. _____	12
Figure 11. Engineering as Context. _____	16
Figure 12. Example for a STEAM lesson template. _____	17
Figure 13. Example of a lesson plan for a STEAM lesson of renewable energies. _____	18
Figure 14. Teacher-focused methodologies. _____	24
Figure 15. Student-focused methodologies. _____	26
Figure 16. Analysis of documentary sources [32]. _____	27
Figure 17. Collaborative learning [34]. _____	27
Figure 18. Virtual discussion [36]. _____	28
Figure 19. Guided discussion [38]. _____	28
Figure 20. Scheme [40]. _____	29
Figure 21. Study of cases [43]. _____	30
Figure 22. Scientific and/or informative events [45]. _____	30
Figure 23. Virtual Forum [47]. _____	31
Figure 24. Glossary [48]. _____	31
Figure 25. Research (research project) [50]. _____	32
Figure 26. Readings [51]. _____	33
Figure 27. Conceptual map [53]. _____	33
Figure 28. Round table [55]. _____	34
Figure 29. Workshop training [57]. _____	35
Figure 30. Student portfolio [59]. _____	35
Figure 31. Physical activity practice [61]. _____	36
Figure 32. Practices through ICT [63]. _____	36
Figure 33. Clinical practices [65]. _____	37
Figure 34. Laboratory practices [67]. _____	38
Figure 35. Oral presentation [69]. _____	38
Figure 36. Association test [71]. _____	38
Figure 37. Test complete [73]. _____	39
Figure 38. Discrimination test [73]. _____	40
Figure 39. Trial test [74]. _____	41
Figure 40. Sort test [75]. _____	41
Figure 41. Short answer test [77]. _____	42
Figure 42. Multiple choice test [79]. _____	42
Figure 43. Objective test [81]. _____	43
Figure 44. Mixed test [82]. _____	44
Figure 45. Oral test [84]. _____	44
Figure 46. Bibliographic review [85]. _____	45
Figure 47. Summary [86]. _____	46
Figure 48. Field trips [88]. _____	47
Figure 49. Seminar [89]. _____	47
Figure 50. Master session [90]. _____	48
Figure 51. Project Based Learning (ABP) [94]. _____	48



Figure 52. Flipped classroom [98].	49
Figure 53. Scape room [101].	50
Figure 54. Gymkhana [102].	50
Figure 55. Obtention of clues [103].	59
Figure 56. Proposed clues.	60
Figure 57. Maps of the location where the clues will be carried out.	61
Figure 58. Start of the game [104].	62
Figure 59. Team.	62
Figure 60. Clue number 1. Name of the wind turbine.	63
Figure 61. Clue number 2. Wind turbine power per unit.	64
Figure 62. Clue number 3. Availability performance.	65
Figure 63. Clue number 4. Electrical losses performance.	66
Figure 64. Clue number 5. Number of generators.	67
Figure 65. Clue number 6. Location.	68
Figure 66. Clue number 7. Energy produced by one wind turbine.	69
Figure 67. Clue number 8. Design and development.	70
Figure 68. Clue number 9. Manufacturing.	71
Figure 69. Clue number 10. Installation.	72
Figure 70. Clue number 11. Operation cost.	73
Figure 55. Charpy pendulum.	75
Figure 56. Charpy test sample.	75
Figure 57. Fracture surface of samples subjected to the Charpy test.	76
Figure 58. Durometer.	77
Figure 59. Furnace.	78
Figure 60. Tensile test machine and tested sample.	79
Figure 61. Diagram of the transmission and distribution system of electrical energy [105].	83
Figure 62. Connected lamps and detail of the measurements.	86
Figure 63. Modification of the period in the sinusoidal waves with the variation of the frequency [106].	87
Figure 64. Equivalent circuit at resonance.	88
Figure 65. Waveforms of voltage and current intensity for resistive, inductive and capacitive systems [106].	89
Figure 66. Resistive load (top) and inductive and capacitive loads (bottom).	90
Figure 67. System in resonance.	91
Figure 68. Resistive, inductive and capacitive charges (top) and signal at the moment of resonance (bottom).	93
Figure 69. Determining the direction of force [107].	94
Figure 70. Diagram of the assembly of the linear circuit [108].	94
Figure 71. Linear motor shows the device used in this part of the activity.	95
Figure 72. Magnetic field direction [109].	96
Figure 73. Rotation of the sphere inside the motor. It shows snapshots of the metal sphere in different positions inside the stator.	97



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1. Objectives

The aim of this guide is to create a STEM Guidebook for teachers in order to satisfy teachers' needs.

The necessity for developing Teachers' guide is based on the need of them to be empowered to shape the new idea and to be able to pass the message, educate, teach and orient efficiently their students.

This Guidebook can accompany STEM teachers step by step through the method of teaching and learning STEM education. Therefore, the target groups of the present guide are the STEM teachers, teachers in general, schools and finally students.

It is focused on the knowledge of advanced approaches to enhance students' enthusiasm concerning the study of STEM, improving their elementary abilities in Science, Technology, Engineering and Mathematics.

In this context, the present guide is organized in the following chapters:

- Chapter 1: Teaching STEM throughout problem-based and real-life case situations.
- Chapter 2: Enhance students' scientific essential abilities through their active participation in the learning practice.
- Chapter 3: Efficient use of novel technologies to encourage the STEM understanding.
- Chapter 4: Transnational collaboration to stimulate STEM knowledge in schools.

These chapters will describe:

- A theoretical framework of STEM education.
- Integration of disciplines and integrated STEM education.
- STEM education models, STEM literacy and thinking skills in STEM education.
- Designing a STEM unit/lesson plan.
- Innovative assessment methods in STEM education.

This guide will allow staff to have a guideline to enrich their competences related to innovative teaching methodological approach.





2. Chapter 1. Teaching STEM through problem-based and real-life case scenarios

2.1. A theoretical framework of STEM education

Science, Technology, Engineering and Mathematics (STEM) education is the next step in order to solve some of the social and environmental problems of society [1]. All these disciplines have a great importance for the global economy.

The competences of the future, such as: creativity, problem-solving or entrepreneurial, will constitute the basis of our societies. In this context, teachers and professors should improve their pedagogies in order to change schools and universities [2]. However, in many countries, teachers and professors are not guided in teaching STEM. For this reason, the nations should define a theoretical framework of STEM education [3]. It is due to the fact of easy-to-understand and easy-to-implement different practical styles. Therefore, different countries can use these frameworks to their contextual requirements [1].

Diverse STEM lines have been considered in several education contexts, even in the same country [3]. Several authors understand that this is the principal source of misinterpretations of STEM education among teachers and professors [4]. In this sense, four theoretical contexts can be explained (see *Figure 1*):

1. **Pathed STEM education.**
2. **Integrated STEM education.**
3. **Continuum STEM education.**
4. **STEAM (Science, Technology, Engineering, Art and Mathematics)**

Figure 1 shows four different colours: **red** for the disconnection of the four disciplines, **orange** for the connection of only 2 disciplines, **blue** for the connection of 3 disciplines and **green** for the connection of the 4 disciplines. In this context, disciplines are: Science, Technology, Engineering, Mathematics and Arts (in the fourth case).



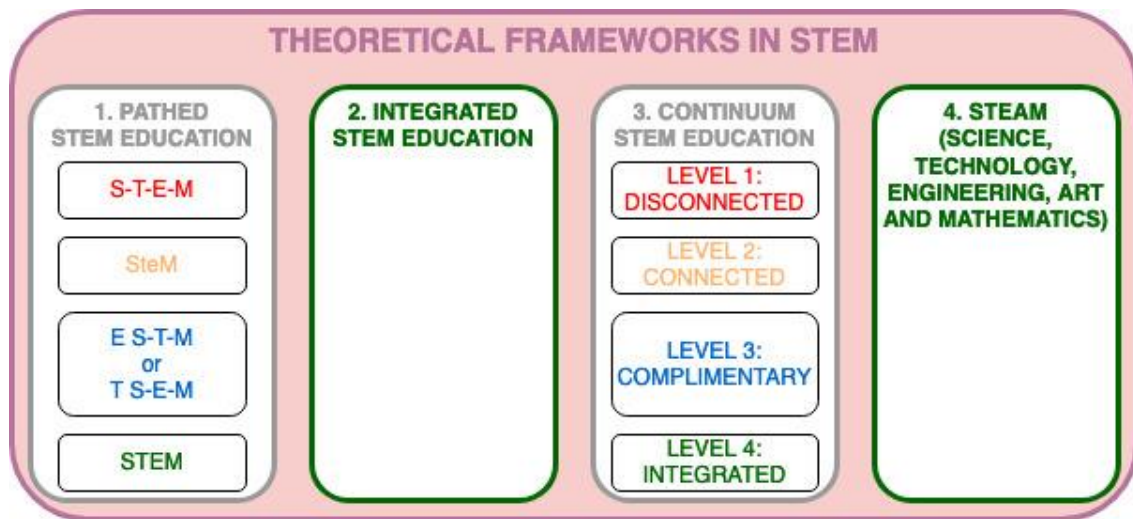


Figure 1. Theoretical frameworks in STEM.

Source: own elaboration.

Firstly, **Pathed STEM education** has four pathways [5]:

- **S-T-E-M**: It considers **individually** each STEM subject. Some people represent this technique of teaching as S-T-E-M to bold its minimal integration.
- **SteM**. It takes into account the combination of **two** (of the four) STEM disciplines. For instance: Science and Mathematics (SteM).
- **E S-T-M**. It studies to mix **one** of the STEM disciplines **into** the other **three**. For instance: engineering content can be joined to science, technology and mathematics (E S-T-M); technology content can be combined with science, engineering and mathematics (T S-E-M).
- **STEM**. It is the infused model of all four disciplines into each other to teach them as an **integrated** subject, which is connected to interdisciplinarity of STEM education. It mixes the four STEM disciplines in one subject. It requires to develop their knowledge and abilities in order to delete the frontiers among the four disciplines. However, this approach achieves that students acquire holistic competences to solve world problems.

Secondly, **Integrated STEM education** is based on an “interconnected entity of disciplines with a strong collaborative connection to life” [6]. It interrelations all types of knowledges, values, languages and skills for integrated them in a whole, such as in

the real life of the students. To achieve this purpose, teachers and professors should improve their knowledge in terms of STEM [6].

Thirdly, **Continuum STEM education** talks about four levels [6]:

- **Level 1: Disconnected.** Individual STEM topics are taught and learnt independently. Therefore, subjects such as mathematics, chemistry or biology live parallel to others in the school curricula, being each one taught by teachers trained specifically to teach it. It decontextualizes learning from real life, being the traditional way of teaching in the twenty century.
- **Level 2: Connected.** It considers linking concerning the areas but considering them separately. There are two options:
 - **Connect 2: mathematics and science.**
 - **Connect 3: E S-T-M.**
- **Level 3: Complimentary.** It wants that teachers explore the interconnections and synergies between the STEM subjects. In this context, the four disciplines are distinctive, but they share matches.
- **Level 4: Integrated.** It is the equivalent to the STEM infused model and the Integrated STEM education. It consists in integrative STEM classroom activities. The four disciplines of STEM are taken into account, but indistinctly. Thus, this level motivates creativity in solving real life problems.

Finally, **STEAM (Science, Technology, Engineering, Art and Mathematics)** considers that “we now live in a world where you cannot understand Science without Technology, which couches most of its research and development in Engineering, which you cannot create without an understanding of the Arts and Mathematics” [7]. Therefore, this view considers STEM + Arts, introducing the interdisciplinary framework to solve the real-world problems and giving a holistic approach of STEM disciplines.

2.2. Integration of disciplines and integrated STEM education

Therefore, considering the differences shown in *Figure 2*, a general approach can be done in order to generalize and summarized the four theoretical frameworks of STEM education. In this sense, *Figure 2* shows the STEM Education model (STEME).



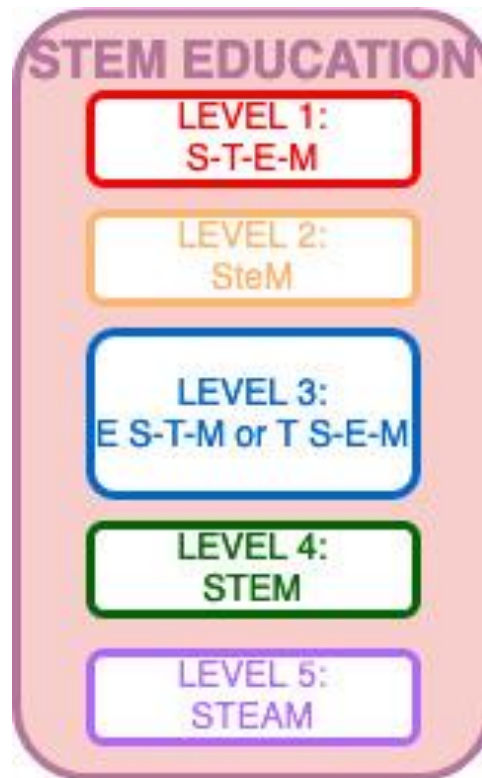


Figure 2. STEM Education model considering the four basic colors.

Source: own elaboration based on [5].

Considering STEM integration, students should [8]:

- Solve problems.
- Invent.
- Innovate.
- Develop logical thinking.
- Be self-rely.
- Know technological literacy.

Level 1 is called S-T-E-M because the four disciplines are separated and disconnected: Science, Technology, Engineering and Mathematics. In this context, integration consists on adding the STEM subject to the school curricula [9]. Usually, this subject is Technology or Engineering. This is the simplest and cheapest way of implementing STEM

education, because you only need to train teachers. For instance, in the case of Galicia (North-West region of Spain) [10], there are a special program called “STEMBACH” which as a new specific subject for this purpose in which teachers from schools and professors from universities share learning.

Level 2 is called SteM integration because integrate and connect only two disciplines (Science and Mathematics), which difficult more the application to school. The main motivation is that “science leads to the understanding of nature that holds resource for sustaining life” [5]. It is due to the fact that in the real world sciences (such as chemistry, physics or biology) and maths in engineering and technology are integrated [6]. However, for implementing this level it is important that teacher can teach in mathematics a science subject.

Level 3 is called E/T S-T/E-M integration. It consists in integrating of both Technology or Engineering into one of the other three STEM disciplines. For instance: in E S-T-M is engineering which is integrated in Science, Technology and Mathematics; in T S-E-M is technology which is integrated in Science, Engineering and Mathematics.

Level 4 is called STEM integration. It consists in interdisciplinary or multidisciplinary integration. Interdisciplinary is based on STEM teaching incorporates the four disciplines into one unified teaching and learning [5], in terms of knowledge, methods, values, reality and language. In this approach, teachers guide students to join school, society, work and enterprises considering science, technology, engineering and mathematics [11].

Level 5 is called STEAM integration. This concept talks about five disciplines: Science, Technology, Engineering, Art and Mathematics. It also includes people with functional diversity. It considers that Art includes Languages and Social Sciences. It considers that all the real world is connected.

2.3. STEM education models, STEM literacy and thinking skills in STEM education

The theoretical framework of STEM education gave an overview of its different conceptions. In this sense, the existence of these concepts gives great discussions about STEM education and how teachers implement STEM in their schoolroom. These differences also generate a communication frontier between teachers and administrators, who should collaborate in order to elaborate programmatic decisions [12]. In this context, if each is drawing from different conceptions of STEM education,



decisions carried out by administrators may be at chances with teachers' practices [12]. Therefore, being able to share a standard of STEM education turn out to be of great importance for promoting STEM between teachers.

Consequently, it is important to define the different models in what way teachers conceptualize STEM education. Latest research has tried to study this topic [12]. Several researchers have considered elementary pre-service plans to understand how teachers conceptualize STEM. In this sense, Bartels et al. [13] discovered that even after pre-service teachers organized and executed what they considered to STEM modules, they still were not confident in categorizing what STEM education was. They identified that STEM should integrate science, technology, engineering and mathematics, it should be focused on students doing hands-on activities and it was integrated in the real-world learning and problem solving. In this paper, teachers did not know how to implement STEM, being the majority creating science-forward units. It reveals the misperception of STEM that diffuses the literature, more highlighting the fact that STEM education is difficult to conceptualize, which involves the difficulty of its implementation. On the other hand, Radloff et al. [14] found that teachers conceptualized STEM education in ways similar to Bybe et al. [15], who is focused on the relationships between the four concepts (science, technology, engineering and mathematics). Nevertheless, they did not describe how teacher should teach STEM.

Otherwise, Ring et al. [16] studied the STEM conceptions of science teachers, who had participated in a learning of three weeks. They concluded that there are eight common conceptual models among teacher participants in the experience.

In this context, this report will consider the following STEM education models [16] (see figure):

1. **STEM as an acronym.** Models presented a traditional prototype of teaching science and/or mathematics in separate schoolrooms. See *Figure 3*.

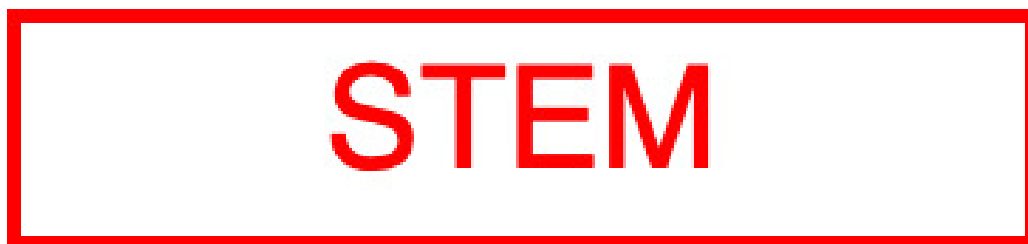


Figure 3. STEM as an acronym.

Source: own elaboration based on [16].



2. **Real-World Problem Solving as Context.** Models exposed STEM education as concentrating on the relationship between school and the real-world, providing backgrounds to make STEM views relevant to students' lives. See *Figure 4*.



Figure 4. Real-World Problem Solving as Context.

Source: own elaboration based on [16].

3. **Science as Context.** Models characterised STEM education as teaching scientific notions while calling upon technology, engineering and mathematics as desired. See *Figure 5*.

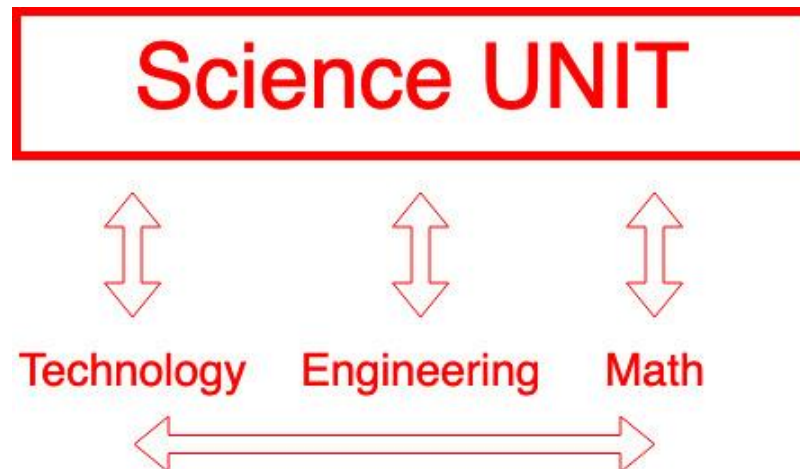


Figure 5. Science as Context.

Source: own elaboration based on [16].

4. **Science, Technology, Engineering and Mathematics as Unconnected Disciplines.** Models showed separated disciplines that involved other disciplines as supporting roles, but these did not incorporate across the disciplines in important ways. See *Figure 6*.

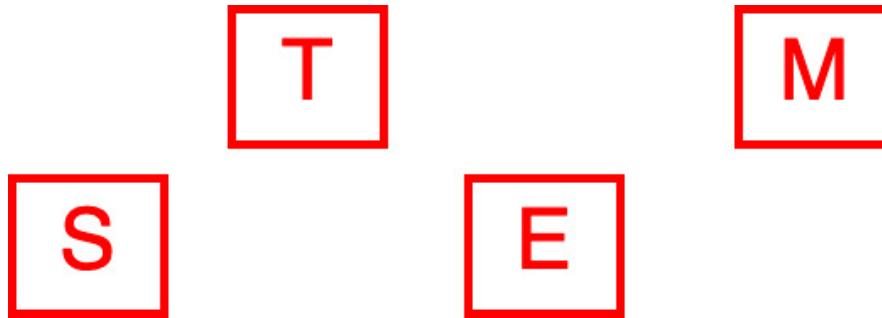


Figure 6. Science, Technology, Engineering and Mathematics as Unconnected Disciplines.

Source: own elaboration based on [16].

5. **Integrated Disciplines.** Models had mechanisms that represented the convergence of science, technology, engineering and mathematics teaching. See *Figure 7*.

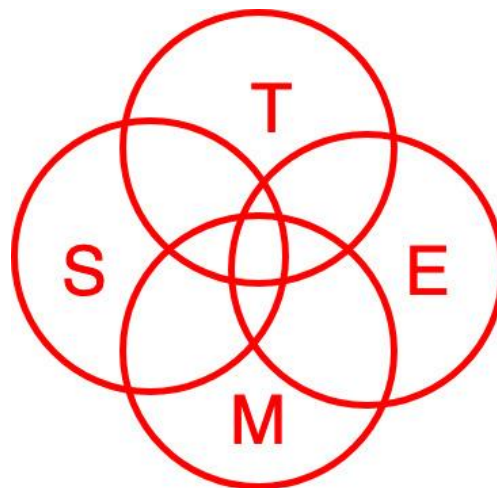


Figure 7. Integrated Disciplines.

Source: own elaboration based on [16].

6. **Engineering Design Process as Context.** Models concentrated on the iterative development of engineering design as the process by which schoolchildren learn science and mathematics models using technology. See *Figure 8*.

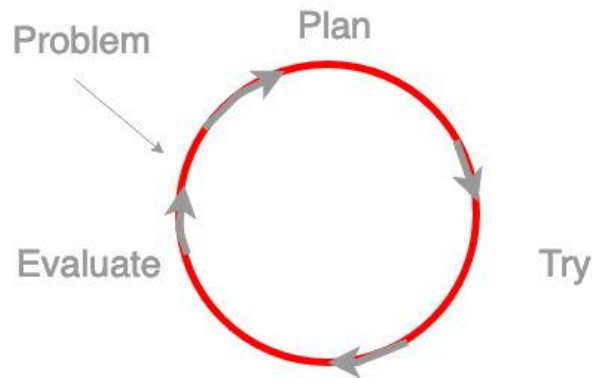


Figure 8. Engineering Design Process as Context.

Source: own elaboration based on [16].

7. **Science and Engineering Design Process as Context.** Models employed an equal importance on teaching scientific concepts and the engineering design process using technology and mathematical concepts when it is applicable. See *Figure 9*.

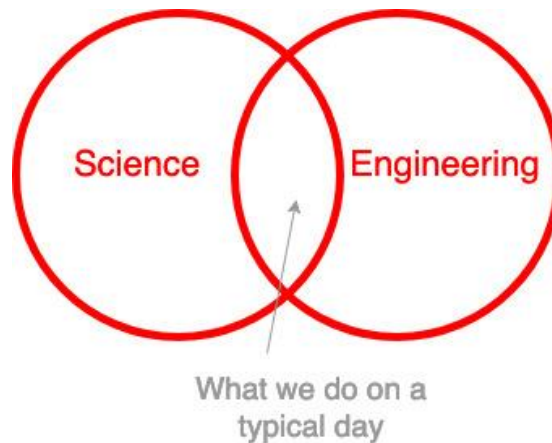


Figure 9. Science and Engineering Design Process as Context.

Source: own elaboration based on [16].



8. **Engineering as Context.** Models characterised an emphasis on engineering calling upon science, technology and mathematics as required. See *Figure 10*.

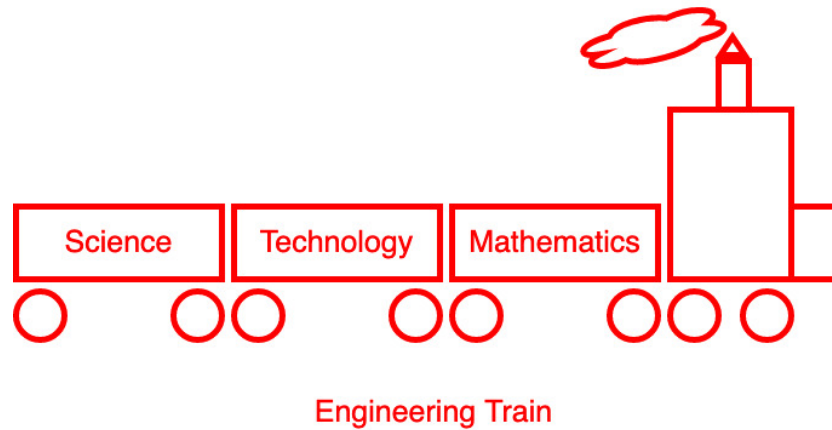


Figure 10. Engineering as Context.

Source: own elaboration based on [16].



3. Chapter 2. Enhance student's scientific basic skills through their active involvement in the learning process

3.1. Designing a STEM unit/lesson plan

3.1.1. Introduction

A lesson plan has two main characteristics [17]:

1. To plan the lesson.
2. To manage the learner during the lesson.

Considering the plan of the lesson, there are a lot of examples of lesson plans of several authors. For instance, Harmer [18] defined the main components of a lesson plan as follows:

1. "Description of the class.
2. Recent work.
3. Objectives.
4. Contents.
5. Additional possibilities."

Nevertheless, it is important to know that the teacher always should adapt the lesson plan provided in a book or a report. In this sense, he/she must create its own lesson plan in order to adapt it to its students. Therefore, this procedure of planning the lesson and adapt it is decisive because he/she will do a lot of decisions to carry out a great lesson of a particular subject.

Regarding the managing of the learner during the lesson, it comprises the following aspects:

1. Causing learners attention.
2. Maintaining their engagement during the lesson.
3. Organizing the students (individually or groups).

