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DIDACTECH

TRAINING PROGRAM

IN TEACHING FOR EXPERT RESEARCHERS



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Coordinator:
Ikasia Technologies SL

Written by:
Luis Martins
Laura Gómez Estrada
Luis Gómez Estrada
Pierre Carrolaggi
Carlo Zoli
Juliana Oliveira
Panagiotis Chatzipapas
Georgios Charalampidis
Panagiotis Karampelas
Dimitrios Fligos
Raquel Navarro Cerveró
César Almarcha

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Topic 1. Introduction

As a result of the crises we have experienced in recent years, there has been unprecedented technological development that has affected not only the economic, medical, and labor sectors, but also education. Science has become a dynamic and effective mechanism for overcoming the limitations of these crises, bringing education to those who could not attend school and becoming an increasingly valuable asset for the employability of high school students.

However, this technological advancement has not reached all schools equally, and its implementation often does not reach the schools that need it most: those in areas especially affected by the social emergency.

In this context, seven technology companies and secondary schools in Europe, within the framework of the Erasmus Plus project “Didactech”, have created an innovative methodological strategy that promotes technological training and an interest in science and technology for disadvantaged secondary school students. This is achieved through the creation of Techlabs, technology fabrication workshops where students from disadvantaged areas (especially women; according to the White Paper on Women in Technology (2019), only 16% of STEM professionals are women, and very few teenage girls, 0.7%, are interested in studying technology degrees) use state-of-the-art digital fabrication equipment (such as 3D printers) not only to acquire scientific and technological training, but also to create educational materials that support under-resourced primary schools.

In this regard, technology companies can play a fundamental role. Their experience in research, development, and innovation is key to collaborating with educational institutions and creating learning experiences that bring science and technology closer to primary and secondary school students.

However, for the implementation of the Techlab methodology, we consider it important that researchers and technicians from technology companies know how these laboratories work, what their role is within them, as well as key pedagogical concepts that help them both in the training of teachers included in the Techlab methodology and in the design and creation of scientific activities.



With this objective, within the framework of the Erasmus Plus “Didactech” project, we have created the TRAINING PROGRAM FOR EXPERT RESEARCHERS IN TEACHING. This is an online training course aimed at researchers and technicians from technology companies to equip them to provide training in the educational field, so that educational institutions can benefit from the support of technology sector experts with specific training in teaching.

Topic 2. TechLab Methodology: Design and Implementation of Technological Laboratories

2.1. What is a TechLab and what is it for?

Techlabs are technology labs designed to bring science and technology closer to secondary school students, especially those facing learning challenges and difficulties. They are free learning spaces equipped with cutting-edge technology that allow students to learn science by doing science.

A real, motivating, and useful educational experience that makes learning tangible and exciting. Using state-of-the-art digital fabrication equipment (such as 3D printers), teachers can easily and dynamically incorporate 3D into their students' education, and students delve into the fascinating world of science, developing essential skills for their academic and professional future.

Thanks to the world of 3D, students design, model, and create their own projects, sparking their creativity and critical and scientific thinking while learning STEM concepts. In this sense, each classroom becomes an opportunity to learn science in a dynamic and fun way, work in teams, and acquire key and transversal skills.

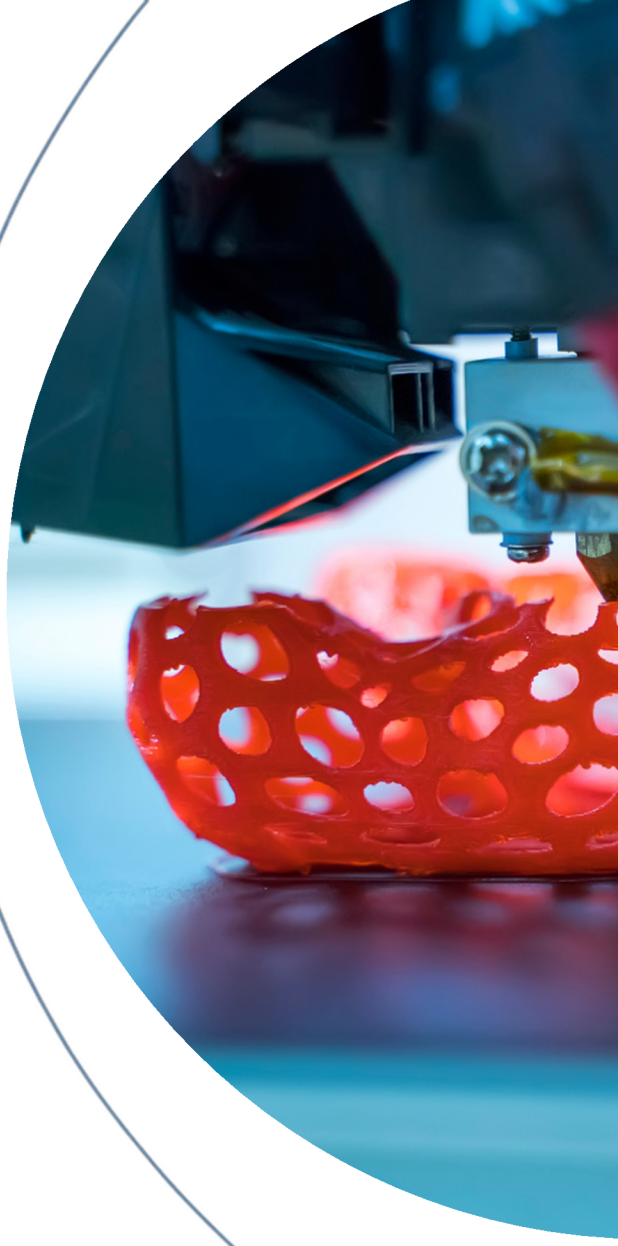
The goal is not only to equip educational centers with advanced equipment, but to implement a space where 3D technology becomes a key tool to bring science and technology closer to these students, acquire STEM knowledge, develop key skills for their future, both academic and professional, and motivate them and reduce early school leaving rates.