All of them are crucial in order to improve the time of the lesson, without losing time during the activities involved.

Thomas S.C. Farrell said that "*planning daily lessons is the end result of a complex planning process that includes the yearly, term, and unit plans*" [17]. He said that "*lesson*



plans are systematic records of a teacher's thoughts about what will be covered during a lesson" [17]. On the other hand, other authors, such as Richards [19], said that a lesson plan support the teacher meditate about her/his lesson in advance, providing a map to follow and reducing complications during the class.

Develop a lesson plan help teachers in several ways:

- Teachers have an impression of be more confident, providing security.
- Teachers learn more their subject.
- It predicts problems before they occur.
- It helps teacher to think about content, resources, timing, activities, etc.
- It is a record of what has been taught, which can help the teacher or his/her substitute in future lessons.
- It takes into account the diversity of the students.

3.1.2. Steps of lesson plans

The prevailing model of a lesson plan is the rational-linear view of Tyler [20], who defined the following steps:

1. Detail objectives.
2. Choice learning activities.
3. Organize learning activities.
4. Identify evaluation.

On the other side, Yinger [21] defined the following phases:

1. Problem conception.
2. Formulate the problem and its solution.
3. Implement the plan and its evaluation.

The present guide is focused on developing STEM lesson plans. In this context, considering the experience of previous authors, it is proposed the following schedule:

1. STEP 1: Planning a STEM lesson plan.



2. STEP 2: Implementing a STEM lesson plan.
3. STEP 3: Evaluating a STEM lesson plan.

Therefore, there are a wide variety of conceptions of developing lesson plans, which involves that we need to define our own method in order to teach for our students.

The design of a lesson plan that can be used for different subjects and for different courses is a laborious process that involves to consider a multitude of factors such as: the age of the students, the type of educational system (which will vary in each country and even in different regions of the same country), the type of subject to be taught, etc. In this case, in terms of the type of subject to be taught, all of them have in common that they are STEM subjects, but despite this common characteristic, there can be big differences between an engineering subject and a science subject.

3.1.3. STEP 1: Planning a STEM lesson

Firstly, the most important aspects of a lesson plan are the **objectives/goals**, which are an explanation of the learning outcome. They describe the purpose that teachers want their students to reach. Therefore, objectives should be clear and well-written. Their appropriate definition help teachers to select the suitable activities, direct the lesson on the right path and evaluate if their students have learned them when they finished the tasks carried out on the lesson.

For explaining the objectives are preferred action verbs [17] such as:

- Identify.
- Describe.
- Demonstrate.
- Calculate.
- Debate.
- Contrast.
- Etc.

All of them help students to comprehend what will be expected from them in the lesson.



Secondly, the plan should describe the **activities and procedures** that will be used to guarantee the effective execution of the purposes. Therefore, teachers should define the objectives and schedule of the activities.

In this context, the main steps of a lesson plan were defined by Shrum and Glisan [17,22] (see Figure 11):

- Opening.
- Stimulation.
- Instruction.
- Closure.
- Follow-up.

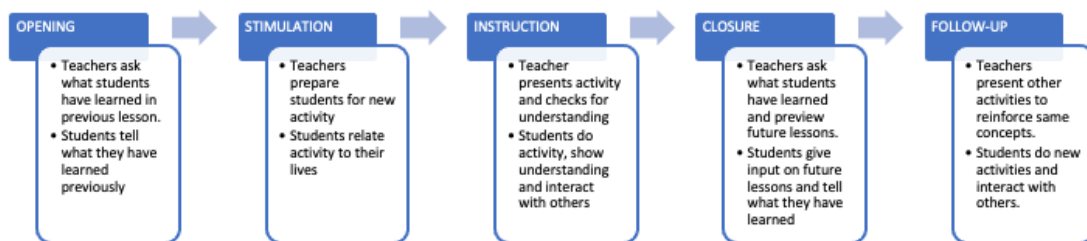


Figure 11. Engineering as Context.

Source: own elaboration based on [22].

In addition to the objectives/goals and the activities and procedures, a STEAM lesson plan can explain other issues such as:

- the name of the lesson plan.
- the subject in which is involved.
- the skills promoted.
- the target audience.
- the typology.
- the duration of the lesson.
- the materials involved in it.

- the way of evaluating the students.
- more information that the teacher considers in order to students achieve the objectives of the lesson plan.

An example of a general lesson plan for a STEM lesson is shown in *Figure 12*.




 Co-funded by the European Union				LESSON PLAN		 UNIVERSIDADE DA CORUÑA			
PHOTO									
Subject: Renewable energies									
Contents: ...		Goals: ➤ ...				Skills: ➤ ...		Subject (s): ...	
Target audience: ...		Typology: ...				Duration/Program: ...			
Materials: ...									
Activities and procedures									
Activity 1: ...									
Activity 2: ...									
...									
Evaluation: ...									
Know +: ...									

Figure 12. Example for a STEAM lesson template.

Source: own elaboration.

An example of a particular STEAM lesson of renewable energies is shown in *Figure 13*.

Subject: Renewable energies			
<p>Contents: Getting to Know the energy of an offshore wind farm</p>	<p>Goals:</p> <ul style="list-style-type: none"> ➤ Discover specific themes and topics related to energy. ➤ Discover specific themes and topics related to renewable energies. ➤ Discover specific themes and topics related to marine energy resources. ➤ Discover specific themes and topics related to wind energy. ➤ Discover specific themes and topics related to offshore wind energy. ➤ Recognize the location where installing an offshore wind farm. ➤ Analyze the restrictions to the location of an offshore wind farm. ➤ Characterize the offshore wind energy farm. ➤ Know the power curve of the offshore wind turbine. ➤ Characterize the power curve of the offshore wind turbine. ➤ Calculate the Weibull probability density distribution. ➤ Calculate the energy produced by an offshore wind farm. ➤ Calculate the capacity factor of an offshore wind farm. 	<p>Skills:</p> <ul style="list-style-type: none"> ➤ Learning about the renewable energies. ➤ Understanding the importance of a sustainable and alternative way of producing energy. ➤ Learning about the use of a spreadsheet. ➤ Discovering geographical locations of their region, their country, or the entire world. ➤ Understanding the way of calculating the energy produced. ➤ Know the importance of the units of the International System. ➤ Assessing responsible energy consumption. ➤ Learning to teamwork. ➤ Learning to use truthful bibliographic information. ➤ Learning to do oral presentations. 	<p>Subject (s):</p> <p>Technology Maths Geography</p>
<p>Target audience: 15 age</p>	<p>Typology: Project work</p>	<p>Duration/Program: 60 min</p>	
<p>Materials: Computer devices with internet connection for each student group, Microsoft Excel (licenses will be given by the professor)</p>			

1

Activities and procedures
<p>Activity 1: Before the lesson, students install the Microsoft Excel in their computers. The professor sends to students the spreadsheet template.</p> <p>Activity 2: The students select the location where they want to install the farm. They should enter in the official webpage of ports of their country. In the case of Spain: http://www.puertos.es/es-es/oceanografia/Paginas/portus.aspx. They look for the wind resource parameters (scale parameter, shape parameter, anemometer height) and the depth of the location selected.</p> <p>Activity 3: The students must select if the location selected is valid considering the restrictions (environmental protected areas, navigation areas, etc.) (see the map).</p> <p>Activity 4: The students characterize the offshore wind farm (size and type of offshore wind platform: fixed or floating). They should research the present size of the offshore wind farms in Europe and the main types of offshore wind platforms installed in documents provided by WindEurope (https://windeurope.org/), European Wind Energy Association (EWEA) (https://www.ewea.org/) and National Renewable Energy Laboratory of USA (NREL) (https://www.nrel.gov/).</p> <p>Activity 5: The students will identify the offshore wind turbine according to the platform selected and they should introduce in the spreadsheet its main parameters: power of the turbine (MW), rotor diameter (m), rotor height (m), cut-in speed (m/s), nominal speed (m/s), cut-out speed (m/s).</p> <p>Activity 6: The students will introduce the power curve of the wind turbine selected in the spreadsheet and they will learn how to represent it in an Excel graph.</p> <p>Activity 7: The students will calculate the Weibull probability density distribution in the spreadsheet. They will fill the spreadsheet using the scale parameter and the shape parameter of the offshore wind resource obtained previously. They will use the spreadsheet function =DISTR.WEIBULL(...).</p> <p>Activity 8: The students will calculate the energy produced by one wind turbine, by the farm and its capacity factor.</p> <p>Activity 9: Students will elaborate a report of the entire project and they will do an oral presentation. A specialized jury will evaluate their work.</p> <p>Evaluation: The student discovers the energy produced by an offshore wind farm. They learn new sustainable ways of producing energy, which can make that the countries become more independent in energy terms.</p> <p>Know +: https://windeurope.org/; https://www.ewea.org/; https://www.nrel.gov/; https://www.idae.es/; https://lauracastrosantos.wordpress.com/; https://www.microsoft.com</p>

Figure 13. Example of a lesson plan for a STEAM lesson of renewable energies.

Source: own elaboration.

This lesson plan was designed to be implemented in coordination with teachers of three different subjects: Technology, Mathematics and Geography. Its main objectives/goals are:

- Discover specific themes and topics related to energy.
- Discover specific themes and topics related to renewable energies.
- Discover specific themes and topics related to marine energy resources.
- Discover specific themes and topics related to wind energy.
- Discover specific themes and topics related to offshore wind energy.
- Recognize the location where installing an offshore wind farm.
- Analyze the restrictions to the location of an offshore wind farm.
- Characterize the offshore wind energy farm.
- Know the power curve of the offshore wind turbine.
- Characterize the power curve of the offshore wind turbine.
- Calculate the Weibull probability density distribution.
- Calculate the energy produced by an offshore wind farm.
- Calculate the capacity factor of an offshore wind farm.

And its main activities are the following:

- **Activity 1:** Before the lesson, students install the Microsoft Excel in their computers. The professor sends to students the spreadsheet template.
- **Activity 2:** The students select the location where they want to install the farm. They should enter in the official webpage of ports of their country. In the case of Spain: <http://www.puertos.es/es-es/oceanografia/Paginas/portus.aspx>. They look for the wind resource parameters (scale parameter, shape parameter, anemometer height) and the depth of the location selected.
- **Activity 3:** The students must select if the location selected is valid considering the restrictions (environmental protected areas, navigation areas, etc.) (see the map).



- **Activity 4:** The students characterize the offshore wind farm (size and type of offshore wind platform: fixed or floating). They should research the present size of the offshore wind farms in Europe and the main types of offshore wind platforms installed in documents provided by WindEurope (<https://windeurope.org/>), European Wind Energy Association (EWEA) (<https://www.ewea.org/>) and National Renewable Energy Laboratory of USA (NREL) (<https://www.nrel.gov/>).
- **Activity 5:** The students will identify the offshore wind turbine according to the platform selected and they should introduce in the spreadsheet its main parameters: power of the turbine (MW), rotor diameter (m), rotor height (m), cut-in speed (m/s), nominal speed (m/s), cut-out speed (m/s).
- **Activity 6:** The students will introduce the power curve of the wind turbine selected in the spreadsheet and they will learn how to represent it in an Excel graph.
- **Activity 7:** The students will calculate the Weibull probability density distribution in the spreadsheet. They will fill the spreadsheet using the scale parameter and the shape parameter of the offshore wind resource obtained previously. They will use the spreadsheet function =DISTR.WEIBULL(...).
- **Activity 8:** The students will calculate the energy produced by one wind turbine, by the farm and its capacity factor.
- **Activity 9:** Students will elaborate a report of the entire project and they will do an oral presentation. A specialized jury will evaluate their work.

Obviously, teachers can have adaptations of this general model. However, it is important that the lesson plan always have the objectives and activities clearly defined in order to help teachers and students to follow the lesson.

3.1.4. STEP 2: Implementing a STEM lesson

During the implementation of the STEM lesson plan, it can suffer different modifications due to the fact of unexpected events (a student that makes a lot of questions during the activities, different speeds of learning of students, diversity of the group, etc.). In this context, teachers will do amendments to their lesson planning during the implementation step. Some authors [17] suggest motivations for teachers to vary from the lesson plan scheduled:



- *“When the lesson is going badly and the plan is not helping to produce the desired outcome”.*
- *“When something happens during an early part of the lesson that necessitates improvisation”.*

On the other hand, the implementation of a STEM lesson plan should manage two issues [17]:

1. **Lesson diversity.** It generates attention and interest in students. Teachers can change:
 - The type of interaction in the class: from individual to group, for instance.
 - The type of difficulty: from difficult to easy activities.
2. **Lesson cadency.** It is related to the speed of the evolution of the lesson. In this context, teachers:
 - Cannot go from long to short, mixing the short and long activities.
 - Should do the transitions among activities directly.

3.1.5. STEP 3: Evaluating a STEM lesson

Finally, the last step in developing a STEM lesson plan is the STEP 3, linked to its evaluation. It helps teacher to assess if the lesson was effective or unsuccessful. Therefore, teachers should look for their mistakes during the implementation of their lesson and how to solve them in future implementations of the same STEM lesson. In this sense, the most important issue to be evaluated is if the student has learned the skills and content that were the objective of the lesson.

Some authors, such as Ur [23], explained the criteria for evaluating lesson efficacy as follows:

- *“The class seemed to be learning the material well.*
- *The learners were engaging with the lesson.*
- *The learners enjoyed the lesson and were motivated.*
- *The learners were active all the time.*
- *The lesson went according to plan.*



- *The language was used communicatively throughout”.*

Therefore, teachers can ask themselves and students the efficacy of their STEM lesson [17]:

- What do you consider the students learned?
- Did you complete your lesson on time?
- What activity of the lesson was easier?
- What activity of the lesson was more difficult?
- ...



4. Chapter 3. Effective use of new technologies to promote the STEM knowledge

4.1. Innovative assessment methods in STEM education

There is a general consensus to recognize the importance of educational processes for the development of individuals and societies. An important factor for the educational quality is how the teaching exercise occurs in the classroom, since a good part of the result derives from how the teaching is carried out [24]. Far from being a simplistic activity that anyone can carry out, teaching is a complex and multidimensional act, as it is a task in which someone purposefully and deliberately tries to learn from another [25].

Within education in general we focus our study on STEM subjects. Engineering, science, technology and mathematics are as old as life [26]. From the moment in which society began to count, to transform and to create, it was possible to speak of their development, in order to achieve the ends that were considered convenient at each moment and for each civilization. This has not changed over the years, but at this moment in which the digitalization of daily activities (both domestic and industrial and social) these disciplines become even more important and will be the ones that mark the future of society [27]. For many years, both education from an early age to the university stage has taught its students the necessary contents for their development, but the way of teaching (teaching methodologies) and the way of evaluating it has varied a lot [28].

Initially and for many years, education was based on the role of teachers who gave their lectures and evaluated the knowledge of the students through exams to an education based on the role of the students [29] trying to get the students to commit to their learning process. But this process has been long and has undergone many changes. Numerous approaches have been created for which a wide spectrum of teaching methodologies have been developed. Part of the reason why different teaching technologies appear, especially those that are appearing today, is due to the arrival of new technologies and their numerous possibilities in the student world. They have modified both the ways of learning and the ways of teaching and teachers have been forced to continuously modify their ways of teaching, their teaching materials, the methodologies used, etc.

Below (see *Figure 14*) is a list of the main teaching methodologies prior to or throughout history. *Figure 14* shows those methodologies in which the leading role was focused on



the teaching staff that were in force for many years and *Figure 15* shows the most current methodologies more focused on the student body.

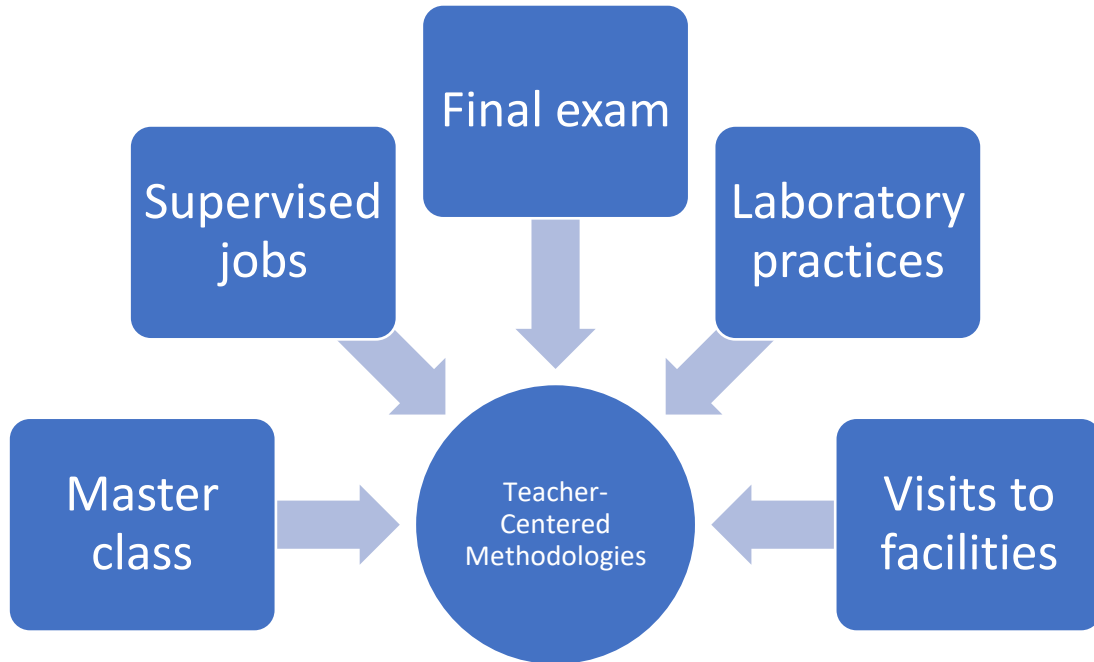


Figure 14. Teacher-focused methodologies.

Source: own elaboration

Teacher-Centered Methodologies

- *Initial activities*
- *Analysis of documentary sources*
- *virtual discussion*
- *guided discussion*
- *Scheme*
- *Study of cases*
- *Scientific and/or informative events*
- *virtual forum*
- *Glossary*
- *Research (research project)*
- *readings*
- *Conceptual map*
- *Round table*
- *Workshop*
- *student portfolio*
- *physical activity practice*
- *Practices through ICT*
- *clinical practices*
- *Laboratory practices*
- *Oral presentation*
- *association test*
- *test complete*
- *discrimination test*
- *trial test*
- *sort test*
- *short answer test*
- *multiple choice test*
- *objective test*
- *mixed test*
- *Oral test*
- *Bibliographic review*
- *Summary*
- *Field trips*
- *Master session*
- *Project Based Learning (ABP)*
- *Flipped classroom*
- *Gymkhana*
- *...*



Figure 15. Student-focused methodologies.

Source: own elaboration

As can be seen in *Figure 14* and *Figure 15*, the range of teaching methodologies has changed to a great extent, going from 5 teaching methodologies, of which the most used were (1) and (3), that is, the master class and the final exam to a range of teaching methodologies of more than 39 most current methodologies more focused on the student body.

Below is an explanation of each of the most used teaching methodologies.

The initial activities are carried out before starting any teaching-learning process in order to know the skills, interests and/or motivations that the students have to achieve the objectives they want to achieve, linked to a training program. With it, it is intended to obtain relevant information that allows articulating teaching to promote effective and significant learning, based on the prior knowledge of the students. [30,31].

Analysis of documentary sources. The methodological technique (see *Figure 16*. Analysis of documentary sources) that involves the use of audiovisual and/or bibliographic documents (fragments of documentary reports or films, current news, graphic panels, photographs, biographies, articles, legislative texts, etc.) relevant to the subject matter with specifically designed activities for your analysis. It can be used as a general introduction to a topic, as a case study application tool, for the explanation of processes that cannot be directly observed, for the presentation of complex situations or as a synthesis of theoretical or practical content [30,31].



Figure 16. Analysis of documentary sources [32].

Collaborative learning (see Figure 17) set of teaching-learning procedures guided in person and/or supported by information and communication technologies, which are based on the organization of the class in small groups in which the students work together to solve assigned tasks. by teachers to optimize their own learning and that of the other members of the group [33].



Figure 17. Collaborative learning [34].

Virtual discussion (see Figure 18) is a group dynamics technique that revolves around a discussion where people talk about a specific topic following a planned scheme. A moderator intervenes, who leads the debate. It is developed through synchronous (chat) or asynchronous (forum) communication tools. [35].

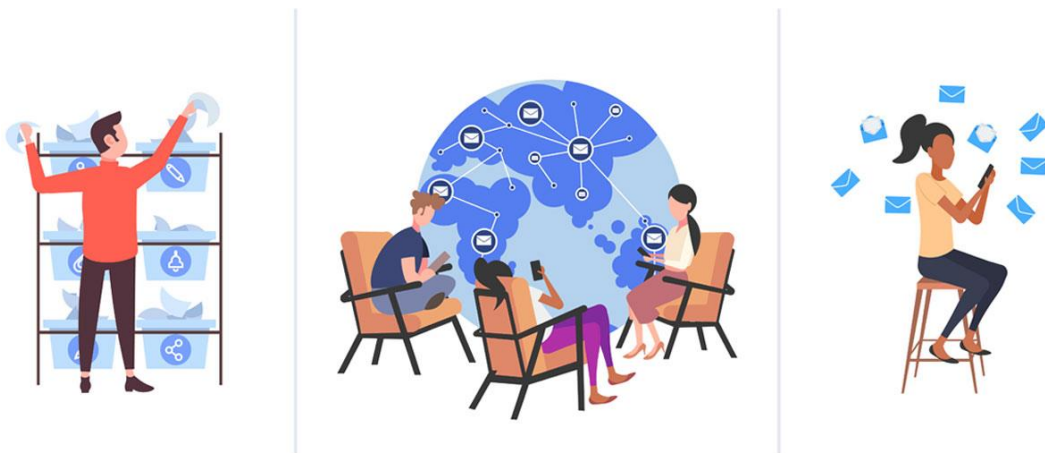


Figure 18. Virtual discussion [36].

Guided discussion (see *Figure 19*) is a group dynamics technique in which the members of a group discuss a topic freely, informally and spontaneously, even though they may be coordinated by a moderator [37].



Figure 19. Guided discussion [38].

A **scheme** (see *Figure 20*) is the graphic and simplified representation of the information that involves certain learning contents. [39].

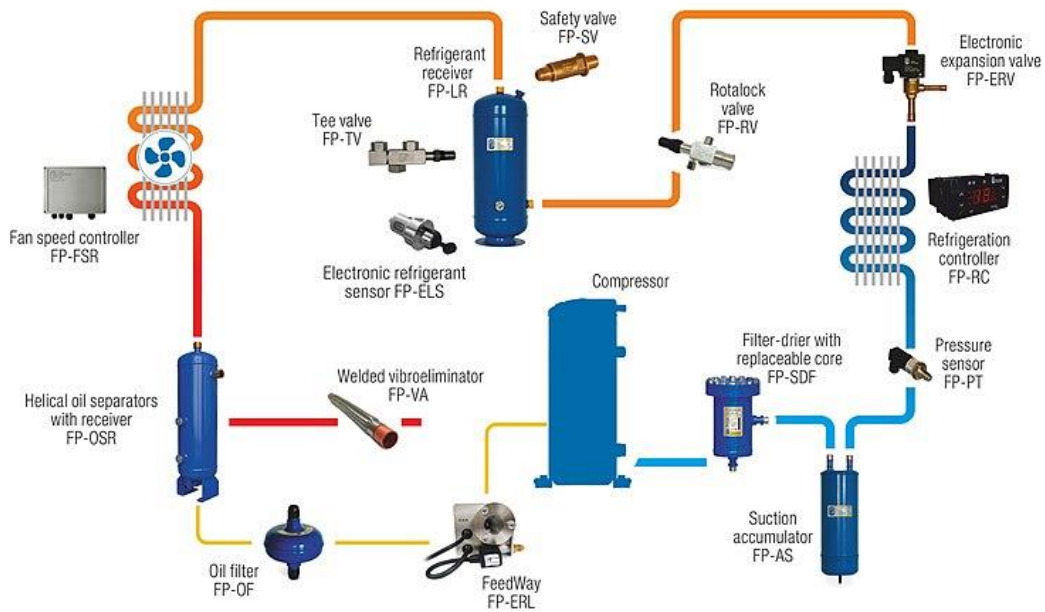


Figure 20. Scheme [40].

Study of cases (see *Figure 21*) is a methodology where the subject faces the explanation of a particular situation that raises a problem that has to be comprehended, regarded and resolved by a group of people, using a debate process. Students are faced with a specific problem (case), which defines a real professional life situation, and they must be able to examine a series of realities, referring to a precise field of knowledge or action, in order to arrive at a reasoned decision through a discussion process in small working groups [41,42].



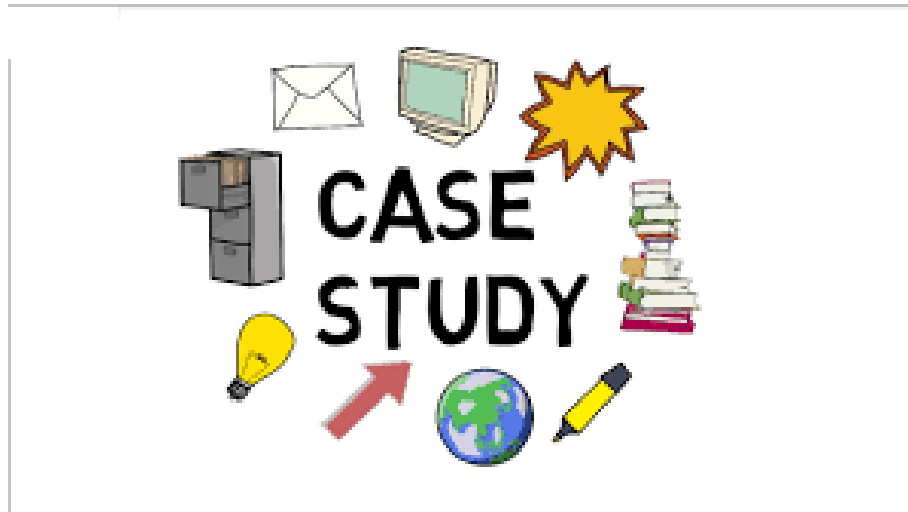


Figure 21. Study of cases [43].

Scientific and/or informative events (See Figure 22) are activities carried out by students that involve attendance and/or participation in scientific and/or informative events (congresses, conferences, symposiums, courses, seminars, conferences, exhibitions, etc.) with the aim of deepening the knowledge of study topics related to the matter. These activities provide students with current knowledge and experiences that incorporate the latest developments in a specific field of study [44].



Figure 22. Scientific and/or informative events [45].



Virtual forum (see *Figure 23*) is an informal discussion space for students to deal with a topic or problem, which is developed through a virtual learning environment using asynchronous communication tools (forum) [46].



Figure 23. Virtual Forum [47].

Glossary (see *Figure 24*) is a resource that consists of the explanation and contextualization of a set of terms or concepts typical of a specialized material to facilitate its understanding.

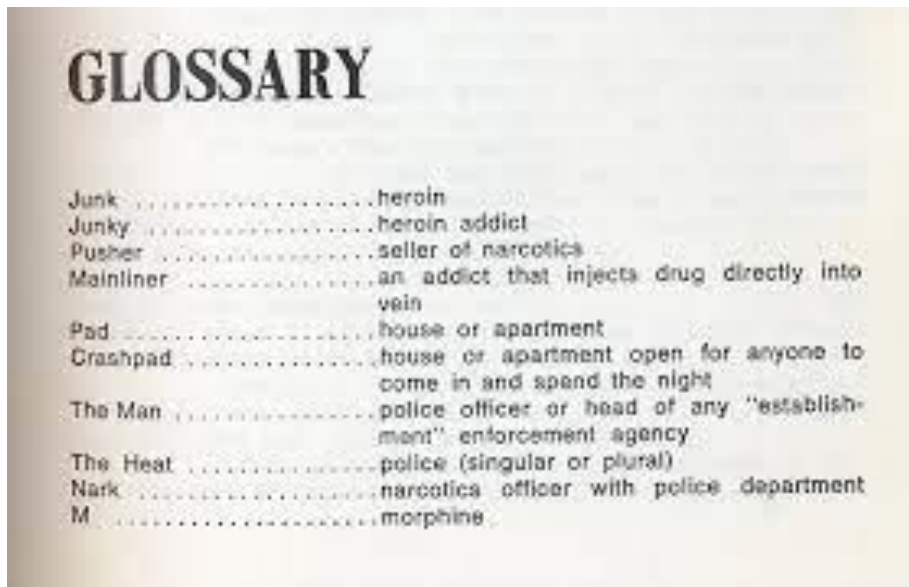


Figure 24. Glossary [48].

Research (research project) (see *Figure 25*) is a Teaching process oriented towards student learning by carrying out practical activities through which situations are proposed that require the student to identify a problem under study, formulate it with precision, develop the relevant procedures, interpret the results and establish the timely conclusions of the work carried out [49].



Figure 25. Research (research project) [50].

Readings (see *Figure 26*) are a set of texts and written documentation that were collected and edited as a source to deepen the content worked on.





Figure 28. Round table [55].

Workshop Training (see Figure 29) is a modality oriented to the application of learning in which various methodologies/tests can be combined (exhibitions, simulations, debates, problem solving, guided practices, etc.) through which students develop eminently practical tasks on a specific topic, with support and supervision of teachers [56].



Figure 29. Workshop training [57].

Student portfolio (see Figure 30) is a folder (physical or virtual) ordered by sections, duly identified or labeled, which contains the records or materials resulting from the learning activities carried out by the students over a period of time, with the comments and grades assigned by the teaching staff. The portfolio or folder includes everything that the student does, such as: notes or class notes, research papers, guides and work and its development, notes comments, summaries, written tests, self-assessments, tasks developed, comments on the student's progress. made by teachers, etc.[58].

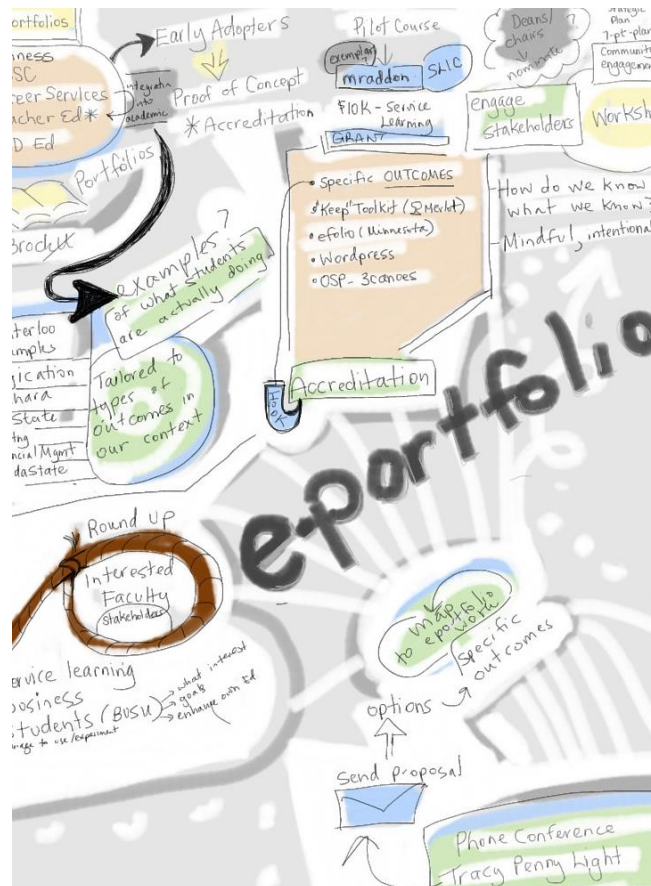


Figure 30. Student portfolio [59].

Physical activity practice (see Figure 31) is a methodology that allows students to learn effectively, through physical and/or sports activities of a practical nature, such as demonstrations, exercises, etc., the execution of the psychomotor and/or sociomotor fundamentals of the different sports skills [60].





Figure 31. Physical activity practice [61].

Practices through ICT (see *Figure 32*) is a method that lets students to learn successfully, using applied activities (demonstrations, simulations, etc.) the theory of a field of knowledge, through the use of information and communication technologies. ICTs are an excellent support and channel for the treatment of information and practical application of knowledge, facilitating learning and the development of skills by students. [62].



Figure 32. Practices through ICT [63].

Clinical practices (see *Figure 33*) can be understood as an instructional process that takes place in a natural environment related to the practice of a profession, in which students observe and participate in clinical activities designed to provide them with opportunities involving the application of related facts, theories and principles. with your practice [64].



Figure 33. Clinical practices [65].

Laboratory practices (see *Figure 34*) is a technique that permits students to learn effectively through practical activities, such as demonstrations, exercises, experiments and investigations [66].



Figure 34. Laboratory practices [67].

Oral presentation (see *Figure 35*) is an intervention inherent to the teaching-learning processes based on verbal exposition through which students and teachers interact in an orderly manner, proposing questions, making clarifications and exposing topics, works, concepts, facts or principles in a dynamic way [68].



Figure 35. Oral presentation [69].

Association test (see *Figure 36*) is an objective test that involves showing a series of features in two parallel columns in which each word, symbol or phrase of one column can be associated with the elements of another column. It consists of establishing relationships with elements of the two groups [70].



Figure 36. Association test [71].

Test complete (see *Figure 37*). The objective test aimed at provoking the memory of a presented learning. A statement is presented that has to be completed at one or more points with a specific phrase, word, figure or symbol [72].

Level	Ciencias sociales y naturales	Lengua	Matemáticas	Inglés	Religión	Total
1 PRIMARIA	16 test. 253 preguntas	21 test. 321 preguntas	24 test. 352 preguntas	12 test. 142 preguntas	11 test. 103 preguntas	84 test. 1.371 preguntas
2 PRIMARIA	17 test. 255 preguntas	26 test. 497 preguntas	26 test. 488 preguntas	11 test. 132 preguntas	11 test. 125 preguntas	91 test. 1.497 preguntas
3 PRIMARIA	17 test. 268 preguntas	23 test. 319 preguntas	18 test. 329 preguntas	13 test. 172 preguntas	11 test. 131 preguntas	82 test. 1.219 preguntas
4 PRIMARIA	18 test. 271 preguntas	29 test. 424 preguntas	19 test. 374 preguntas	9 test. 130 preguntas	9 test. 104 preguntas	84 test. 1.303 preguntas
5 PRIMARIA	21 test. 382 preguntas	25 test. 508 preguntas	17 test. 375 preguntas	11 test. 130 preguntas	9 test. 104 preguntas	83 test. 1.499 preguntas
6 PRIMARIA	18 test. 330 preguntas	22 test. 424 preguntas	15 test. 328 preguntas	9 test. 109 preguntas	9 test. 120 preguntas	73 test. 1.311 preguntas

Figure 37. Test complete [73].

Discrimination test (see *Figure 38*) consists of opting for one of the two options or alternatives that are presented to a given question. The alternative response variants that are presented to the questions formulated can be “yes/no” or “true/false”.

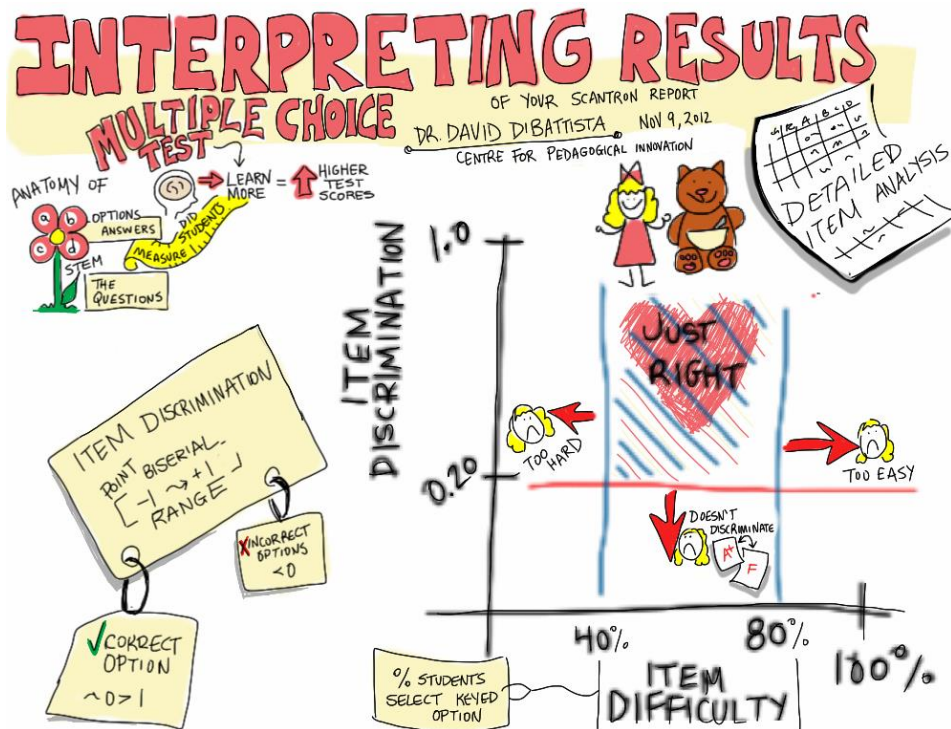


Figure 38. Discrimination test [73].

Trial test (see Figure 39) seeks to answer questions of a certain breadth in writing, assessing whether the expected response is provided, combined with the ability to reason (argue, relate, etc.), creativity, and a critical spirit. It is used for a diagnostic, formative and summative evaluation. It makes it possible to measure skills that cannot be assessed with objective tests, such as the student's ability to criticize, synthesize, compare, write, and originality; Therefore, it implies a comprehensive study of the contents and their relations.

Short answer test (see Figure 41). The objective test aimed at provoking the memory of a presented learning. A statement is presented in the form of a question to be answered with a specific phrase, word, number or symbol [76]

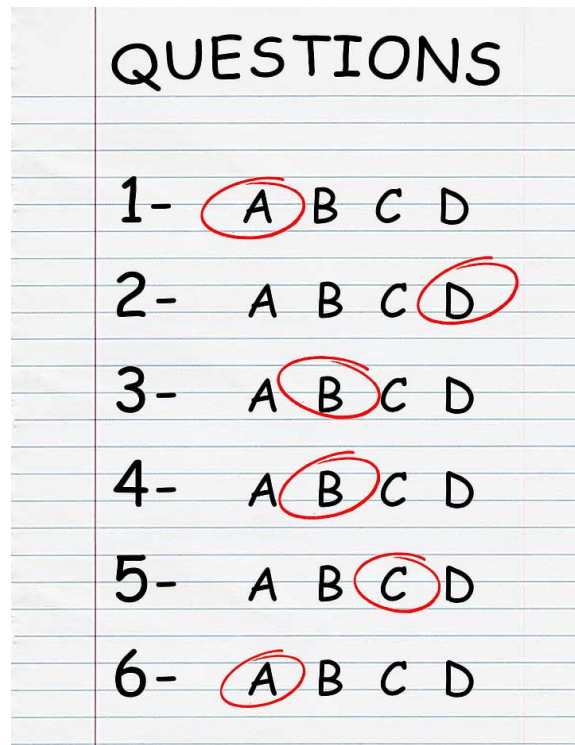


Figure 41. Short answer test [77].

Multiple choice test (see Figure 42) consists of formulating a question in the form of a direct question or incomplete statement, and several options or alternative answers that provide possible solutions, of which only one of them is valid [78].

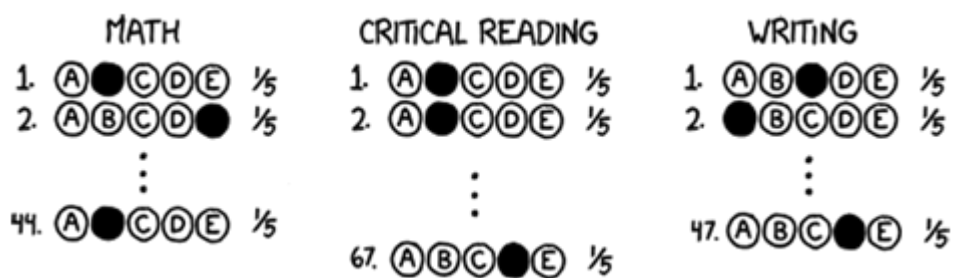


Figure 42. Multiple choice test [79].

Objective test (see Figure 43) used for the evaluation of learning, whose distinctive feature is the possibility of determining if the responses given are right or not. It constitutes a measurement tool, meticulously elaborated, that allows to evaluate knowledge, abilities, skills, performance, aptitudes, attitudes, intelligence, etc. It is applicable to both analytical, formative and summative assessment. The objective test can combine different types of questions: multiple-choice, ordering, short-answer, discrimination, completion, and/or association questions [80].

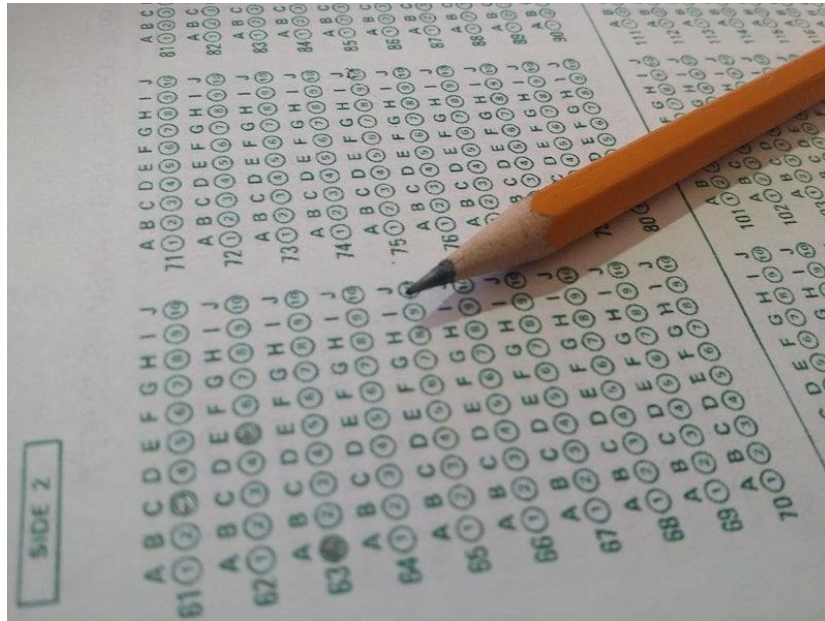


Figure 43. Objective test [81].

Mixed test (see Figure 44) integrates essay test type questions and objective test type questions. Regarding the first, it includes open development questions; the latter can combine multiple-choice, ordering, short-answer, discrimination, completion, and/or association questions.



Figure 44. Mixed test [82].

Oral test (see Figure 45) is a that seeks to answer, orally, short questions or questions of a certain length, assessing the ability to reason (argue, relate, etc.), creativity and critical spirit. It makes it possible to measure skills that cannot be evaluated with objective tests, such as the student's ability to criticize, synthesize, compare, elaborate, and originality; Therefore, it implies a comprehensive study of the contents and their relationships [83].



Figure 45. Oral test [84].

The bibliographic review (see Figure 46) supposes a process of critical reading of a book, an article, a thesis or a communication to a congress. As such process includes the reading of the work, the analysis of its content and its criticism and assessment in relation to the existing literature on a subject. A review does not imply a summary of the work, nor a mere analysis of the content, since what gives it meaning and a scientific academic dimension is the criticism that it deserves, in the opinion of the author of the review, in relation to other known works in the same field or in relation to his own experience.

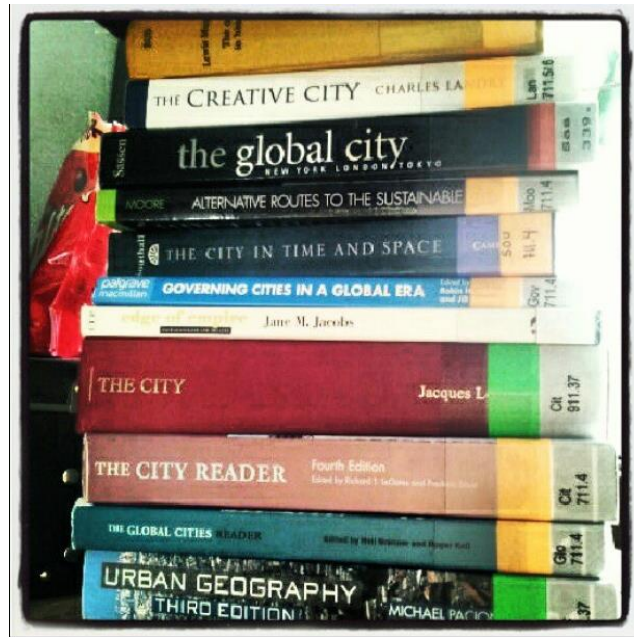


Figure 46. Bibliographic review [85].

Summary (see Figure 47) consists of a synthesis of the main contents worked on. It is an optimal resource to facilitate the understanding of the text and personal concentration on the material under study. It is also an important aid for review and exam preparation.





Figure 47. Summary [86].

Field trips (see Figure 48) are activities carried out in a context outside the university academic environment (companies, institutions, organizations, monuments, etc.) related to the field of study of the subject. These activities focus on the development of capacities related to direct and systematic observation, the collection of information, the development of products (sketches, designs, etc.) [87].



Figure 48. Field trips [88].

Seminar (see Figure 49) is a group work technique whose purpose is the intensive study of a topic. It is characterized by the discussion, participation, preparation of documents and the conclusions that all the components of the seminar have to reach.



Figure 49. Seminar [89].

Master session (see Figure 50) is an oral exposition accompanied by the use of audiovisual media and the introduction of some questions addressed to students, in order to transmit knowledge and facilitate learning. The master class is also known as "conference", "expository method" or "master lesson". This last modality is usually reserved for a special type of lesson given by a teacher on special occasions, with a content that supposes an original elaboration based on the almost exclusive use of the word as a means of transmitting information to the audience.



Figure 50. Master session [90].

Project Based Learning (ABP) (see Figure 51) is a learning methodology in which the student body acquires an effective role and academic enthusiasm is favoured. The method consists of carrying out a project usually in a group. The project has been earlier analysed by the teachers to assure that the students have all they need to solve it, and that in its resolution they will develop all the skills they want [91–93].



Figure 51. Project Based Learning (ABP) [94].



Flipped classroom (see Figure 52) is a learning model that relocate the work of certain learning procedures outside the classroom using class time and the teacher's experience, to simplify and improve other processes of knowledge acquisition and practice within the classroom, supporting all phases of the learning process. learning cycle [95–97].

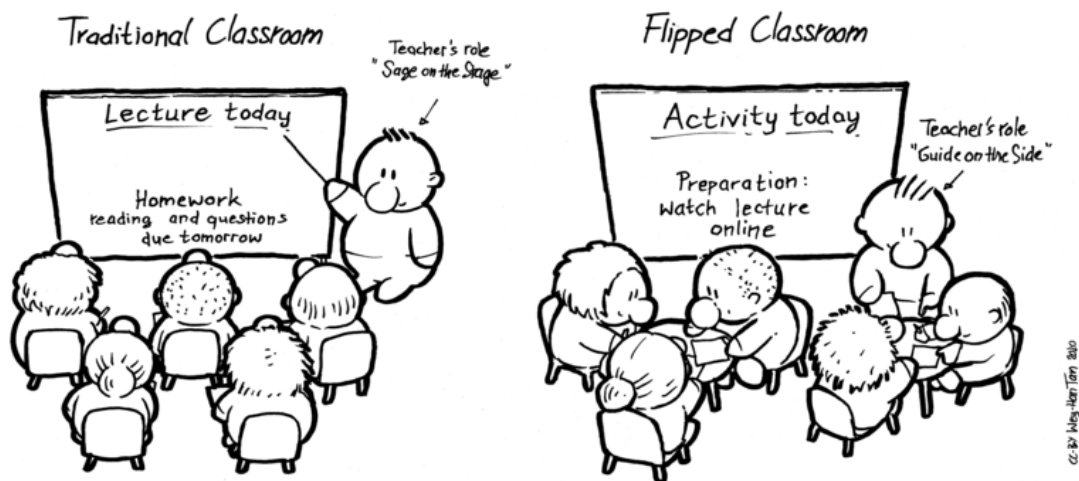


Figure 52. Flipped classroom [98].

Scape room (see Figure 53) is a methodology based on the development of mental abilities to solve enigmas and problems so that students put creativity and critical thinking into play [99,100].



Figure 53. Scape room [101].

Gymkhana (see Figure 54) is a teaching methodology that consists of the set of tests of dexterity or ingenuity that are carried out -always in groups- by teams throughout a course [58,59].



Figure 54. Gymkhana [102].

4.2. Gymkhana

As an example of some of these activities, the following section shows a Gymkhana carried out during a Learning, Teaching and Training (LTT) of this ERASMUS project.

The activity was carried out in the facilities: classrooms, laboratories and common services of the Ferrol Polytechnic School of Engineering, belonging to the University of A Coruña and partner of the Erasmus+ project "STEM Is Inspiring Future Careers".

In this LTT, eleven professors from different STEM degrees (Industrial Engineering, Naval and Ocean Engineering, Economics and Business, etc.) organized an event that consisted of giving the student an initial presentation in which the activity to be carried out was contextualized. In this presentation several questions were shown through different codes and different ways to obtain them. What was intended was to carry out the lesson plan shown below, in this case that of the subject of "Renewable Energies".





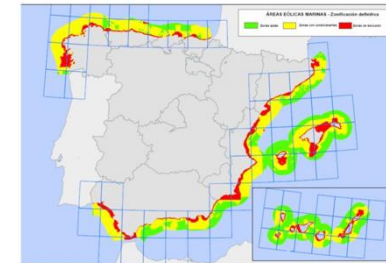
Subject: Renewable energies

Contents:	Goals:	Skills:	Subject (s):
Getting to Know the energy of an offshore wind farm	<ul style="list-style-type: none"> ➤ Discover specific themes and topics related to energy. ➤ Discover specific themes and topics related to renewable energies. 	<ul style="list-style-type: none"> ➤ Learning about the renewable energies. 	Technology Maths

	<ul style="list-style-type: none"> ➤ Discover specific themes and topics related to marine energy resources. ➤ Discover specific themes and topics related to wind energy. ➤ Discover specific themes and topics related to offshore wind energy. ➤ Recognize the location where installing an offshore wind farm. ➤ Analyse the restrictions to the location of an offshore wind farm. ➤ Characterize the offshore wind energy farm. ➤ Know the power curve of the offshore wind turbine. ➤ Characterize the power curve of the offshore wind turbine. ➤ Calculate the Weibull probability density distribution. ➤ Calculate the energy produced by an offshore wind farm. ➤ Calculate the capacity factor of an offshore wind farm. 	<ul style="list-style-type: none"> ➤ Understanding the importance of a sustainable and alternative way of producing energy. ➤ Learning about the use of a spreadsheet. ➤ Discovering geographical locations of their region, their country, or the entire world. ➤ Understanding the way of calculating the energy produced. ➤ Know the importance of the units of the International System. ➤ Assessing responsible energy consumption. ➤ Learning to teamwork. ➤ Learning to use truthful bibliographic information. ➤ Learning to do oral presentations. 	<p>Geography</p>
<p>Target audience:</p>	<p>Typology:</p>	<p>Duration/Program:</p>	



16 – 18 age	Project work	60 min
Materials: Computer devices with internet connection for each student group, Microsoft Excel (licenses will be given by the professor)		
Activities and procedures		
<p>Activity 1: Before the lesson, students install the Microsoft Excel in their computers. The professor send to students the spreadsheet template.</p> <p>Activity 2: The students select the location where they want to install the farm. They should enter in the official webpage of ports of their country. In the case of Spain: http://www.puertos.es/es-es/oceanografia/Paginas/portus.aspx. They look for the wind resource parameters (scale parameter, shape parameter, anemometer height) and the depth of the location selected.</p> <p>Activity 3: The students must select if the location selected is valid considering the restrictions (environmental protected areas, navigation areas, etc.) (see the map).</p> <p>Activity 4: The students characterize the offshore wind farm (size and type of offshore wind platform: fixed or floating). They should research the present size of the offshore wind farms in Europe and the main types of offshore wind platforms installed in documents provided by WindEurope (https://windeurope.org/), European Wind Energy Association (EWEA) (https://www.ewea.org/) and National Renewable Energy Laboratory of USA (NREL) (https://www.nrel.gov/).</p> <p>Activity 5: The students will identify the offshore wind turbine according to the platform selected and they should introduce in the spreadsheet its main parameters: power of the turbine (MW), rotor diameter (m), rotor height (m), cut-in speed (m/s), nominal speed (m/s), cut-out speed (m/s).</p> <p>Activity 6: The students will introduce the power curve of the wind turbine selected in the spreadsheet and they will learn how to represent it in an Excel graph.</p>		





Activity 7: The students will calculate the Weibull probability density distribution in the spreadsheet. They will fill the spreadsheet using the scale parameter and the shape parameter of the offshore wind resource obtained previously. They will use the spreadsheet function =DISTR.WEIBULL(...).

Activity 8: The students will calculate the energy produced by one wind turbine, by the farm and also its capacity factor.

Activity 9: Students will elaborate a report of the entire project and they will do an oral presentation. A specialised jury will evaluate their work.

Evaluation: The student discovers the energy produced by an offshore wind farm. They learn new sustainable ways of producing energy, which can make that the countries become more independent in energy terms.

Know +: <https://windeurope.org/>; <https://www.ewea.org/>; <https://www.nrel.gov/>; <https://www.idae.es/>;
<https://lauracastrosantos.wordpress.com/>; <https://www.microsoft.com>



This activity was carried out in three buildings of the University of A Coruña: Polytechnic School of Engineering of Ferrol Building of Technological Workshops and university cafeteria and for this, a series of tests were carried out in different laboratories in order to obtain the data necessary to solve the problem posed in this lesson plan.

The problem posed consisted of knowing the value of the LCOE (levelized Cost of Energy) for a farm of offshore wind turbines with some input data.

For this, the problem of the generation of electrical energy with respect to greenhouse gas emissions was shown and a possible solution was proposed. To reach the solution it was necessary to have knowledge of renewable energies, in this case offshore wind energy. A brief explanation was made about what offshore wind energy is, the definition of LCOE, and CAPEX and OPEX, showing the necessary formulas for its calculation and subsequent interpretation.



5. CALCULATION

$$LCOE = \frac{\sum_{t=0}^{t=N_{farm}} \frac{LCC_t}{(1+r)^t}}{\sum_{t=0}^{t=N_{farm}} \frac{E_t}{(1+r)^t}}$$

$$LCC = CAPEX + OPEX$$

Being:

- C_1 : Conception and definition cost.
- C_2 : Design and development cost.
- C_3 : Manufacturing cost.
- C_4 : Installation cost.
- C_5 : Exploitation cost.

LCOE (Levelized Cost Of Energy) **is a measure of the average net present cost of electricity generation for a generator over its lifetime.**

It is used for investment planning and to compare different methods of electricity generation on a consistent basis.

$$CAPEX = C_1 + C_2 + C_3 + C_4$$

Capital expenditure (CAPEX) is the money an organization or corporate entity spends to buy or improve its fixed assets, such as buildings, vehicles, equipment, or land.

$$OPEX = C_5$$

Operational expenditure (OPEX) is an ongoing cost for running a product, business, or system

Once these terms were known, they were given an Excel sheet in which the costs they had to find out in order to solve the problem were shown.

5. CALCULATION



I. Características del parque/Characteristics of the farm		
Características GENERADOR/Characteristics of the GENERATOR		
Tipo energía/Type of energy	Energía eólica marina/Offshore Wind energy	Units
Denominación generador/Name of the generator		--
Potencia unitaria/Power per unit		MW
Rta. Disponibilidad/Availability performance		--
Rta. pérdidas eléct. Transmisión/Electrical losses performance		--
Número de generadores (NG)/Number of generators		avogeneradores/wind turbines
Características UBICACIÓN/Characteristics of location		
Punto de ubicación/Location	Costa de Ferrol/Ferrol Shore	
Energía producida por 1 aerogenerador (E1G)/Energy produced by 1 wind turbine		kWh/año
II. Inversión/Investment		
INVERSIÓN INICIAL/INITIAL INVESTMENT	Valor/Value	Units
Diseño y desarrollo/Design and Development (C1 & C2)		€
Fabricación/Manufacturing (C3)		€
Instalación/Installation (C4)		€
Vida del proyecto/Life-cycle of the project	25 años/years	
Razo de construcción/Time of construction	3 años/year	
III. Operación/Operation		
Concept	Valor/Value	Units
Gasto explotación/Operating Costs (C5)		€/año /year
Potencia media/Mean power		MW
F. Capacidad /Capacity factor	#(O)/#I	
Energía vendible por el parque = E = NG*E1G*rendimiento. /Energy sold by the farm		kWh/año /MWh/year
IV. Otros/Others		
Coste del capital/Capital cost		6%
RESULTADOS/RESULTS		
LCOE (€/MWh)		--

MISSING INFORMATION....



Each of these values to find out could be achieved by solving some clues (Figure 55).



Figure 55. Obtention of clues [103].

The tracks were classified into 4 main groups that are:

Group 1. Initial investment and O&M Costs

Group 2. Number of Wind Turbines

Group 3. Characteristics of location

Group 4. Characteristics of the generator

These clues are shown in Figure 56:

Clue	Name	Located in	Related with
#1	Name of the generator	Room 14	Wind turbines
#2	Power per unit	Laboratory of Electricity	Wind turbines
#3	Availability performance	Laboratory of Electricity	Wind turbines
#4	Electrical losses performance	Laboratory of Electricity	Wind turbines
#5	Number of generators	Room 14	Location

#6	Location	Laboratory of Materials	Location
#7	Energy produced by 1 wind turbine	Laboratory of Materials	Costs
#8	Design and Development	Laboratory of Materials	Costs
#9	Manufacturing	Laboratory of Materials	Costs
#10	Installation	Laboratory of Materials	Costs
#11	Operating Costs	Laboratory of Materials	Costs

Figure 56. Proposed clues.

This table shows each of the data that they have to obtain, the track number, the laboratory where they will obtain them and what they are related to (wind turbines, costs or locations at sea). As shown in the table, the clues are color coded depending on whether they are related to the wind turbine (blue), location (yellow) or cost (green).

In order to find the locations in which they had to carry out the inquiries to describe the requested values, they were given a map of the facilities (*Figure 57*).

5. CALCULATION

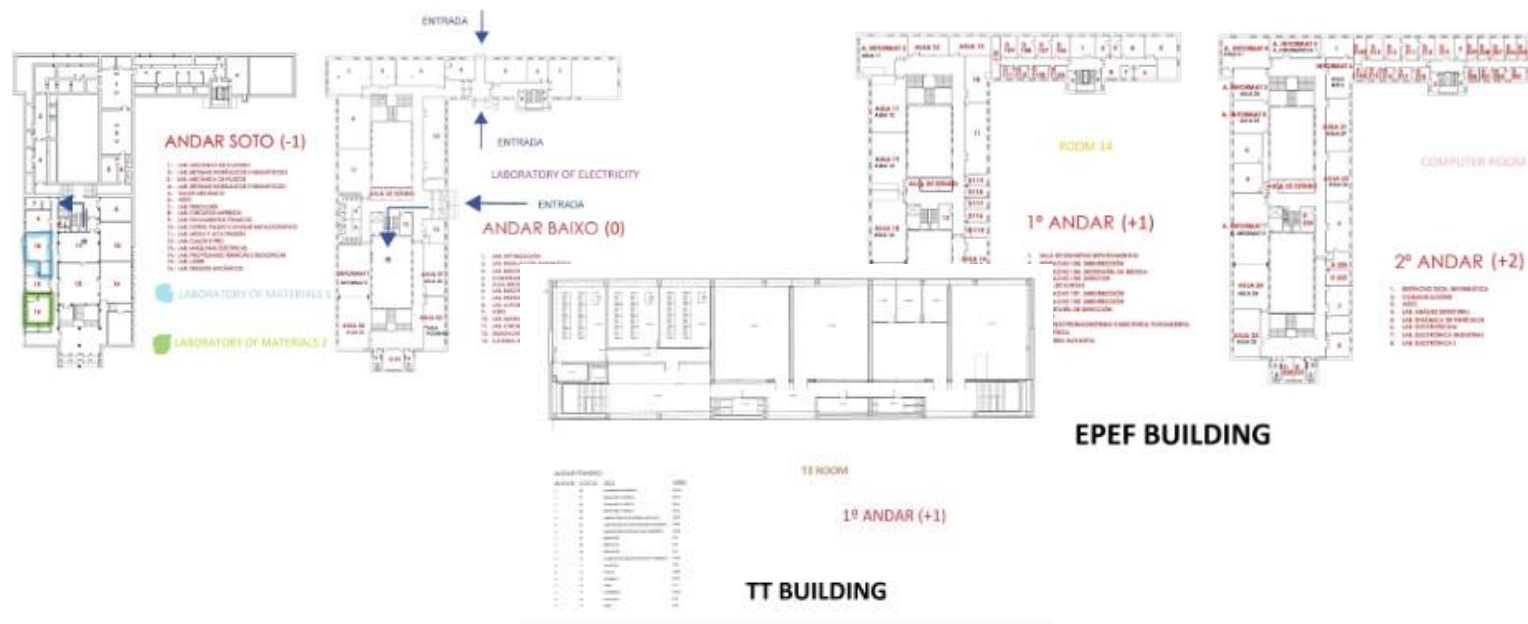


Figure 57. Maps of the location where the clues will be carried out.

And at this moment the game started (Figure 58).



Figure 58. Start of the game_[104].

“In 2022, a command made up of eleven of the best teachers in the European army were sent to prison for a crime they had not committed. They soon escaped from the maximum security prison and hide in the city of Ferrol. Today, still wanted by the government, they survive as professors of fortune. If you have a problem and come across them, maybe you can hire them: The E Team” (Figure 59)



Figure 59. Team.



The clues that were provided to them are shown from *Figure 60* to *Figure 70*.



Figure 60. Clue number 1. Name of the wind turbine.
Source: Own elaboration



Figure 61. Clue number 2. Wind turbine power per unit.

Source: Own elaboration



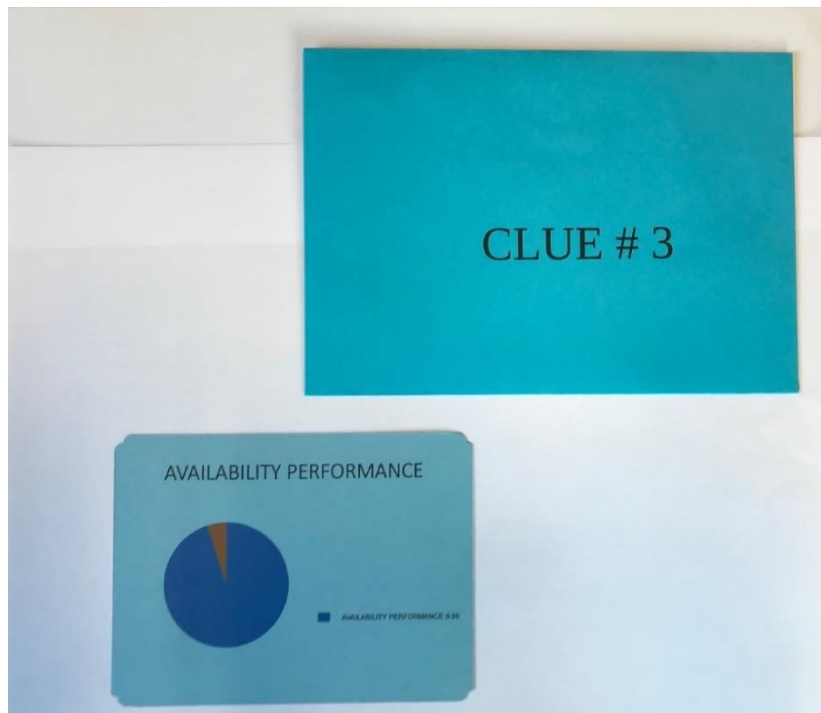


Figure 62. Clue number 3. Availability performance.
Source: Own elaboration



Figure 63. Clue number 4. Electrical losses performance.
Source: Own elaboration

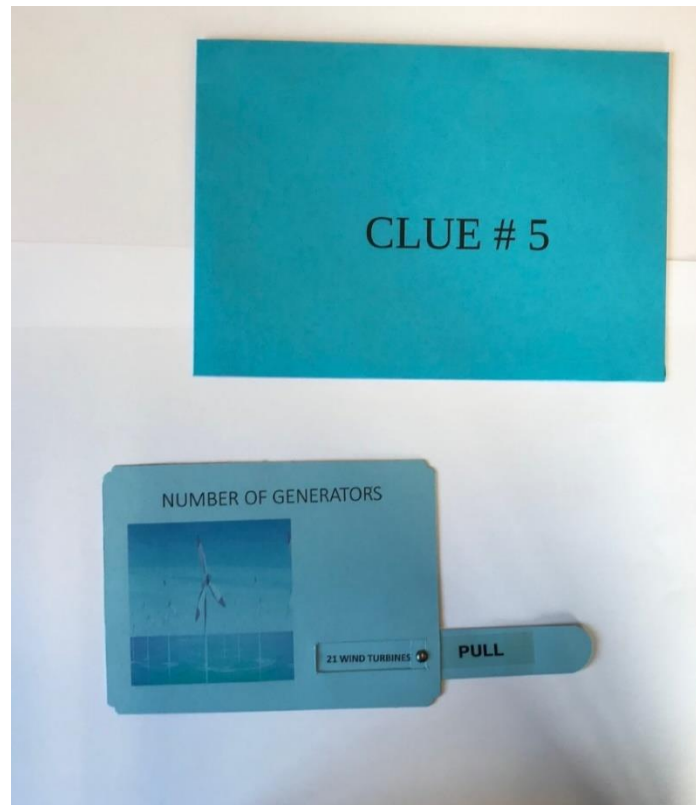


Figure 64. Clue number 5. Number of generators.
Source: Own elaboration



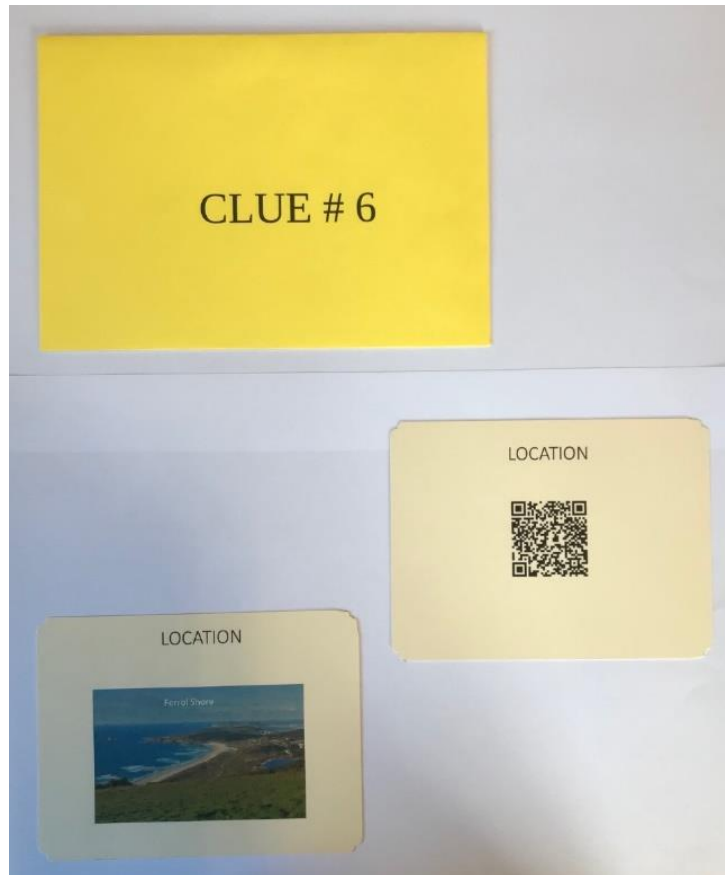


Figure 65. Clue number 6. Location.
Source: Own elaboration



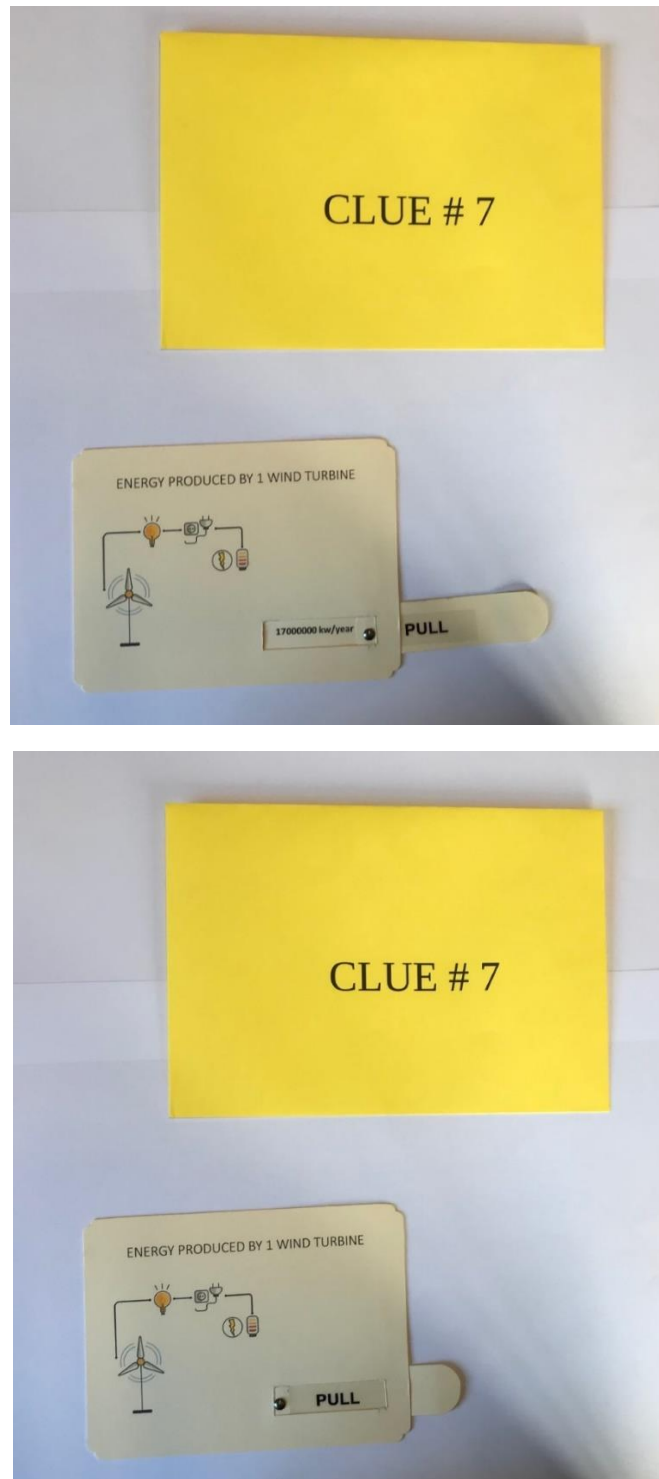


Figure 66. Clue number 7. Energy produced by one wind turbine.

Source: Own elaboration



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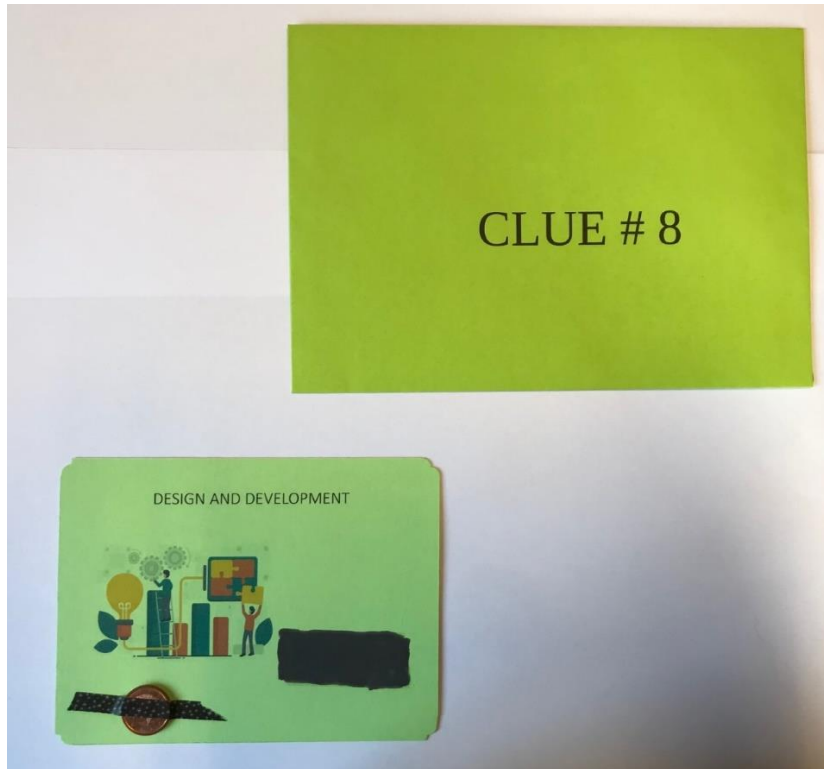


Figure 67. Clue number 8. Design and development.
Source: Own elaboration

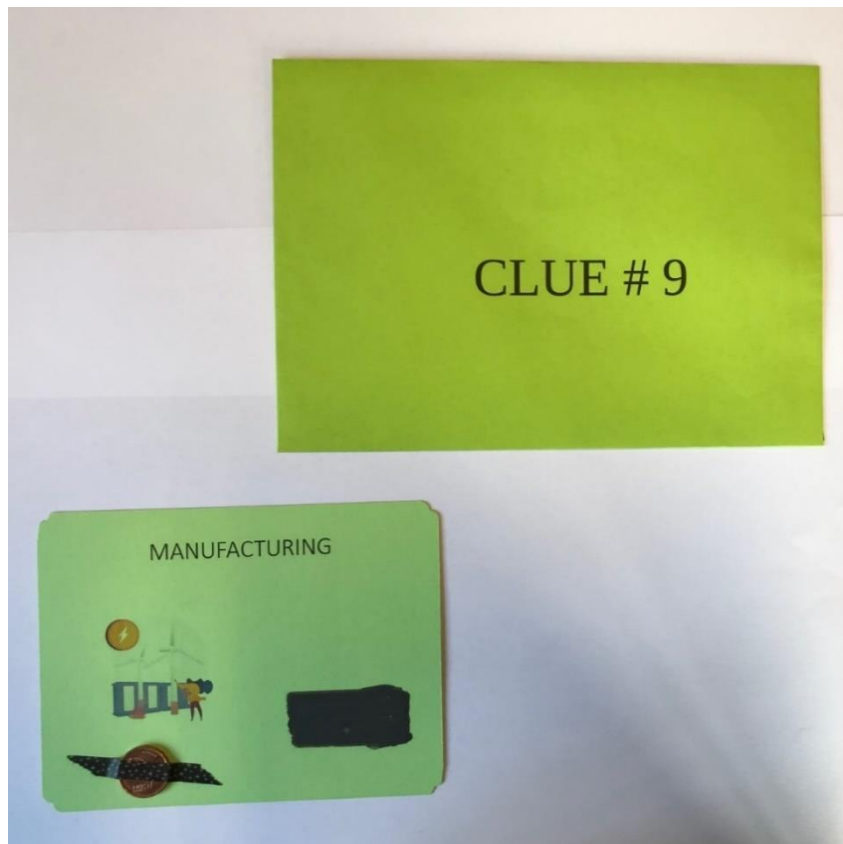


Figure 68. Clue number 9. Manufacturing.
Source: Own elaboration

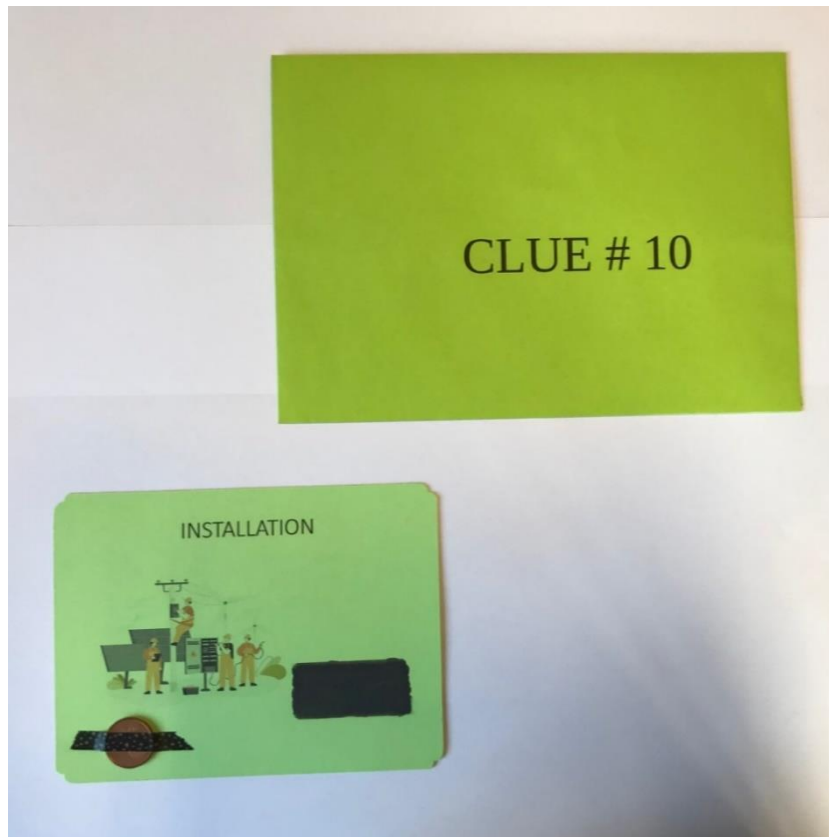


Figure 69. Clue number 10. Installation.
Source: Own elaboration

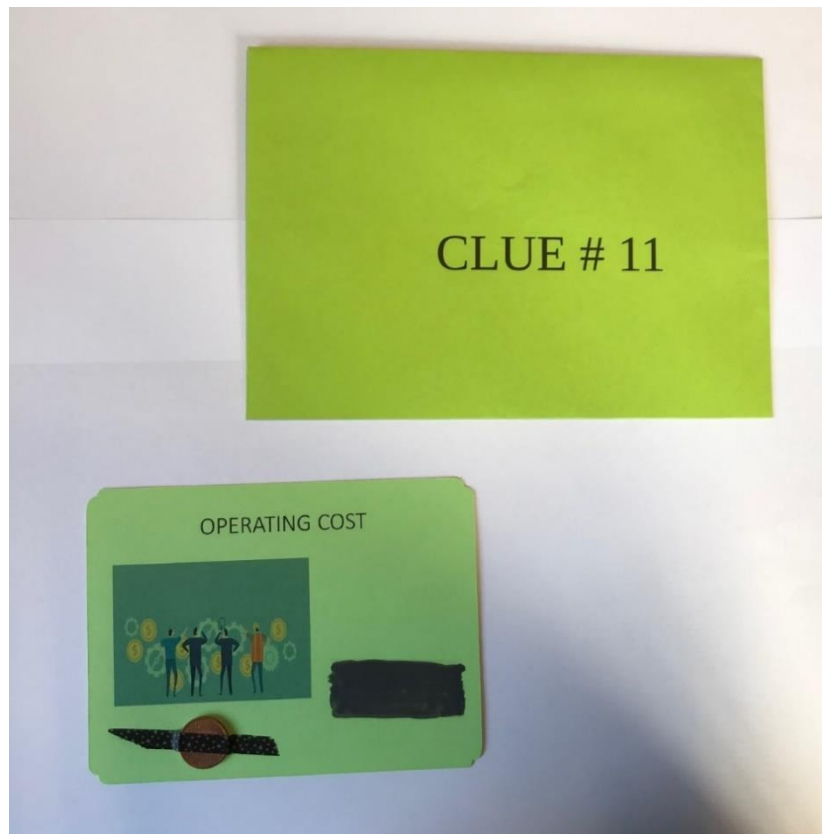


Figure 70. Clue number 11. Operation cost.
Source: Own elaboration

Teaching practices were carried out in different classrooms and laboratories, some of which are shown below:

ONE MATERIAL A SINGLE BEHAVIOUR?

The goal of this activity is to demonstrate two things. On the one hand, two different materials (with different chemical compositions) will have different properties and behaviour, and on the other hand, the same material may have different properties and behaviour depending on the conditions in which it is found.

The activity is divided into several experimental parts, and previously there will be a brief theoretical introduction.

Introduction

The properties of materials are variable, and depend on several circumstances:

- The chemical composition
- The history of the material

With history of the material, we are referring to the previous processes to which it has been subjected. These processes can be thermal (heating-cooling cycles) and previous stresses and deformations. In the case of thermal cycles, the temperature reached and the speed of temperature change must be considered.

Part 1: Different materials-Different behaviour

To demonstrate that the behaviour of the materials depends on the chemical composition, five different materials will be tested, which will be subjected to a Charpy test to determine their brittleness.

The materials evaluated will be:

- Two carbon steels, whose only difference is the carbon content you present: F-114 steel and F-111 steel
- Two stainless steels with different alloying elements: AISI 304 and AISI 316
- pure aluminum

The necessary equipment to evaluate the fragility of the materials will be a Charpy pendulum and a notcher to prepare the samples.



Figure 71 and Figure 72 show the aforementioned equipment and the samples for the test.



Figure 71. Charpy pendulum.

Source: Own elaboration

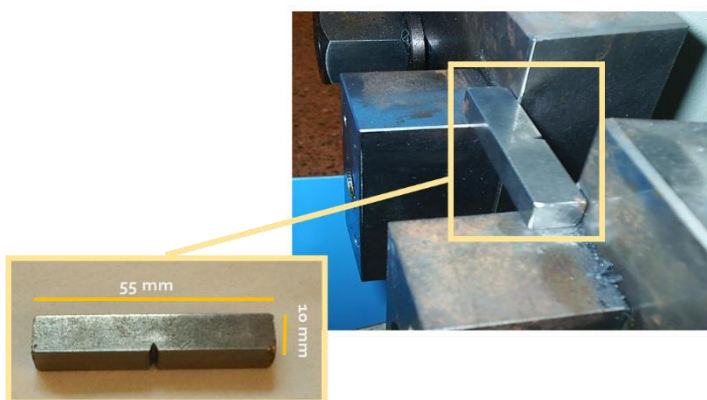


Figure 72. Charpy test sample.

Source: Own elaboration

With this equipment the resistance to brittleness can be measured. The test consists of applying a force in the form of impact to get the sample to fracture. The measure obtained is the energy absorbed by the sample in its deformation and fracture. If the value is high, it means that the material absorbs a lot of energy, therefore it deforms a lot before breaking and it is considered a ductile material. If, on the other hand, the measured value is low, it means that there is no deformation prior to fracture and, therefore, the material is brittle.

In addition to the measured value, an observation of the fracture surface makes it possible to assess whether the material is ductile or brittle. A ductile material will present a dull, deformed surface, while a brittle material will present a shiny, grainy, undeformed surface. When the behavior is intermediate, it will be possible to observe a surface with a typically ductile fraction and the other typically brittle (Figure 73).

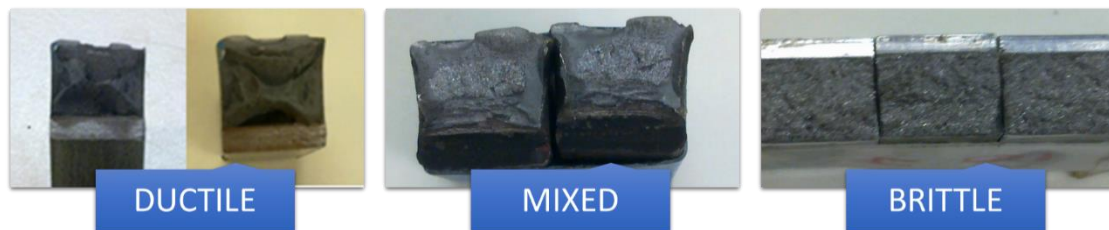


Figure 73. Fracture surface of samples subjected to the Charpy test.

Source: Own elaboration

Part 2: Influence of history: thermal cycles (Thermal temperature and cooling rate)

This part of the activity has two sections. The first one will evaluate the influence of the treatment temperature, and in the second one the cooling speed.

In this section we try to demonstrate that the behavior of a material can be modified if it is subjected to thermal cycles. These thermal cycles are called thermal treatments and they are differentiated from each other by the temperature reached in heating and by the cooling speed.

For this demonstration, samples of the same material will be used, a F1250 steel.

In this case another property of the materials is measured, the hardness. For this, a durometer such as the one in the image of figure 4 will be used.



Figure 74. Durometer.

Source: Own elaboration

Section One: Influence of thermal temperature

The samples of F1250 Steel are heat treated in an oven (Figure 5). The heat treatment applied is as follows:

- Quenching, which consists of heating up to 850 °C, maintaining this temperature for 30 minutes to ensure that the temperature is homogeneous throughout the mass, and cooling by placing the sample in water
- Tempering, which is carried out on previously tempered samples. This treatment consists of heating each sample to a different temperature (from 150 to 650 °C with intervals of 100 °), maintaining the temperature for 30 minutes and air cooling.



Figure 75. Furnace.

Source: Own elaboration

Once the heat treatments have been carried out, the hardness of the samples is measured, and it is observed that the higher the temperature of the tempering treatment carried out, the lower the hardness value of the material.

Section Two: Influence of cooling rate

In this case, the F1250 steel samples are also subjected to quenching treatment, but three different quenching media will be used: water, oil and air. The water-cooled sample will cool faster than the oil-cooled sample, and this in turn will be faster than the air-cooled sample.

When we measure the hardness value of the treated samples, we see that the higher the cooling rate, the higher the hardness of the steel.

It has been shown that for samples with the same chemical composition, the temperature of the thermal cycles and the cooling rate that is applied modify the properties of the starting material.

Part 3: Influence of history: previous deformation processes

To demonstrate the influence of deformation processes that a material may have experienced on its properties, a low carbon steel and a tensile testing machine have been used (Figure 76)

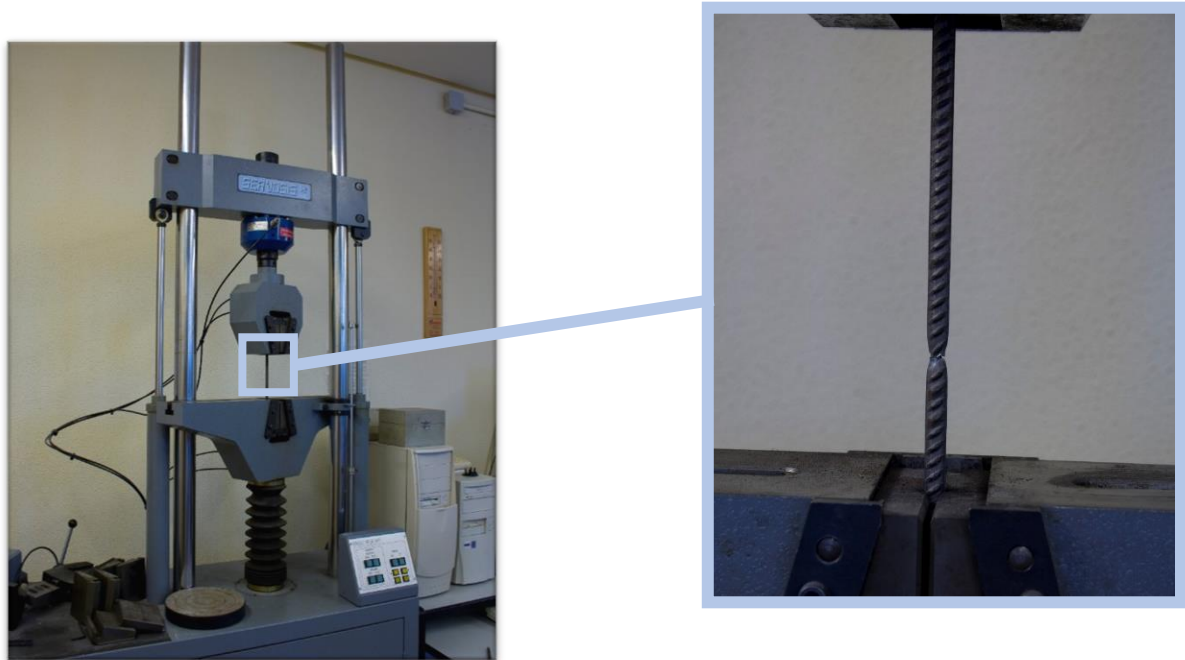


Figure 76. Tensile test machine and tested sample.

Source: Own elaboration

In order to determine if the fact that a material has been subjected to a certain effort can modify its behavior, in this part the tensile strength will be evaluated as a property of the material. The tensile test consists of subjecting the material to longitudinal stress to stretch the sample until it breaks.

A low carbon steel, F114, will be used and a sample of that steel will be subjected to a tensile test. From the first test it will be observed:

- Shape of the stress-strain curve
- Elastic limit
- Tensile strength



The stress-deformation diagram is the graphical representation of the force exerted during the test against the deformation produced in the sample. This diagram gives an idea of the ductility or brittleness of materials.

The elastic limit is the stress value from which the deformations become permanent. Any deformation that occurs in a material has two components, the elastic component and the plastic component. Elastic deformations recover when the stress ceases, and plastic deformations are permanent. Furthermore, elastic deformations are proportional to stress and plastic ones are not.

Tensile strength is the maximum stress that the sample is capable of withstanding during the test.

After the first test, one of the pieces of the sample will be taken and subjected to a new tensile test. Subsequently, the data discussed above are compared between tests. In the data comparison, it is observed that the stress-strain diagram has changed notably, observing a less ductile behavior of the material (it deforms less). In addition, it is seen that the elastic limit and tensile strength increase with respect to those obtained for the undeformed material.





ELECTRICAL CURIOSITIES

This activity will try to discover the electrical energy losses that occur from the point where they are generated, the electrical energy generation plants, until the moment they are consumed. In addition, it will be verified experimentally how electrical energy is converted into movement.

The focus will be on three points:

- Losses from transportation from the generation plant to the final consumer
- Losses due to the operation of electrical equipment or appliances
- The transformation of electrical energy into motion

1: Transport. Minimizing energy losses in transportation from the point of generation to the point of consumption

The devices that we use in domestic uses use low-voltage electrical energy, while in the streets we can see that electricity is distributed in high-voltage lines. This forces the incorporation of intermediate equipment (substation), which convert high voltage into low voltage ready for use.

In this section you will discover why the transport of electrical energy is done from the generation plant to the consumers using high voltage lines.



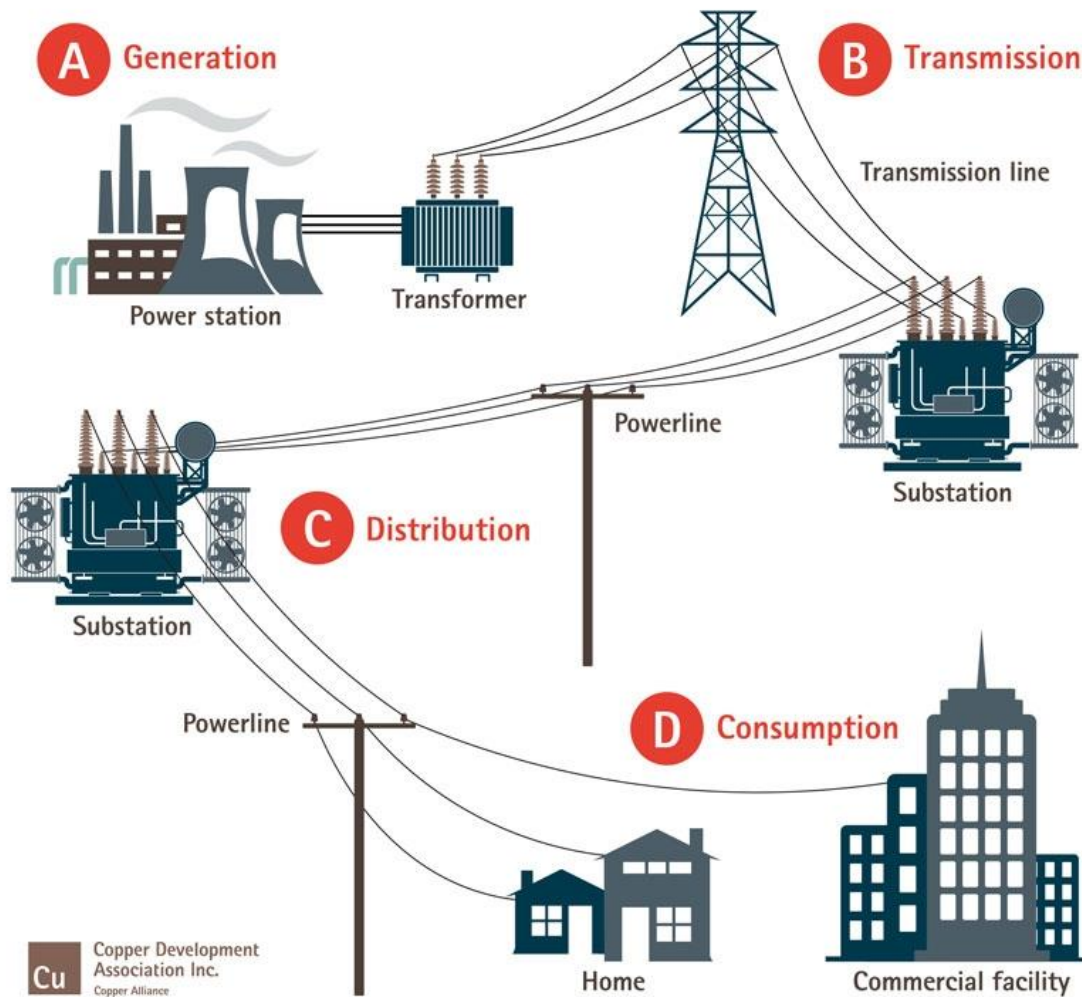


Figure 77. Diagram of the transmission and distribution system of electrical energy [105].

Theoretical explanation

When an electrical current flows through a conductor, a loss of energy is inevitable. This loss of energy is due to the resistance that the material constituting the conductor opposes to the passage of the current.

As a consequence of these losses, the energy at the beginning is greater than the one that arrives at the end. This means that for a device to function properly it is necessary to generate more energy than it requires. This means that at a global level the loss of

resources acquires a significant value, so it is necessary to minimize these losses as much as possible.

As has been said, the losses depend on the resistance of the conductor, and can be expressed by the following equation:

$$P_L = R * I^2$$

Where

- P_L is the lost power
- R conductor electrical resistance
- I current intensity (A)

Observing the previous equation, it can be deduced that the power losses not only depend on the resistance of the conductor, but are also a function of the current intensity I. We also know that the relationship between power and current intensity is:

$$P = V * I$$

To reduce the losses that occur in the transport of electrical energy we need, as we have seen, that the current intensity is low. Therefore, to maintain the necessary power, it will be necessary to increase the voltage.

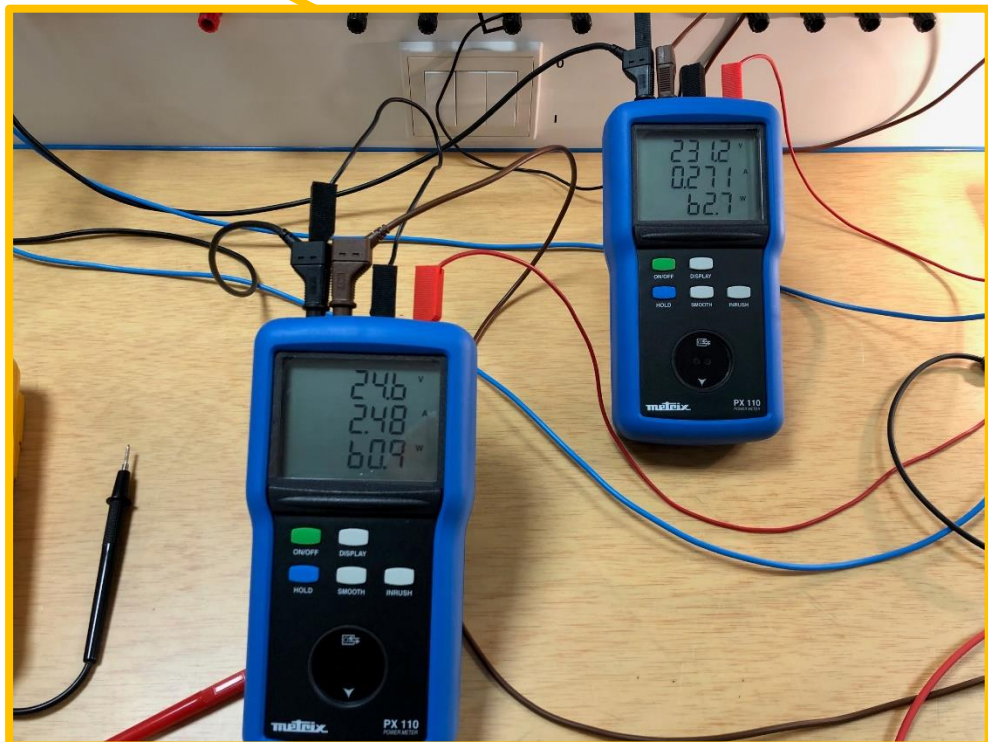
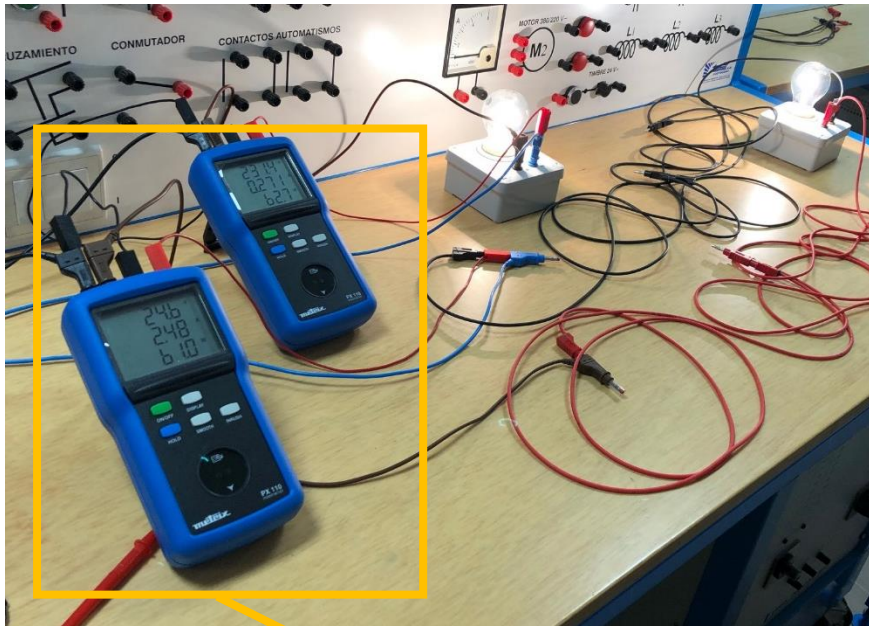
Experimental demonstration

For the experimental work of this section, two lamps of 60 W are used, one that works with a voltage of 24 V, and another that works with 230 V, and two wattmeters.

Each lamp is powered by a power source with which the current intensity can be varied and is connected to a wattmeter capable of measuring the voltage, current intensity and power consumed.

Once the assembly is done, the current intensity is varied until the power consumed by the two bulbs is similar. It will be found that when the voltage is higher, the current required to produce the same power as in the other case is much lower. Therefore, since to avoid losses it is necessary to work with low currents, it will be necessary to increase the voltage during transport.





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Figure 78. Connected lamps and detail of the measurements.

Source: Own elaboration

2. Resonance. Optimizing energy use

Once the electrical power reaches the final consumer, it is important that its consumption be efficient. In this section we will try to evaluate how to achieve the highest efficiency of electrical devices.

Theoretical explanation

The basic components of any electrical circuit are Resistors (R), Coils (L), Capacitors (C). These last two (L and C) when applying a source of sinusoidal alternating current (A.C.) present an opposition to the passage of the current that crosses them, which varies with the frequency of the applied voltage according to the following equations:

Inductive reactance:

$$X_L = 2\pi fL$$

Capacitive reactance

$$X_C = \frac{1}{2\pi fC}$$

In Figure 79 you can see the effect of the variation of the frequency in the period of a sinusoidal wave.



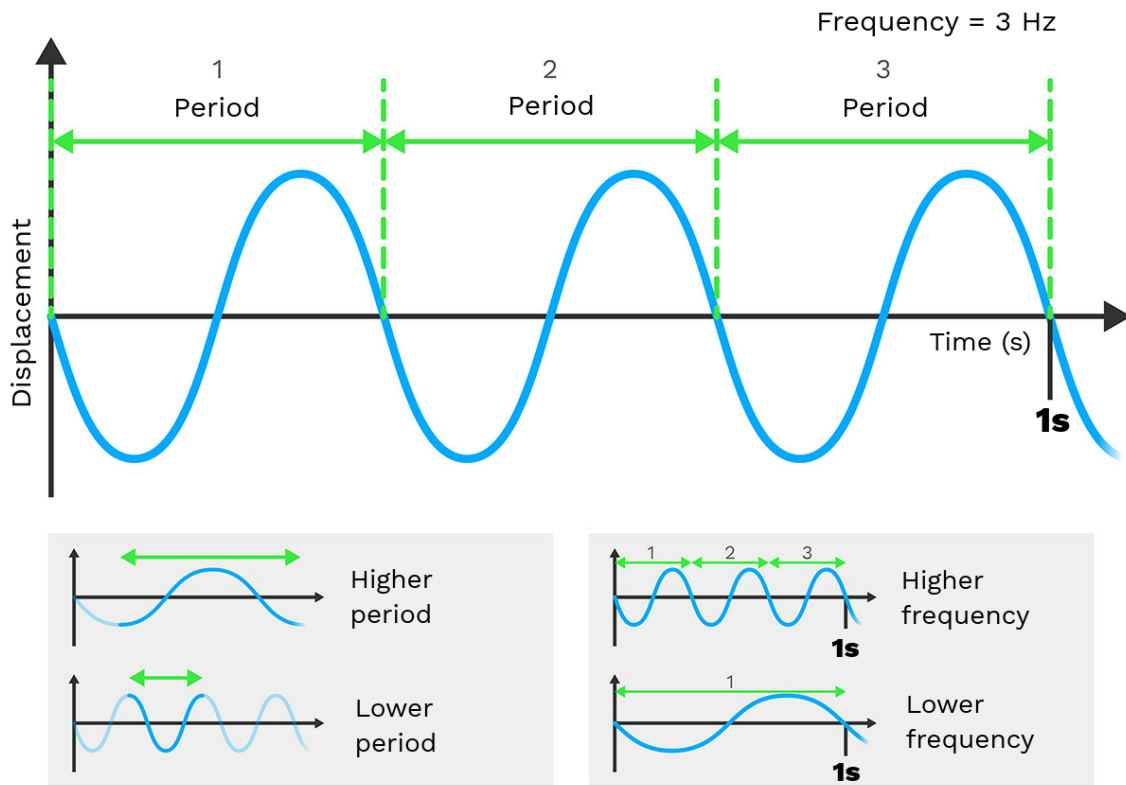


Figure 79. Modification of the period in the sinusoidal waves with the variation of the frequency [106].

The highest efficiency of electrical systems occurs when the load is purely resistive, but most electrical systems have an inductive character (predominance of L). A series RLC circuit like the one in the following figure.

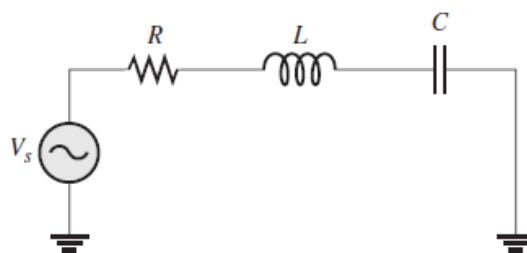


Figure 4. RLC circuit.

Source: Own elaboration

The system will go into resonance when X_L is equal to X_C , and this occurs for a single frequency of the voltage applied to the circuit, called the resonance frequency, and

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

whose expression is:

For this resonant frequency, the circuit behaves as if the voltage source had to supply only a resistive load, the voltage applied to the resistor (R) being the same as the voltage of the voltage source, since the voltages in the coil V_L , and in the capacitor V_C are equal and opposite and cancel each other.

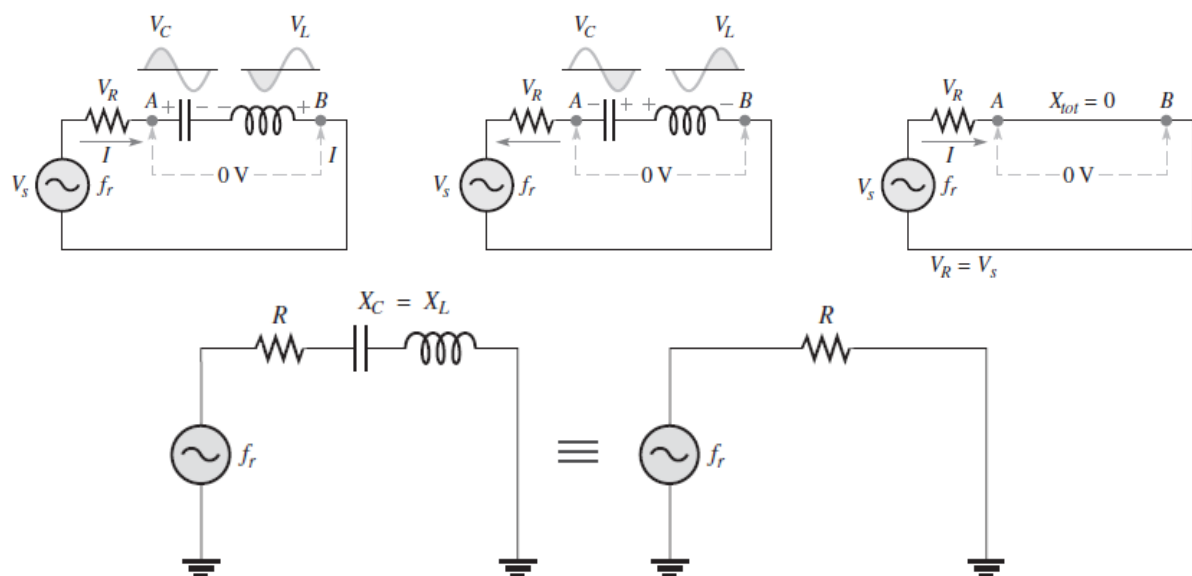


Figure 80. Equivalent circuit at resonance.

Source: Own elaboration

Experimental demonstration

Figure 81 shows the waveforms of the voltage and current intensity. It can be seen how the waves are coupled for the case of the resistive system, while in the other two cases, there is a phase difference between both curves. The maximum efficiency is, as previously mentioned, in the purely resistive system.

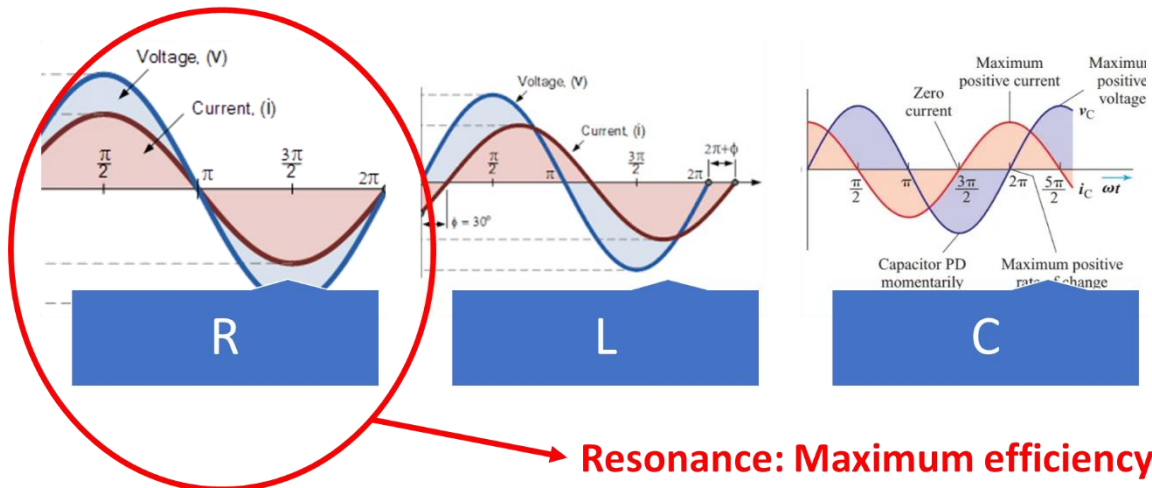


Figure 81. Waveforms of voltage and current intensity for resistive, inductive and capacitive systems [106].

To get a circuit into resonance there are two ways, modifying the components that form it (L and C) or modifying the frequency of the current. If we assume that the electrical device is already manufactured and it is not possible to modify its components, the only way to achieve resonance is by acting on the frequency.

In order to determine the resonant frequency of a circuit with determined values of L and C, a voltage source must be used that allows its frequency to be varied.

To carry out this practice, a lamp was used as a resistive load, and specific components for working in laboratories as capacitive and inductive loads (Figure 82).

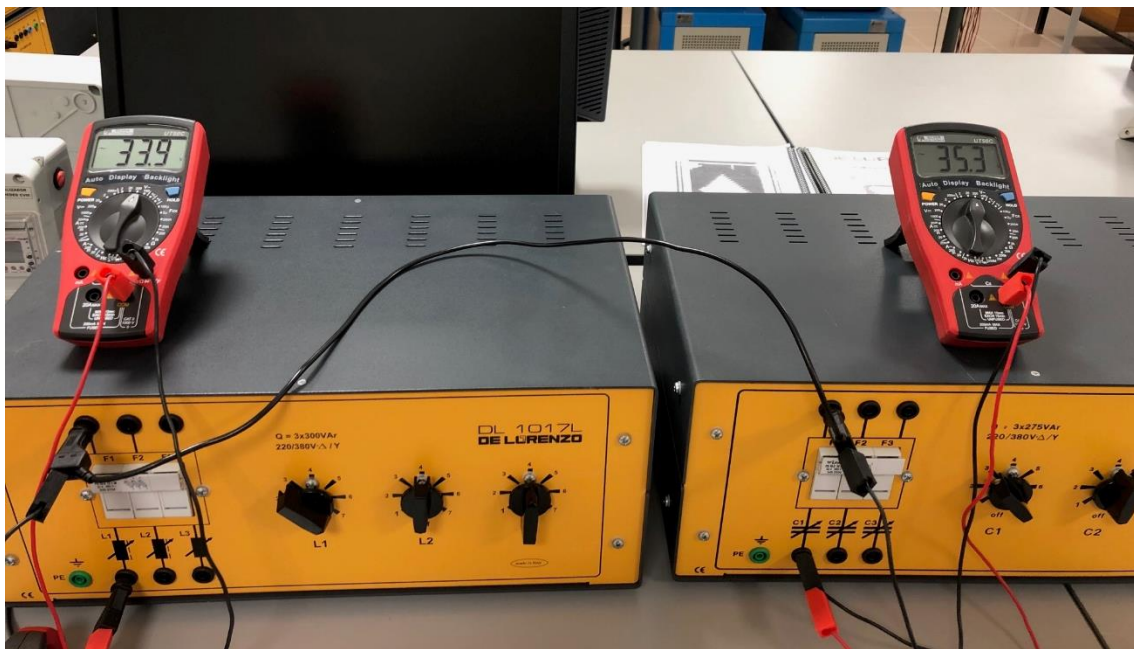
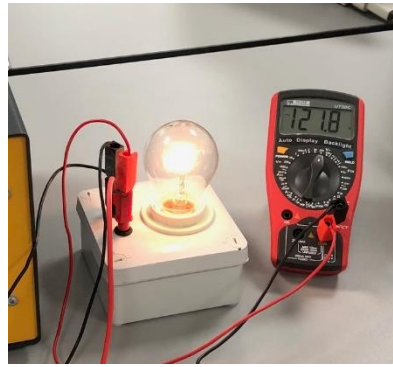


Figure 82. Resistive load (top) and inductive and capacitive loads (bottom).

Source: Own elaboration

Figure 83 shows the voltage signal and current intensity at resonance.



Figure 83. System in resonance.

Source: Own elaboration

On the other hand, if the network frequency is constant since it is imposed by the electrical system, the only possibility that an RLC circuit is in resonance, will be due to the variation of its L and C values.

In Europe, the network frequency is 50 Hz, so if we want the resonance phenomenon to occur for that frequency, we must set a value for L, and we obtain a value for C, which meets the condition imposed by the resonant frequency expressed by the equation:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

The second assembly is made with simpler components, a resistor, a coil, and a capacitor (Figure 84, top) that comply with the values defined by the previous equation. Using these components, it is verified that the system is in resonance by observing the

measured signal (Figure 84, bottom). It shows that the voltage in the coil VL (blue color) is equal to the voltage in the capacitor VC (yellow color), after varying the frequency of the source until reaching the value of the resonant frequency.

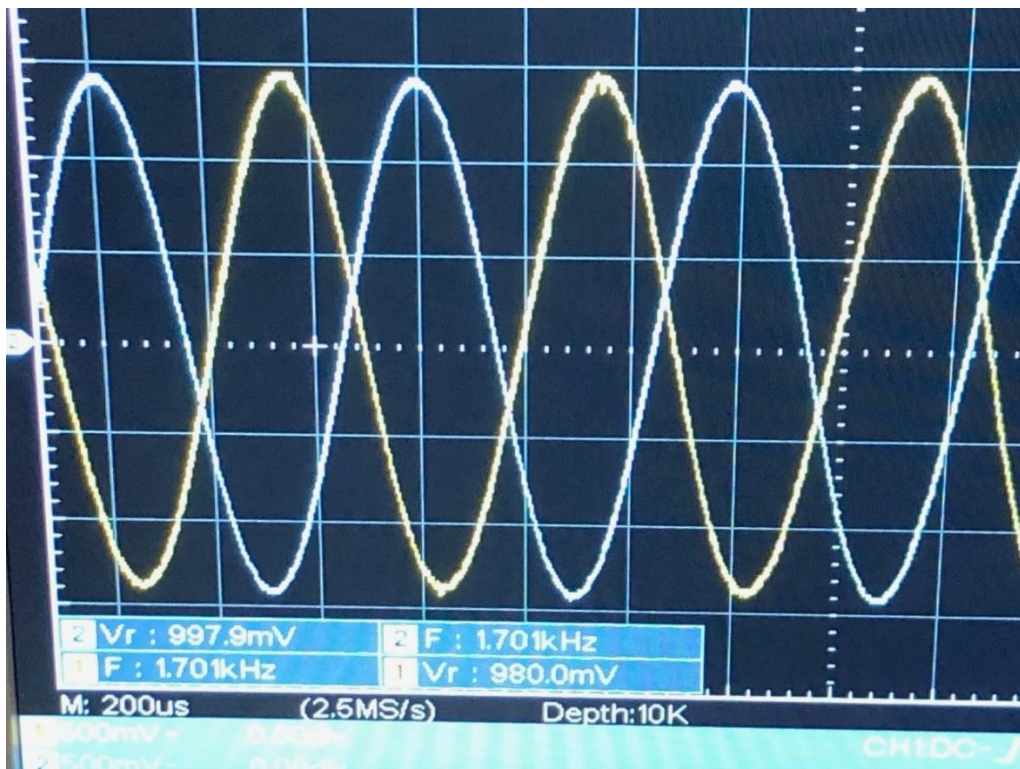
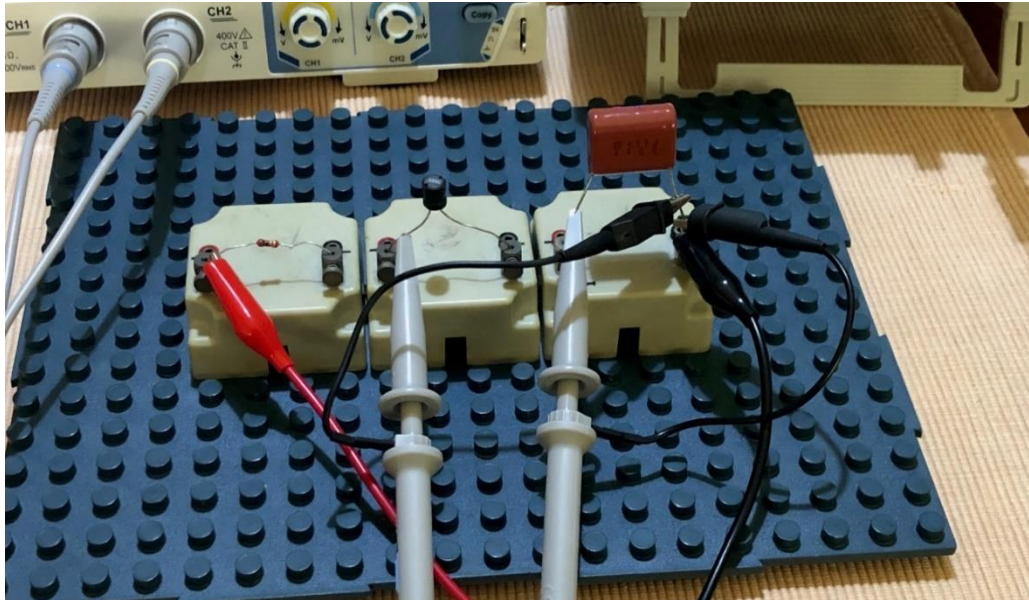


Figure 84. Resistive, inductive and capacitive charges (top) and signal at the moment of resonance (bottom).

Source: Own elaboration

3. Use of electrical energy. Transformation of electrical energy into mechanics

Generators are used in electrical power generation plants, which convert mechanical energy into electrical energy. For example, wind turbines transform the movement of wind generator into electricity.

This process is reversible, and those in charge of transforming electrical energy into mechanical energy (movement) are the motors.

In this section we will seek to understand how electrical energy is converted into mechanical energy, that is, how things can work from electricity.

Theoretical explanation

To transform electrical energy into movement there are two types of motors, linear motors and rotary motors.

In both cases the operating principle is based on the following statement:

“A force (F) is exerted on every conductor through which a current flows (I) that is immersed in a magnetic field (B)”

The force produced will follow the following expression

$$F = I * L * B$$

Where F is the force, I the current, L the conductor length and B the magnetic field. The direction in which the force is produced can be determined by applying the left hand rule, as shown in Figure 85. Determining the direction of force [107]



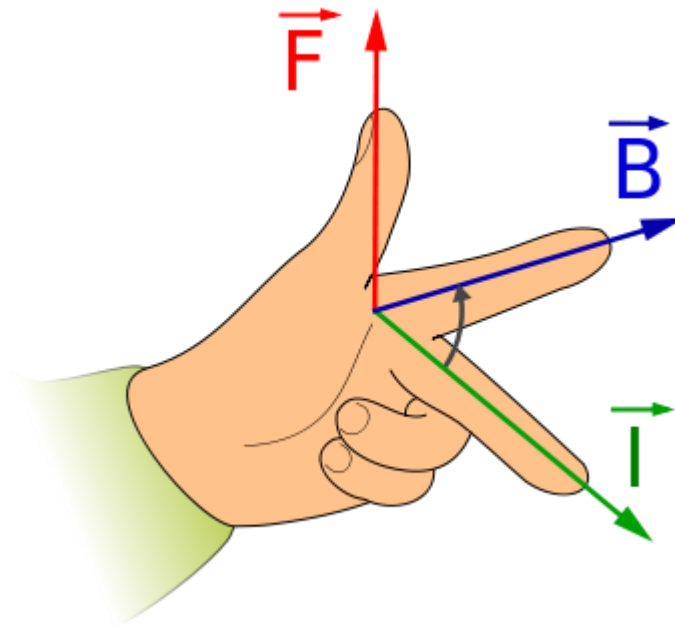


Figure 85. Determining the direction of force [107].

Experimental demonstration. Linear motor

To demonstrate the operation of the linear motor we will have to assemble an electrical circuit within a magnetic field, following the scheme of Figure 86.

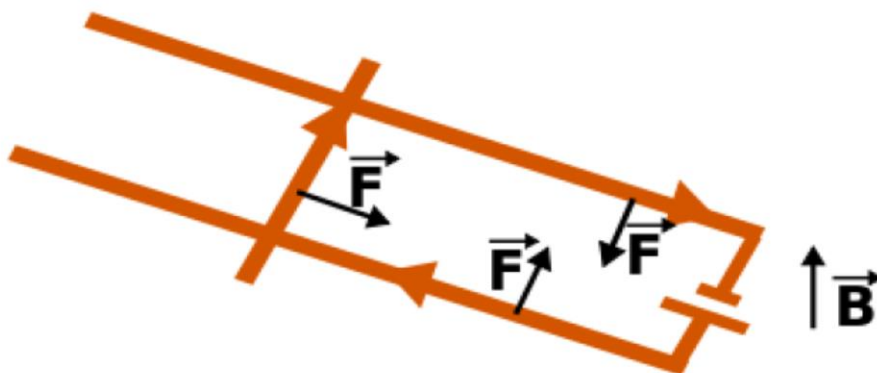


Figure 86. Diagram of the assembly of the linear circuit [108].

To do this, an electrical circuit is formed with two metal rails and a tube, also metal, that can move on them. The circuit is closed by connecting it to a direct current source. The magnetic field will be generated by the presence of magnets. This device exemplifies the

forces that are produced on currents in the presence of a magnetic field (Lorentz Force). In this assumption, the magnetic field produced by the magnets is uniform and with a vertical direction (upwards) and that the current generated in the circuit is clockwise.

The direction of the force is indicated in the diagram in Figure 86. Since the tube of conductive material can move on the rails, the force exerted on it pushes it to move to the right (see Figure 87). If we change the direction of the current (exchanging the wires), the force on the copper tube changes direction and therefore also the movement of the tube.

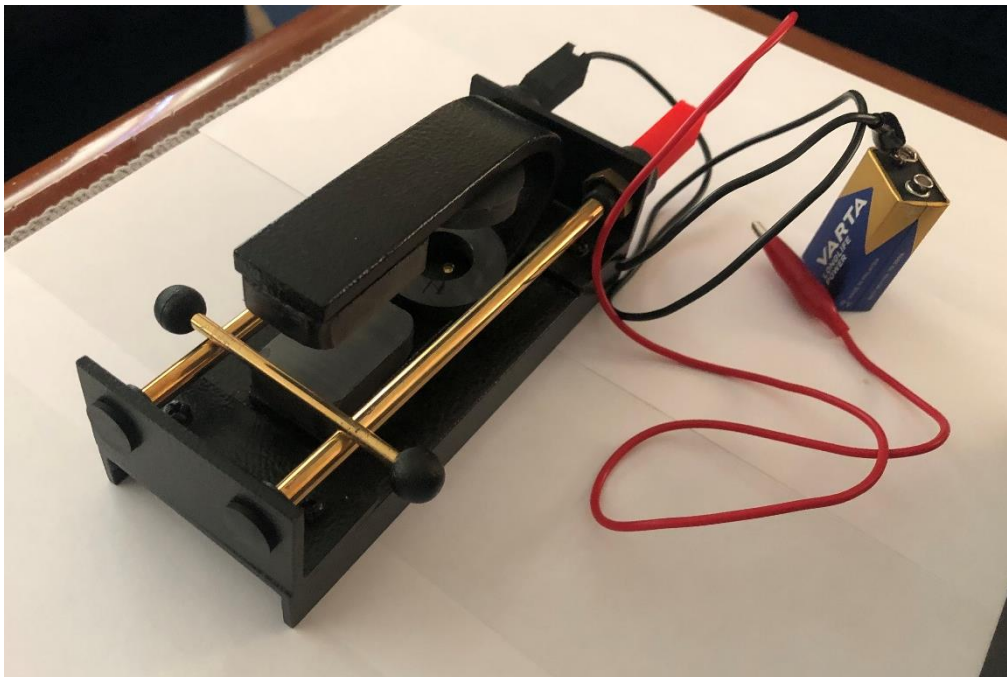


Figure 87. Linear motor shows the device used in this part of the activity.

Source: Own elaboration



Experimental demonstration. Rotative motor

When a motor is connected to alternating current, three currents 120 degrees out of phase are generated. The sum of these three currents generates a rotating magnetic field, as can be seen in Figure 88.

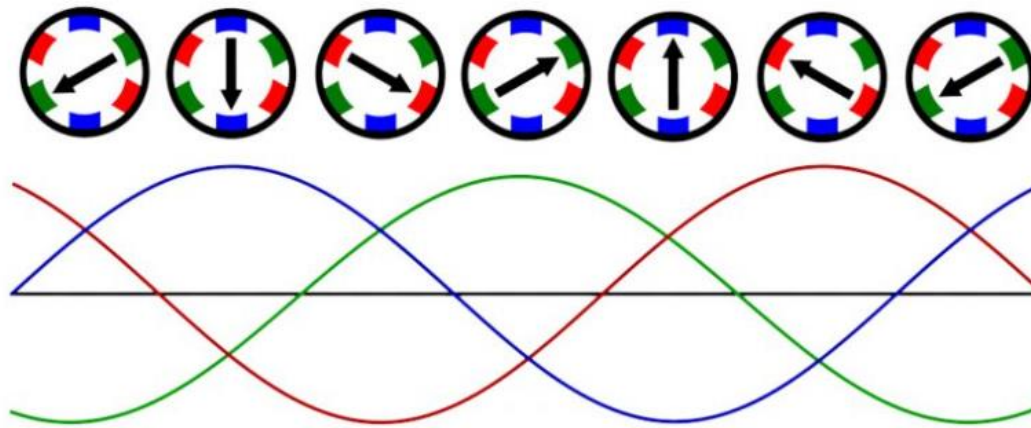


Figure 88. Magnetic field direction_[109].

To demonstrate this experimentally, a rotary motor is used from which the rotor has been removed, which is the moving part of the motor that transmits the rotation to the shaft.

A metallic sphere is inserted inside the motor (Figure 89). When the motor is connected and the speed increases, it is observed how the sphere begins to rotate inside it, following the rotating magnetic field.

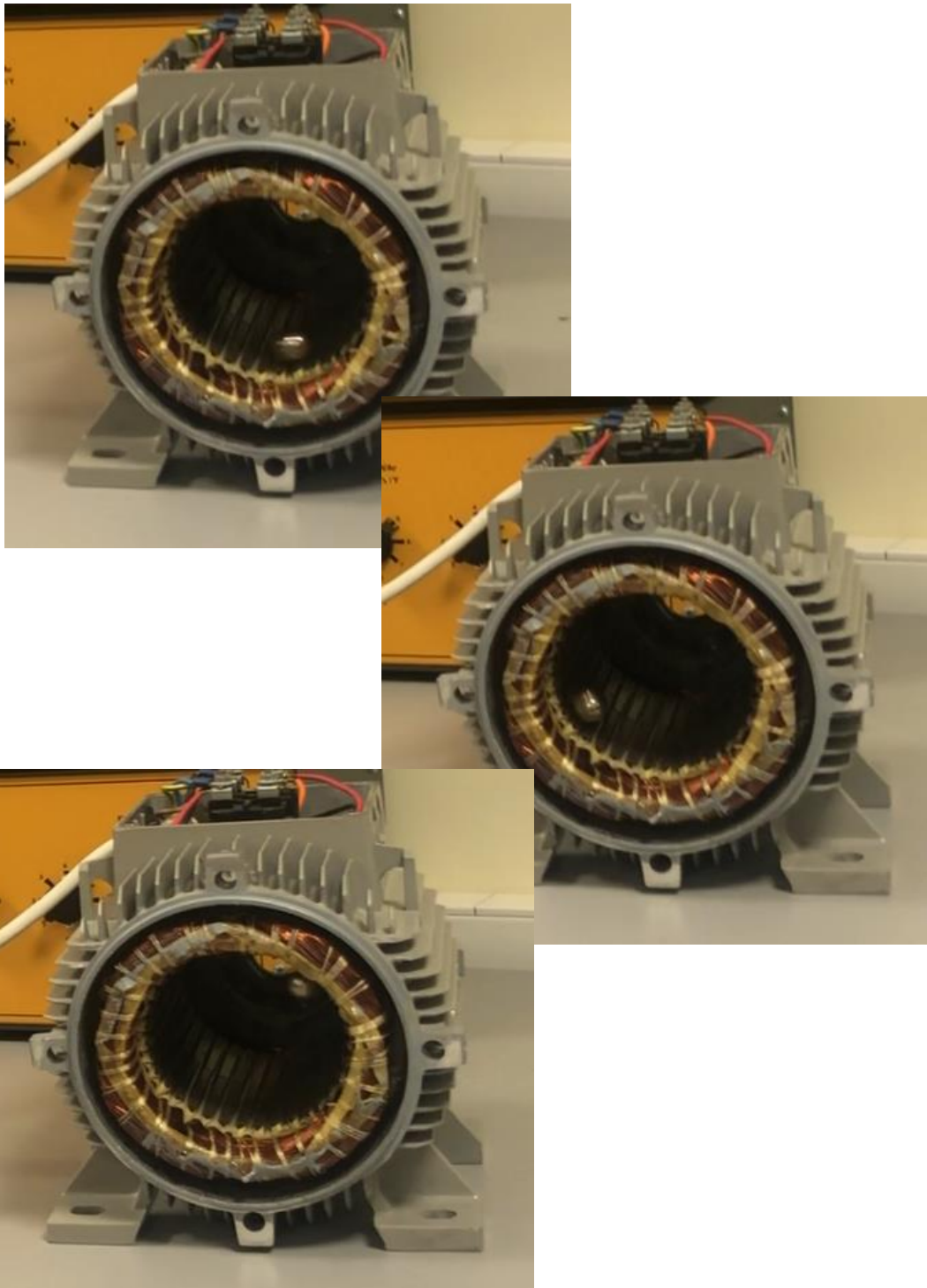


Figure 89. Rotation of the sphere inside the motor. It shows snapshots of the metal sphere in different positions inside the stator.



Source: Own elaboration



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5. Chapter 4. Transnational cooperation to promote STEM knowledge in school education

As the world turn out to be more interconnected and competitive, and technological knowledge and investigation expands, new opportunities and more complex challenges arise. Research, novelty and practices in science education must be more open to the needs and goals of society, and must support citizens of all ages and capacities in rising positive attitudes towards science, and reflect science. that citizens need.

Science education is very important. Its main objectives are:

- Encourage a culture of scientific views and inspire young people to use evidence-based thinking for decision making.
- Guarantee that people have the conviction, knowledge and capacities to actively participate in the difficult scientific and industrial world.
- Acquire skills for problem solving and originality, as well as systematic and critical views.
- Enable European-based public and private organizations to find qualified staff to stimulate and foster a pioneering environment across Europe, where corporations and other stakeholders.
- Encourage active participation by European citizens in the great challenges facing humanity today.

The problem worldwide is that there is a shortage of persons with scientific knowledge. That is why programs have been created to promote these deficiencies. In Europe, the European Commission in the 2014-2020 framework program committed more than 13 M€ to promote initiatives that are dedicated to “raise the attractiveness of science education and scientific careers and boost the interest of young people in STEM” [66].

Some of these initiatives are shown below:

1. **SCIENTIX PROJECT.** <https://www.scientix.eu/home>. [110]





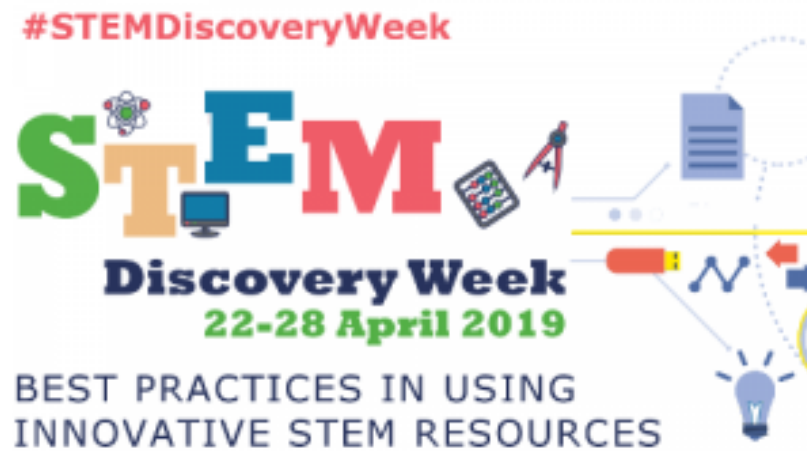
Source: Scientix. [110]

2. **STEM ALLIANCE PROJECT.** <http://www.stemalliance.eu/home>. [111].



Source: [111]

3. **STEM DISCOVERY WEEK.** <https://www.scientix.eu/events/campaigns/sdw19>. [112].



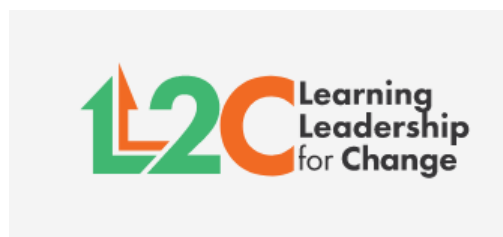
4. **PILOT PROJECT: GIRLS 4 STEM IN EUROPE.** [113].
5. **MASDIV.** <https://icse.eu/international-projects/masdiv/>. [114]
6. **STEM PD NET.** <https://www.stempd.net/>. [115].
7. **SPACE EU.** <http://space-eu.org>. [116].
8. **TIWI - TEACHING ICT WITH INQUIRY.** <http://tiwi.eun.org/>. [117].



9. **BRITEC.** <https://britec.igf.edu.pl/>. [118]



10. **LEARNING LEADERSHIP FOR CHANGE (L2C).** <http://l2c.eun.org/>. [119].



11. **BLOOM (BOOSTING EUROPEAN CITIZENS KNOWLEDGE AND AWARENESS OF BIOECONOMY RESEARCH AND INNOVATION).** <https://bloom-bioeconomy.eu/>. [120].



12. **STEM SCHOOL LABEL.** <https://www.stemschoollabel.eu/>. [121]



13. AMGEN TEACH. <http://www.amgenteach.eu/>. [122]



14. GLOBAL ONLINE SCIENCE LABS FOR INQUIRY LEARNING AT SCHOOL (GO-LAB).
<http://www.go-lab-project.eu/>. [123].

GO-LAB

15. NEXT-LAB (NEXT GENERATION STAKEHOLDERS AND NEXT LEVEL ECOSYSTEM FOR COLLABORATIVE SCIENCE EDUCATION WITH ONLINE LABS). <http://project.golabz.eu/>. [124]

next lab



6. Acknowledgments

This work was performed in the scope of the “STEM is inspiring future careers” Project (2021-1-ES01-KA220-SCH-000031524), Erasmus + Program.





**Co-funded by
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Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them

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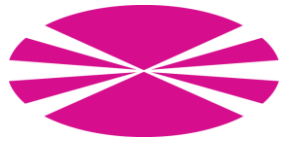
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8. The Partnership



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STEM IS INSPIRING FUTURE CAREERS

Project no 2021-1-ES01-KA220-SCH-000031524

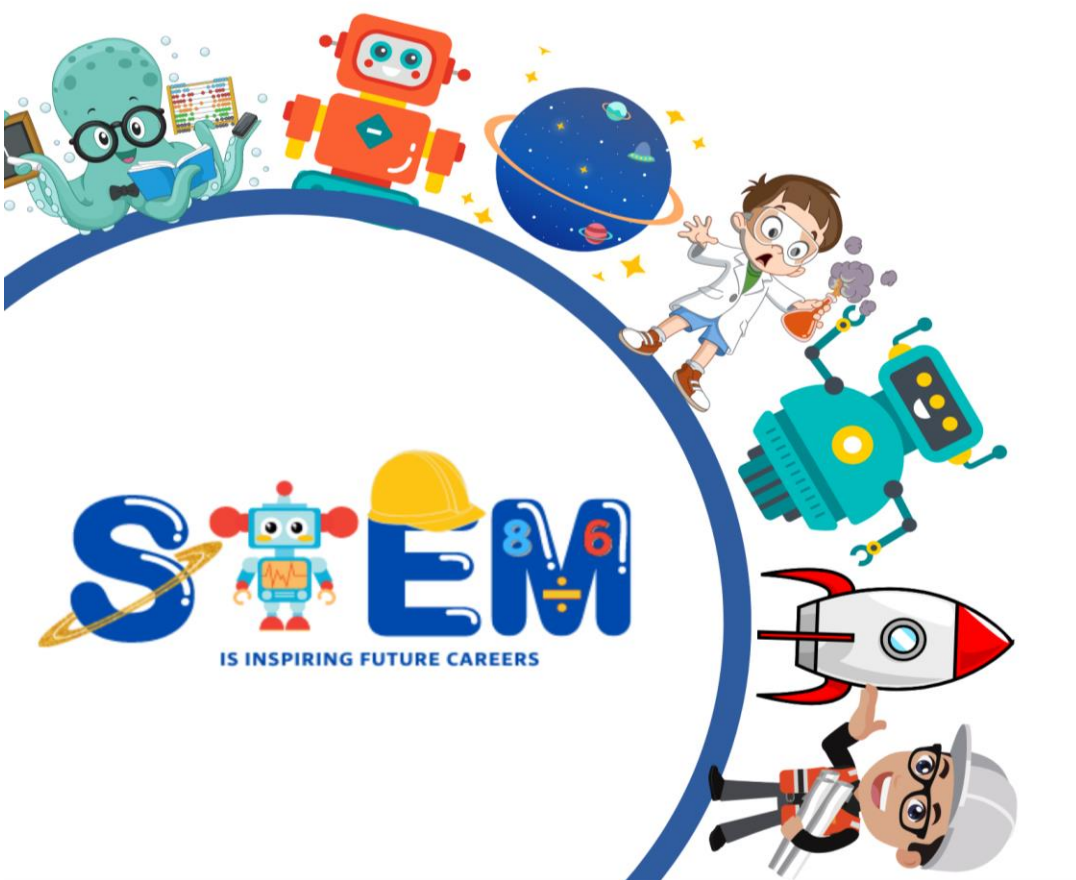
DESK RESEARCH-GUIDELINES:

Summative Desk Research

Developed by EUROSUCCESS CONSULTING

2023

ENGLISH



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Contents

<u>INTRODUCTION</u>	118
PROJECT'S TARGET GROUPS	118
STEM & STEM EDUCATION	118
PROJECT RESULT 1 - DESCRIPTION	118
<u>RESULTS</u>	119
1. THE MAJORITY OF THE SCHOOLS IN YOUR COUNTRY ARE PUBLIC OR PRIVATE?	119
2. HOW THE EDUCATIONAL SYSTEM IN YOUR COUNTRY WORKS?	120
3. STEM EDUCATION: WHAT IS IT IN YOUR COUNTRY/HOW IT IS DEFINED, IS IT POPULAR, HOW IT WORKS?	124
4. ARE THERE ANY SPECIFIC EDUCATIONAL PRACTICES REGARDS STEM EDUCATION IN YOUR COUNTRY?	126
5. LEGISLATIONS, NORMS/REGULATIONS RELATED TO STEM EDUCATION?	131
6. PROFILE OF STEM TEACHERS/EDUCATOR	133
<u>REFERENCES</u>	137



Introduction

The project aims to develop teachers' and educators' competences – especially integrated STEM (science, technology, engineering, mathematics) teaching skills, based on collaborative problem solving (CPS) – sharing experiences among countries involved in the project (the project was compatible with Europe stem aims to evaluate students' performance in mathematics, science and financial literacy; performance in problem-solving and reading). Throughout the project activities and results, will be promoted a positive image of science, raise awareness of science, make improvements in school based science teaching and learning, increase student's interest in science.

Project's Target Groups

- **Students:** 40% improving their mathematical, scientific and technical competences by participating in this project. 70% increasing IT competences. 25% raising foreign languages competences. Increasing of initiative and creativity. Having better understanding of cultural diversity.
- **Teachers:** Increasing teaching competences, improving skills in the field of foreign languages, gaining new professional experience and increasing of motivation and job satisfaction.
- **Parents:** Increasing social activity, changing of approach to European projects, establishing international partnerships, exchanging experiences.

STEM & STEM EDUCATION

According to STEM definition: *the term STEM (science, technology, engineering, mathematics) is an acronym used by those relevant to the educational method concerning to these fields.*

STEM is an educational approach designed to combine technology and engineering along with science and mathematics, which are vital in order to understand the laws of the universe. ¹

STEM Education, at its core, simply means educating students in four specific disciplines, namely. Instead of training students in any of these domains, STEM combines all four in an interdisciplinary and applied approach, to better equip students to have a career and consider real-world applications. ²

Project Result 1 - Description

PR1 of STEM is inspiring future careers is about a STEM guidebook for teachers. One of the activities of this result (R1, A2) is a Country Specific Desk Research for the guidebook. EUROSUCCESS CONSULTING is the main leader of the research with the coordination of ERA.

¹ <https://stem.edu.gr/en/what-is-stem/>

² <https://www.liysf.org.uk/blog/what-is-stem-education>

An actual research and publishing work, peer review and improvement of papers depending on feedback from peer reviewers. There will be emphasis towards joint publishing of papers to augment the effort of working together and seeking new avenues in STEM.

Results

1.The majority of the schools in your country are public or private?

SPAIN

Spain has 34,168 non-university educational centers, according to the State Register of Non-University Teaching Centers of the Ministry of Education, Culture and Sports. Of these, the majority are public (65.9%) and two out of ten are concentrated in Madrid and Barcelona. All educational centers, publicly or privately owned, that provide non-university regulated education are registered in this registry, which includes nursery schools, primary and secondary education centers or centers for adults, among other types of education [1]. The map shows the proportion of public centers in relation to private ones in each postal code. 65.9% of all centers present in the registry are public, compared to 34% private. However, depending on the region and each neighborhood, the weight of the public school compared to the private one changes. Valencia (50.59% private), Madrid (50%), Vizcaya (43.81%) and Seville (43.66%) are the provinces with the highest proportion of private centers, while in Teruel, Cuenca and Soria the public centers exceed 80%.

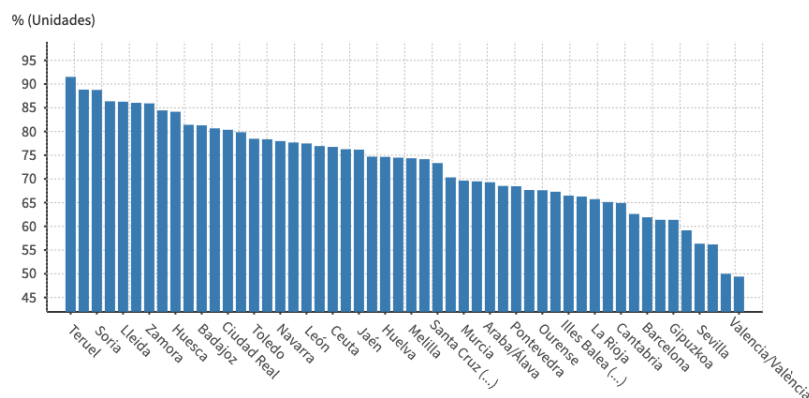


Figure 90. Proportion of non-university public educational centers by province [2]

TURKEY

According to the formal education statistics of the Ministry of National Education, there are 18 million 85 thousand 943 students in formal education (official + private) in Turkey. Out of a total of 67,125 educational institutions/schools, the number of state-owned institutions/schools is 53,620 (80 percent), while the number of private schools is 13,501 (20 percent). The number of students studying in public schools is 15 million 194 thousand

504 (84 percent), and the number of students studying in private schools is 1 million 310 thousand 605 (7.25 percent). There are 1 million 580 thousand 764 (8.75 percent) students studying in open education. When we look at the distribution of students according to gender, 9 million 352 thousand 605 (51.71 percent) are men and 8 million 733 thousand 338 (48.29 percent) are women. While the rates of State of Education in the light of the Ministry of National Education Formal Education Statistics 3 are close to each other in public schools, the rate of boys studying in private schools is higher than girls. A total of 1 million 112 thousand 305 teachers work in public and private schools in Turkey. 453,529 (41 percent) were men and 658,776 (59 percent) were women of these teachers. As of 2021, the number of teachers working in public schools is 950 thousand 90. As of the end of the 2020/2021 academic year, there are 103 thousand 961 contract teachers in public schools. 43 percent (404,972) of the teachers working in public schools are men and 57 percent (545,118) are women.

The highest number of private schools in Turkey is pre-school education. As of the end of the 2020/2021 academic year, 5 thousand 320 (39 percent) of the 13 thousand 501 private schools operating are private pre-school education institutions. With 4+4+4, the government has taken steps to encourage special education in pre-school education as in other education levels and to direct parents to private pre-school education institutions. As a result of these steps, according to the formal education statistics of the Ministry of National Education, the share of private pre-school education institutions in the total has increased significantly as of the end of the 2020/2021 academic year.

The formal education statistics released by the Ministry of National Education every year show that while the number of state-owned primary and secondary schools has decreased significantly, the number of private primary, secondary and high schools and the number of students directed to these schools have started to increase remarkably. It is noteworthy that the number of state-owned primary schools has decreased by 5 thousand 650 since the beginning of the 4 + 4 + 4 application in education. In the same period, the decrease in the number of students attending public schools was 367 thousand 450 in primary school and 189 thousand 723 in secondary school. As of the end of the 2020/2021 academic year, there are a total of 13 thousand 501 private education institutions (pre-school, primary, secondary and high school) in Turkey. Before 4+4+4, the ratio of private schools (4 thousand 664) to public schools in Turkey is 11 percent. The ratio of private schools to public schools (53 thousand 620), which showed a significant increase in education with 4 + 4 + 4, more than doubled and exceeded 25 percent as of the end of the 2020/2021 academic year. While there were 4 thousands 664 private schools (2,848 private pre-schools, 931 private primary schools, 885 private high schools) in Turkey before the 4+4+4 implementation in education, the number of private schools increased to 13 thousand 501 (5,320 private pre-schools; 2,049 private primary schools; 2,343 private secondary schools; 3,789 private high schools) and the total number of students increased by approximately 2.5 times in the same period from 535 thousand 788 to 1 million 310 thousand 605.

CYPRUS

In Cyprus, there are a lot of private schools (39 in total, in each school level), but still, the public schools remain the majority. Also, the majority of the students prefer to study in public schools, than in private (only the 18,75% study in private schools).

2. How the educational system in your country works?

SPAIN

The two main laws in Spain regarding the educational system are:



- **Vocational Training Integration Law: Organic Law 3/2022, of March 31, on the organization and integration of Vocational Training [3].** For the first time, a unique Vocational Training system is regulated, which articulates the offer aimed at both young students and workers. Five qualification grades are established (A, B, C, D and E) that start from the partial accreditation of competence and allow progress to specialization courses. It promotes training in the company and speeds up the process of accreditation of skills acquired through work experience.
- **LOMLOE. Organic Law 3/2020, of December 29, which modifies Organic Law 2/2006, of May 3, on Education [4].** The measures proposed in its articles are committed to increasing the degree opportunities for all students, reinforcing equity and more precisely regulating the management of subsidized centers, among other measures. The modifications that it entails began to be applied in the 2021-2022 academic year and its implementation will continue until the 2023-2024 academic year.

The Spanish educational system follows the eight educational levels, as established in the International Standard Classification of Education (ISCED) [5]. Early Childhood Education (non-compulsory), Primary Education and Compulsory Secondary Education, which are required levels. Once the compulsory training is finished, students can choose Baccalaureate studies or Intermediate Vocational Training studies. After finishing Secondary Education, they can opt for University Studies or Higher Level Vocational Training.

Child education (between 0 and 6 years) is not compulsory [6]. At this stage we find a series of objectives aimed at developing skills in children such as observing and exploring their family, natural and social environment; develop their affective capacities or relate to others and progressively acquire elementary patterns of coexistence and social relationship, as well as exercising in the peaceful resolution of conflicts.³ In the different legal provisions referring to Early Childhood Education, the purpose of contributing to the physical, affective, social and intellectual development of children.

Primary education (between the ages of 6 and 12) is compulsory [6]. It is fully covered by taxes in public and subsidized institutions, including books in some autonomous communities.

Secondary education (separated into a compulsory part and a post-compulsory part) [6]. Compulsory Secondary Education (ESO) consists of four courses, between 12 and 16 years of age. Likewise, it is covered by taxes in public and subsidized institutions. Post-compulsory secondary education refers to four independent courses that require possession of the ESO title to be completed: the baccalaureate (two courses), intermediate level vocational training, intermediate level professional training in visual arts and design, and Middle Grade sports teachings.

Higher education (with different access criteria, depending on the chosen education) includes [6], independently from each other, university education, higher artistic education, Higher Level

professional training, professional education in plastic arts and undergraduate design. Higher Education, and Higher Grade sports education.

TURKEY

The Turkish education system is divided into three levels as 12 years of compulsory gradual education. The first level is organized as a four-year primary school (1st, 2nd, 3rd and 4th grade), the second stage as a four-year secondary school (5th, 6th, 7th and 8th grade) and the third level as a four-year high school (9th, 10th, 11th and 12th grade).

PRIMARY EDUCATION

Primary education consists of four-year and compulsory primary schools and four-year secondary schools that allow the choice between compulsory and different programs and Imams and Preachers secondary schools. In secondary schools and Imams and Preachers secondary schools, elective courses are created according to the abilities, development and preferences of the students in order to support high school education.

SECONDARY EDUCATION

It covers all general, vocational and technical education institutions providing primary, four-year compulsory, formal or non-formal education. Those who finish these schools are awarded a diploma of secondary education. Secondary education consists of high schools that implement various programs. Schools that focus on a certain program are given names that determine the branches of education such as high school, technical high school and agricultural vocational high school.

Secondary education institutions providing education in different categories in Turkey are as follows:

General High School:

All students who have completed eight years of secondary education can attend these schools. High school graduates take the Higher Education Institutions Examination (YKS), which consists of the Basic Proficiency Test (TYT), and optionally the Field Proficiency Test (AYT) and Foreign Language Test (YDT) sessions, in order to be placed in universities .

Vocational High School:

Vocational high school graduates can attend vocational high schools without examination. Vocational high schools can be grouped as Technical, Communication, Health, Hotel Management and Tourism, Teacher, Maritime Vocational High Schools. This may require high schools plus another year of studying.

Anatolian High School:

These are high schools where foreign language courses are mainly given and in some Anatolian high schools, foreign language preparatory class is studied for one year. The hours are more than in regular high schools; There are options in a second foreign language. Galatasaray High School, Kadıköy Anatolian High School, Istanbul High School (Istanbul Boys' High School).

Science High School:

These are high schools for students with special interest and ability in Science. In these schools, students are trained to place in the Science fields of universities.



High School of Imams and Preachers:

These are educational institutions that implement preparatory programs for both profession and higher education within the secondary education system opened by the Ministry of National Education in order to train the staff responsible for the fulfillment of religious services such as imam, orator and Qur'an course teaching.

Fine Arts High School:

These are high schools opened to raise children with special interests and skills in the fields of Fine Arts from a young age.

Private High School:

Also called colleges, some of which are courses such as Mathematics and Science in foreign languages, where the tuition fee is high and admission is difficult, and which are generally of foreign origin such as Robert College, Saint Joseph High School, Austrian High School.

Vocational Higher School Education(Diploma Degree)

Those who have completed high school or equivalent schools are eligible to be candidates to enter higher education institutions. In order to enter the university, students are required to obtain a certain score from the Higher Education Transition Exam (YGS) and Undergraduate Placement Exam (LYS) conducted by the Assessment Selection and Placement Center (ÖSYM) and the Higher Education Institution (YÖK). The scores obtained by the students from the YGS and LYS exams and the total score obtained from the high school GPAs are the determining factors in their placement in undergraduate programs. After taking the YGS, some universities sometimes conduct a special aptitude test. However, this requirement may vary according to the university and faculty.

The higher education system in Turkey consists of universities, institutes of technology, vocational colleges and other educational institutes (military and police academies).

Associate's Degree

Vocational high school graduates can transfer to vocational high schools without examination. However, in order to transfer from straight high schools to vocational high schools, it is necessary to get a certain score from the Higher Education Transition Exam (YGS). The duration of education of vocational colleges is two years. Some vocational schools have foreign language preparatory classes. Students who successfully complete their two-year education can transfer to universities that offer four-year undergraduate education by taking the Vertical Transfer Exam (DGS).

Bachelor's Degree

To obtain a bachelor's degree, you need to complete four years of study at a university. However, for professional branches such as Medicine, Dentistry, Pharmacy, and Veterinary Medicine, it is necessary to complete a training period ranging from five to six years.

GRADUATE

Master's Degree

On top of their undergraduate education, students who complete a two-year master's program with or without a thesis are awarded a master's degree. Master's programs with thesis usually require at least 21 credits and a thesis

to be written. Non-thesis master's degree programs are programs that can be completed in 1.5 years and require at least 30 credits and a semester project to be written.

Doctorate Degree

Those who have a bachelor's or master's degree can apply to doctoral programs. In doctoral programs, it is necessary to take at least 7 courses and 21 credits and pass the qualifying exam. Students who successfully pass their courses and proficiency exam write a thesis and verbally defend their theses before the thesis committee.

Specialization in Medicine

The medical specialty degree is the equivalent of a doctorate degree obtained in medical schools, hospitals and research hospitals. Graduates of medical faculties take the Medical Specialty Examination (TUS) in different branches of medicine to become a specialist in Medicine. Expert candidates are required to submit a thesis and defend their thesis in front of the committee.

Proficiency in Arts

It is a degree equivalent to a doctorate, which is accessed by taking an exam in that branch of art after finishing a faculty or college, creating a work of art and a scientific work.

CYPRUS

In Cyprus, the levels, of mandatory education, are structured like that:

- The pre-primary level, lasts one year, for children 4-5 years old.
- The primary education for children from 5 years old and more, for six years.
- Secondary education, which is separated in two parts, each of them lasts three years, the first one is called Gymnasium and the second High School. In this level of education participate the children between 12 and 18 years old. The children have the choice to study in High school or in a school of secondary technical and vocational education and training.
- In Higher Education there are public and private institutions, at university and non-university level.

General statements for educational system in Cyprus:

- Cyprus continues to follow the traditional educational model of teaching with limited application of differentiated teaching, “virtual education” using ICT.
- Limited recruiting of new teachers who will implement the new way of education.
- Effectiveness & Training problems identified, include insufficient training of Cypriot primary and secondary education to integrate ICT use.

3. STEM Education: What is it in your country/how it is defined, is it popular,how it works?



SPAIN

The world advances technologically very quickly, therefore, it is important to provide students, from an early age, with the development of scientific-technological skills so that they can face social challenges. The term STEM is an acronym that corresponds to the initials of four academic disciplines: Science, Technology, Engineering & Mathematics [5]. In Spain, the majority of the practices related to STEM are S-T-E-M, therefore the four subjects are studied separately.

TURKEY

Stem, which is a new education method in Turkey, is applied in many schools. Teachers who are aware of this issue act by discovering the predispositions and skills of the students in terms of their development.

Students discover themselves with this education they receive until their professional development, including kindergarten, primary education, high school and university, and take solid steps for their career in a highly equipped way. Positive results are obtained in a short time with the guidance of students to this education. Students begin to express themselves in the best way with the combination of mathematics, science, technology and engineering branches and expansions in perspectives. This education system, which has been tried in European countries and has received positive results, continues to spread rapidly.

What Should Turkey Do About It ?

A large number of teachers who have come together for this education system work with great devotion for infrastructure work. So far, we can see interviews about this subject in newspapers and news bulletins. A large number of teachers from European countries who are experts in this sense visit our country and transfer their own knowledge and emphasize that this education is promising. Turkey can contribute to the students by closely following all kinds of technological developments and innovations in this regard by working systematically. In many schools, this method has already been applied and even gifted students are closely interested.

What is done during the training?

In fact, the most important point is to observe the students and start with the determinations about what they have talents. Thus, the part to be concentrated is determined. Within the curriculum, the necessary applications are made to the students within their age groups and capacities. It is among the situations that are likely to be taken out of the curriculum by acting in a coordinated manner and using initiative from time to time.

Our Ministry of National Education and the Adoption of STEM Education:

With STEM education, development is achieved in science and technology. With the right science training, it is ensured that the scientists in need of the country are trained. Our Ministry of National Education, which knows the importance of this, attaches great importance to STEM education. In addition to this, art education also allows students to grow up in a much richer way, as intended. Our Ministry has adopted the stem system in educational institutions and as FETEMM, it is applied in the educational institutions of our country.

CYPRUS

According to TIMSS (2019 data):



- In **primary school** the teaching time of **Mathematics** in classroom is increased, in comparison with the international framework. The opposite is happening in **secondary school**, in which the time of **mathematics** in classroom is less.
- In **primary & secondary school** the teaching time of **Physic Sciences** is less than the one in international level.
- Has been observed that there is **progress** of students is **higher**, when there is use of **computers** during the lessons.
- In the lesson of **Physic Sciences** seems that student's progress is higher, when there is an additional **lab** during the lesson, and when there is support at the teachers for the **experiments**.

During the school year 2022-2023 some primary schools (9 schools) will participate in a STEM educational program, which will be extra hours after the normal school schedule. This program will last 40 minutes and will be in two parts, also, will take place twice a week. The students that will participate are the seniors or if the number of seniors isn't sufficient will participate the pre-senior students.

In this program there will be covered these topics:

- Orientation at innovation.
- Interaction and coexistence of the separate STEM subjects with respect to the diversity and specificities of each subject.
- Application of practices and meanings of STEM for problem solving.
- Design and execution of researching procedures in a skillful and creative way.
- Emphasis on reasoning, critical thinking and modelling.
- Strategic use and development of technology.
- Promoting knowledge about the relevance of the STEM sector to society.
- Interpreting information and communication.
- Promoting communication.

4. Are there any specific educational practices regards STEM Education in your country?

SPAIN

In the 2018/19 academic year, according to data from the Ministry of Education, 209,742 students enrolled in Engineering and Architecture at public universities compared to the 237,259 who did so in the 2015/16 academic year. At the same time, in Sciences, the number of students

enrolled has grown by 2,397. Governments and companies no longer doubt the need to promote scientific and technological research, as well as encourage young people to approach STEM careers. It is about promoting research-based training, spreading the impact of science on society, promoting the use of IT in the classroom and using new educational resources. And you have to start from the bottom, in primary school.

In the case of Galicia (North-West region of Spain) [7], there are a special program called “STEMBACH” which as a new specific subject for this purpose in which teachers from schools and professors from universities share learning.

The STEMBach program can be developed by high school students during their two years studying for obtaining the High School Diploma (Equivalent to A-Levels). It is a subject of the “Bachillerato de Excelencia” [7] in Science and Technology, designed for both the Humanities and Sciences modality and created alongside the Galician Strategy for digital education. It promotes the vocation of the students towards scientific and technological research and allows a connection directly with university education. The STEM works have been carried out between the three universities located in the Galician region: University of A Coruña, University of Vigo and University of Santiago de Compostela and different high schools located in the region.

TURKEY

STEM education can be expressed as an educational method that incorporates science, technology, mathematics and engineering disciplines integrated into science courses in order to meet the increasing technological need and includes the teaching of science achievements by increasing the curiosity and interest of students in order to direct them to technology fields (Karataş, 2017). STEM education is a very useful education in order to have a rich perspective of having activities, positively affecting the attitudes of students to science lessons, and learning in a pleasurable and willing way. STEM education, which is becoming increasingly widespread in our country and in the world, is becoming indispensable with science courses (Ulutan, 2018). In this respect, STEM activities are designed and developed for all age groups receiving education.

When we look at the literature, there are many studies for STEM education. The effects of STEM education with different disciplines and sub-disciplines are examined, relevant scales are developed, macro-sized school and even regional studies are available from grade-level studies, published studies are re-examined, validity and reliability analyzes of studies are carried out (Çolakoğlu & Gökben, 2017; Hacıömeroğlu & Bulut, 2016; Helvacı & Helvacı, 2019; Winged, 2019; Kelley & Knowles, 2016; Ring, 2017).

Although STEM education has such a wide range of literature, there are very few studies for students with special educational needs. In general, studies show that there is education of the gifted among students who need special education (Kanlı & Özyaprak, 2015; Ozelik & Akgunduzu, 2017; Ülger & Çepni, 2017). Considering that STEM education has an important place in increasing the power of countries on a global scale, it is thought that the more individuals this education touches, the more purposeful it will be. As a result of this situation, it is seen that STEM education should be applied to individuals who need special education with any disability (Bülbül & Sözbilir, 2017).

STEM education, which is made in special education, appears as barrier-free STEM in the literature. According to Bülbül & Sözbilir (2017), there are 2 sub-dimensions of barrier-free STEM education:

1. Research Opportunities: Due to the fact that STEM education is integrated into multiple disciplines due to its nature, it allows for very different project or event designs.

In this context, when creating designs with students in need of special education, these activities should be designed according to the characteristics of the students, activities that will affect their inadequacies at the minimum level and that their strengths can be used predominantly should be designed. In other words, STEM activities should be designed by centering on the dominant characteristics of students with disabilities. This situation is thought to increase the efficiency, interest and desire of the students.

2. Difference in Learning Environments: It can be expressed as the completion of the inadequate aspects of each other by the students in the learning environment. At the same time, due to the fact that the students' awareness levels are not one, the level of inadequacy or additional inadequacy is found, STEM planning should be directed towards the interests and abilities of each student. In this way, they can design each other's deficiencies within the group.

When designing and implementing STEM education for students with mild intellectual disabilities, equal research opportunities for each student and their preservation of differences should be considered. Students with mild disabilities are actually a rich community in themselves. In this respect, the strengths and weaknesses of the students should be known.

For example, one student may have a higher ability to perform operations while another student may have a higher ability to conduct experimental observations. The cooperation of these students in STEM activities will strengthen the communication skills of the students, peer learning will take place and increase the observation of target behaviors.

The important thing is that the teacher knows his students well and that the activities are designed for these students. (Bülbül & Sözbilir, 2017; Hwang & Taylor, 2016; Taber-Doughty, 2015).

In order to make STEM education more efficient in students with intellectual disabilities, according to Bülbül and Sözbilir (2017), it is thought that knowing and implementing slow STEM education and STEM literacy and deepened STEM education will increase efficiency.

1. Slow STEM Education: As it is known, the learning and comprehension processes of students with mild intellectual disability occur later than their peers with normal development. In this respect, the preparation of the theoretical part of the course before STEM education is applied to the students can be extended and the elimination of this problem of the students with mild disabilities can increase the efficiency. Learning can be carried out within a theoretical framework through abundant repetition, repeated video viewing and multiple realization of enriched learning environments. Then STEM activity should be started. In STEM activity, the requirements to be applied are as follows;

- ♣ Research periods spread over a wide period of time should be given,
- ♣ Care should be taken to ensure that the projects are clear and understandable,
- ♣ When necessary, additional periods and materials required for the experiment should be given without telling the student,
- ♣ Complementary measurement approaches should be used when measuring and evaluating (Bülbül & Sözbilir, 2017).

2. STEM Literacy: The work of students knowing the stages they need to sketch about STEM education is called STEM literacy (Bülbül & Sözbilir, 2017). STEM literacy is necessary for students with mild intellectual disability to be aware of what to do and how to do it. For this, students should be provided with sample demonstrations, preliminary information about how and how the stages will be carried out, and visual facilities supported by the relevant video. It is important for students with intellectual disabilities to get rid of the complex structure of STEM education and to establish contexts that contain as simple information as possible and that this information is related to daily life (Bülbül & Sözbilir, 2017).

In order to realize barrier-free STEM education, the above practices should be carried out and an evaluation should be made in order to measure whether the student reaches the target behavior. In this context, according to Çil and Çepni (2017), the characteristics of assessment and evaluation in STEM education have been adapted as STEM education assessment and evaluation for students with mild intellectual disability. Accordingly, the things to be done when evaluating the STEM activities of students with mild intellectual disability can be expressed as follows;

- ♣ Students should be evaluated both in a way to summarize the situation and according to their performance. An observation form can be created to ensure this. After the activity is completed, the observation form, which includes questions reflecting both the performance of the students and measuring their knowledge, should be created by the teacher by taking into account the individual differences and characteristics of the students.
- ♣ Contextual questions should be asked when asking questions about the activities that have been commissioned by students.
- ♣ Tips should be given for the questions asked until the student finds the truth and the evaluation should be made according to the frequency of the clues given.
- ♣ Since STEM education is multidimensional, the student's level of inadequacy should be taken into consideration and more questions should be asked about the dominant aspects. For example, a student with mild intellectual disability should be evaluated not on the basis of poor psychomotor skills, but on the basis of their dominant aspects. Otherwise, it is thought that the student may have reluctance and cooling towards the lesson.
- ♣ The measurement of the measurement tools that will be created should be multifaceted, and it is thought that having multiple measurements such as motivation, interest, desire, imagination, as well as information will make the measurement healthier.
- ♣ In addition to individual measurement, group measurement should be made, the contribution of the student in the group should be observed and the measurement tool to be created should be found.
- ♣ Care should be taken to ensure that the measurement tool to be created is compatible with the models and methods in which the course is processed.

In this section, a literature review was conducted on the examinations made as a result of the use of STEM applications in various trainings. The effects on students have been investigated, how STEM education has effects on academic success and learning have been examined. According to the researches on the subject, although it has been more common in our country in recent years, it is seen that researches on STEM education have been carried out in other world countries since the 90s. The widespread use of STEM education in recent years has led to an increase in the number of studies on STEM in education. In our country, it comes to the agenda as STEM with Turkish equivalent. While there are a number of studies in which the effect of STEM education on various variables such as interest, attitude, success and skills are examined in detail; in some studies, teachers and students about STEM and the relationships of STEM fields with career choice are examined (Pekbay, 2017). In their study, Capraro (2012)

examined the relationship between the participation of 149 high school students in computer courses and their choice of science, technology, mathematics or engineering fields in the university education that followed. According to the results of the analysis of the data collected by the online survey, the Scientific Ability Exams scores of the students showed a statistically significant relationship with the STEM field selection of the students. Yıldırım and Altun (2015) concluded that STEM education increases the academic success of learners. In another study, where the attitudes of the learners to the mathematics course and the change of their success with STEM education were examined, it was found that the attitude to the mathematics course and the success of mathematics were positively affected by STEM education. The effect of the activities created for STEM education on attitude and scientific process skills was examined and it was seen that the attitude of all these activities to the courses and the effect on the learning processes were positive. Similarly, according to the results of the study conducted by Ercan and Şahin (2015), it was emphasized that the academic achievements of the learners were positive in the design-based studies conducted on STEM. Venville, Wallace, Rennie and Malone (2000) prepared a learning environment in which students used their science and mathematics knowledge with the technology project "Solar Energy Boat" in their studies carried out as a case study with children aged 13-14. As a result of the study, it was seen that students' knowledge and skills in science, technology and mathematics increased (Pekbay, 2017). Riskowski et al. (2009) participated in the 5th Annual Symposium on Water Resources. They observed the class students. In one group, the courses were taught according to the engineering design process, while in the other group, the lessons were taught with the traditional method. The knowledge of the students about water resources was evaluated by applying pre-test and post-test. As a result of the research, a significant improvement was seen in both the thinking levels of the students in the group where the course was taught according to the engineering design process and the field knowledge on the open-ended questions compared to the students in the group where the course was taught with the traditional method. (Gülhan and Şahin, 2016). According to the research conducted by Ercan (2014), it was concluded that STEM activities positively affected the academic achievements, decision-making skills and knowledge levels of engineering science of the learners about the subject of force and movement. Çorlu and Aydın (2016) investigated the learning outcomes related to STEM education. According to the results of the research, STEM activities have increased the skills of learners.

CYPRUS

- **The Robotics Academy at Frederick University Cyprus**

It developed the Educational Robotics Curriculum which was tested in a non-formal educational settings in collaboration with a Private Summer School for kids from 8-12 years old. Observed that there was a positive impact from this application of the curriculum, and can be used as a cognitive-learning tool, which increases students' excitement, critical thinking skills, creativity, innovation and collaboration.

- **STEM program and Robotics Academy**

At Grammar School, a STEM program has been introduced into its curriculum since 2015. This program follows a teaching approach relying on applied knowledge, real-world problem-solving, structured inquiry-based learning and students' active and creative contribution. Students improving their knowledge by doing, designing, making and programming robots or other equipment. Also, the program helps students to develop their knowledge in emphasizing active problem-solving in cooperation with intelligent



technology where students can create, program and design applications and real-life scenarios. Furthermore, students can participate in Robotics Academy, in which they set up as an extracurricular activity that promotes team spirit, leadership and event-organizing skills. In this Academy, students can learn how to build and program a miniature robots using LEGO MINDSTORMS. Finally, through the participation in this Academy, students can be selected to take place in competitions and fairs at national and international level, such as National Robotics Competitions by WRO (World Robotics Organization).

- **The STEAMers**

Youth Board of Cyprus hosted a program that cultivates young people’s creative development, entertainment and learning, to enhance their creativity, innovation and communication skills, and also, their personal development and wellbeing. Through this program, students participate on workshops on Robotics, Coding, Film making, Photography, Graphic Design, Creative Writing, Music, Drama and Art, by specialized trainers/ educators, based on STEM approaches.

- **National Competitions fostering STEAM**

The University of Nicosia organizes an annual competition entitled “Research by Students” for students from Middle, High and Technical schools and invites them to submit their team-based innovative projects, which can focus on social sciences, applied sciences, economics or health.

The Research and Innovation Foundation in Cyprus, a public organization, which organizes an annual competition entitled “Students in Research”, in order to familiarize primary and secondary education students with scientific research procedures and to boost their creativity and innovation. Through this competition, students are encouraged to go through various stages of the research and development process, such as formulation of hypothesis, methodology, data collection and analysis, experimentation, interpretation of results and presentation of research process. The research topics include, among others, Sustainable Development, Information and Communication Technologies, Health and Biological Sciences, Technology, by using interdisciplinary approach, mostly.

- **Young Students in elementary school aged 8-19 years old**

The making and tinkering approach, in which is involved making, tinkering, programming and playing in group project integrated into the formal mathematics curriculum using a variety of arts, crafts and technological tools, such as a physical robot.

5. Legislations, norms/regulations related to STEM Education?

SPAIN



Galician Government (Galicia is one of the regions of Spain located in the North-West of the Iberian Peninsula) started in 2018 a program in order to promote the studies in STEAM areas among high school students. For this purpose, the students of the last two academic years (called baccalaureate students in Spain) had to do a research project in one of the STEAM fields [7]. During this process, some high school teachers involved expressed the interest that many students had in economic-business topics and entrepreneurship. For this reason, this program was finally extended to Social Sciences.

TURKEY

In order to sustain economic development in many countries around the world, STEM education for students has been started. In order to sustain the economic development of our country, STEM education should be used in our education system.

It is important to start integration studies.

This Report has been prepared by a team of experts working under the General Directorate of Innovation and Educational Technologies of the Ministry of National Education with academic backgrounds for STEM education by scanning the available resources and taking the opinions of subject matter experts, academicians and teachers.

In the report, first of all, STEM education is defined, how STEM education emerged and its objectives are explained. In addition, studies on STEM education in various countries, especially in the United States and European countries, have been examined abroad and the situation related to STEM education in our country has been tried to be revealed.

The report also states; A model proposal has been made in order to switch to STEM education in our country, and topics such as the establishment of STEM Education Centers, conducting STEM Education researches, training teachers for the STEM education approach, updating the curriculum according to STEM and providing the necessary course materials for the creation of STEM education environments in schools were underlined. The results of the research conducted by the General Directorate of Innovation and Educational Technologies to determine teacher opinions on STEM education were also shared.

In the evaluation part of the report, it is stated that STEM education should be integrated into the education system of our country.

evaluations related to the required studies and a suggestive STEM Education Action Plan based on these evaluations were presented. The report is open to all kinds of opinions and suggestions of the relevant units and stakeholders of our Ministry and aims to contribute to the curriculum renewal studies that are on the agenda.

CYPRUS

There is an ongoing plan in Cyprus, called ***Recovery and Resilience Plan of Cyprus***, for the modernization and digitization of education. Furthermore, has been offered budget of 13,8 millionsJ € for: the school digital transformation and the improvement of digital & STEM skills. With these money, will be given digital equipment purchase for students qith less favored socio-economic status, digital equipment purchase for schools, there will be happened trainings for the 1/3 of teachers in digijtal skills and in teaching methodology of STEM, and there will become changes in Curriculum and design of educational materials for development of digital and STEM skills.



Another plan for primary education is the ***Integration of information and communication technologies in primary education***, which includes three parts. First, the development of modern and sufficient logistic infrastructure in all classrooms, by using computers for further learning and interaction of students and teachers and reassuring the internet access in all computers and exploitation of applications. Second, there will be continuous training of teachers about technology, for improving the personal using of computers and applications on internet, for the exploitation of computers in lessons and for the presentation of the use of educational software. Third, there will become the reconfiguration of curricula, in order to reform the aims of education and application of new technologies, by replacing the traditional activities with others, applied on computers, where it is possible, and also, by developing digital materials and training for teachers, for its exploitation.

6. Profile of STEM teachers/educator.

SPAIN

The general profiles of the STEM teachers are teachers from Technology, Science, Maths, etc., all of them with a Degree related to Science or Engineering.

TURKEY

STEM; It is an abbreviation of Science, Technology, Engineering and Mathematics (Math). STEM is a very widely used term recently. Since the primary school years, technical trainings were actually available in practice in our country. In 2011, these trainings became widespread in Europe under the name of STEM. In our country, we have schools that provide education under the name of STEM. Thanks to STEM education, it makes lessons such as Science and Mathematics easier to learn by taking them out of memory and making them practical, increasing memorability and making learning.

STEM Problem-solving techniques, alternative ways, curiosity and research come to the forefront. After the developments in technology, the demand and interest in digital professions in the digital world is increasing. As the demand for these professions increases, so does the importance of STEM education from kindergarten to 12 the grade. The use and dissemination of these trainings until the classroom will provide practicality in their professional lives and other courses. STEM+A has evolved over the past few years. The latest addition in STEM+A education is Art. The activities and designs have become important for art to add visuality. The importance of the project in terms of functionality and visuality comes to the first. It is mentioned as a new interdisciplinary teaching model.

With STEM+A, students get away from memorization and increase their motivation as they learn practically in a practical way. It also ensures that the talents in children come to the forefront. The Turkish equivalent of this model is called FETEMM; Science, Technology, Engineering, Mathematics. STEM allows students to assimilate key achievements related to science and technology. STEM provides critical thinking, problem solving steps, researching resources, teamworking or collaborative working, planning, evaluating and analyzing, producing skills and innovating. Many countries in the USA and Europe attach great importance to STEM education. Many specific schools have STEM education programs. Barack Obama, who was the President of the USA at the time, worked on the improvement of teacher education in the field of STEM in the 2012 budget and decided to do so.



What is a STEM Teacher?

With this interdisciplinary education such as Science, Mathematics, Science and Engineering with STEM education, it helps students to highlight their talents and increase their ability to put forward fast and different ideas. With these behaviors, it enables them to be successful in their daily and professional lives.

The STEM teacher teaches students to put into practice and practice theories in Science, Mathematics, Science, Art and Engineering. It makes us love to produce, to follow the innovations and to move forward by putting them on top of them, and to do research. The STEM teacher ensures that his students have fun and pleasure while learning and being productive at the same time.

What's in the context of STEM education?

Coding and three-dimensional design studies are carried out with Scratch, Mblock, Tinkercad and Arduino programs. By doing science experiments, you can put the theoretical knowledge into practice. You can develop fun projects with Makey Makeys.

Improvements and developments can be made in line with the studies carried out. You can develop a prototype of an invention that is needed in everyday life. You can participate in competitions with the projects you have developed.

Teachers learn by having fun with their students and can change children's perspective on challenging topics and lessons.

Parents can buy ready-made STEM sets to spend quality time at home with their children and apply them at home, or they can produce a work themselves with the materials in the house. These studies carried out with children from a young age will have positive effects on their daily and then on their educational lives. Because children who adopt STEM education gain the ability to do research, make decisions, focus on problems, find resources and reason. STEM education is also an educational method that helps to eliminate this problem in children who have problems such as distraction and inability to focus thanks to the attractiveness of activities. Recycling activities are also included in STEM activities.

There are STEM education books, Applied STEM activity Kits and also STEM Education Project Kits for all age groups. You can make STEM education activities by determining the age group, readiness, curiosity and interest areas of the children and making our selection accordingly. The earlier they are started, the more beneficial STEM education contributes to the development of children's numerical intelligence. Thanks to STEM activities, children learn in coding and enter the field of software and programming.

What Does a STEM Teacher Do?

We can list the behaviors that STEM education teachers try to bring to their students as follows...STEM;

tries to raise a competent individual in the fields of Technology, Science, Science and Engineering,

ensures that its students exhibit behaviors that meet the needs of the age,

provides students analytical thinking and problem-solving skills,

enables them to think design and solution-oriented

increases the learning motivation of students,

provides students have leadership qualities,
gains students working discipline in the laboratory,
carries out all the skills such as coding, model designing and doing experiment and guiding for students,
arouses a sense of curiosity and enthusiasm of students with different activities,
ensures students have 21st century competencies.

Some of the books that pioneer to STEM Teachers;

STEM Education Applications - Compass Publications,

STEM Education from Theory to Practice - Practice Book – Nobel Publication Distribution

STEM – Engineering Talent Coloring and Activity Book for Primary School – Genç Bilge Publishing

A Coding Games STEM (5 to 6 Ages) - Limonkids Commission

20 Strategies for STEM Teaching – Nobel Academic Publishing

30 STEM Activities for STEM Kids / Preschool Children - Nobel Academic Publishing

From Village Institutes to STEM Teacher Institutes - Nobel Academic Publishing

Where STEM Teachers can work;

They can work in many educational institutions such as Robotics Workshops, Science Centers, STEM workshops, Children's Clubs, Public Schools and Private Schools.

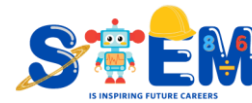
How to Become a STEM Teacher?

In order to become a STEM teacher, specialist instructors who have sufficient competence in this field of interest and training, primarily Computer and Instructional Technology Teaching or Science Teaching (Biology, Chemistry, Physics, Mathematics, middle and high school teachers, classroom teachers, preschool teachers, graduates), who have a 4-year undergraduate department in the Faculties of Education of Universities, can work as STEM teachers. Students who are students in these departments at the university can work as STEM teachers if they have developed themselves in the field of STEM. In addition, many institutions have online or face-to-face education programs and STEM Teacher Education programs. By participating in these trainings, it is possible to complete the programs and get the certificate and teach in this field.

In order to become a STEM Teacher, it is necessary to be dynamic, open to learning strategic and logical thinking, curious and researcher who likes to try new methods. There is no limit to learning in this area.

CYPRUS

According to a survey in *“Journal of STEM Education”*, which highlights the credentials that has an elementary STEM educator. The current profile of this educator seems to be largely female, midcareer and fully certified with a bachelor’s degree from a traditional teacher preparation program, but lately, seems that this category of teachers enhance their knowledge by seeking graduate degrees and more earning certification via alternative programming.



In a pilot program in Cyprus, for STEM education in Primary schools, there will be implemented by permanent teachers with postgraduate qualifications and/or experience in teaching STEM subjects. The teachers, who have been selected for this pilot program, must attend a training program, which offered by the Directorate of Primary Education, in collaboration with the Pedagogical Institute of Cyprus.



**Co-funded by
the European Union**

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them

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