Through TECHLABS, we implement a consistent educational strategy that fosters the direct involvement of technology companies in schools in underserved areas. This strategy generates an innovative methodology encompassing curriculum and content development for STEM subjects both during and outside of school hours. This is achieved by creating technology labs (TECHLABS) equipped with cutting-edge technology that will produce materials for primary schools with limited resources.

Thus, Techlabs act as a bridge between research, technology companies, and education.

2.2. The Techlab Methodological Strategy



The Techlab methodological strategy forms the core of the Erasmus+ DIDACTECH project and represents a new way of conceiving science and technology education in secondary schools. The starting point for this strategy is an observation: the digital and technological divide remains a significant obstacle in schools in socioeconomically disadvantaged areas. In many of these schools, technology does not reach all students with the same intensity or support, leading to inequalities in access to science education and in their future opportunities. The Techlab strategy arises precisely as a response to this inequality, proposing an educational model that democratizes access to technological innovation and transforms it into a tool for inclusion, motivation, and personal development.

In this context, technology companies play an essential role by providing specialized knowledge, technological resources and real-world experiences that enrich student learning and complement the work carried out by educational institutions.

Secondary school students participating in a Techlab become part of a group where they experience their creative abilities firsthand and explore ways to contribute to a more just society. Along the way, they discover how increasing their skills and knowledge in mathematics, design, and technology opens up a world of possibilities.

The participation of researchers and technicians allows students to be introduced to real examples of innovation, showing how scientific and technological knowledge has a direct application in society and in the business environment.

The Techlab laboratory, on the one hand, facilitates the acquisition of STEM skills, ensuring that learning is not generic but rather geared towards achieving a functional objective. This strategy has a great capacity to motivate students towards subjects that, when presented in a general way within a course, might seem too distant.

But the other aspect of the Techlab is that it allows what a group of students designs to be produced and distributed to other primary schools with limited resources. However, organizing production, advertising the products, setting priorities, and securing the necessary funding will require learning many things and considering and discussing fundamental principles of solidarity among individuals, societies, and nations.



With these fundamental ideas in mind, the Techlabs educational methodology is based on the following points:



I work in small groups of students

Under the supervision of a professor with extensive knowledge of the 3D printing systems integrated into the Techlab, students will have access to occasional collaboration from researchers and technology professionals who can contribute specialized knowledge and guide the development of specific challenges or projects. It's a matter of striking a balance between fostering collaborative work experience with the professor and preserving, without interference, the students' creativity and their experience in independently organizing their work.



Focus of the work towards the development of STEM skills (Science, Technology, Engineering and Mathematics).

The strategy fosters the acquisition of STEM skills. The need to understand concepts in these subjects will arise continuously, and it is the teacher's role to help students understand the importance of not just glossing over these concepts, but rather taking the time to grasp them thoroughly and making the most of them to achieve the established objectives. Furthermore, a deep understanding of science and technology is more feasible when students can manipulate, create, and explore. The Techlab strategy introduces a learning approach where scientific concepts cease to be abstract and become tangible, visible, and understandable experiences.

Many situations will also arise that encourage reflection on other essential 21st-century skills: critical thinking, problem-solving, creativity, communication, autonomy, and teamwork. Learning is action-oriented, focused on decision-making and the responsible use of technology.

Educational inclusion and attention to diversity

While the technology workshops (Techlab) are aimed at all secondary school students, we place special emphasis on those students who face obstacles, as they are the ones who encounter the greatest barriers to inclusion. These are secondary school students, especially girls, from disadvantaged regions who face economic, social, and employment barriers, encountering serious difficulties in accessing the technology job market and pursuing higher scientific careers, and consequently losing interest in this field.

Students are integrated into groups in which each one takes on specific tasks, progressing at their own pace and drawing their own conclusions while learning from their peers. The methodology is designed to encourage the participation of all students, regardless of their learning pace or style.

In this sense, both technology companies and educational centers must share this commitment to inclusion, ensuring that activities and resources are accessible to all students.



Collaboration

The E+ Didactech project focuses on collaboration between educational institutions and technology companies across Europe. A key principle is that everything conceived and produced within the framework of this publicly funded project should be made available to society. In this sense, the work in the Techlabs is freed from concerns about profit and competition. There is no need to hide what is being created to protect it from others, whether within the group, the educational institution itself, or among the network of Techlabs spread across the European Union. Creations, in the form of designs and print files, will be made public. The program also integrates a network of technology-based companies that will contribute ideas on relevant objectives, and primary and secondary schools that will demonstrate how to use the materials developed in their educational centers and identify their needs.

The participation of companies does not consist solely of providing equipment or technical knowledge, but in establishing a continuous collaborative relationship with educational centers.

Gender perspective and promotion of female talent in science

The strategy places special emphasis on promoting the active participation of female students in science and technology, fostering their self-confidence and highlighting positive role models in innovation and engineering. Within the framework of the Erasmus Plus “Didactech” project, the Women in Science Today campaign has been developed, an innovative initiative that presents secondary school students with real and current examples of women who are contributing to scientific advancements in various fields.

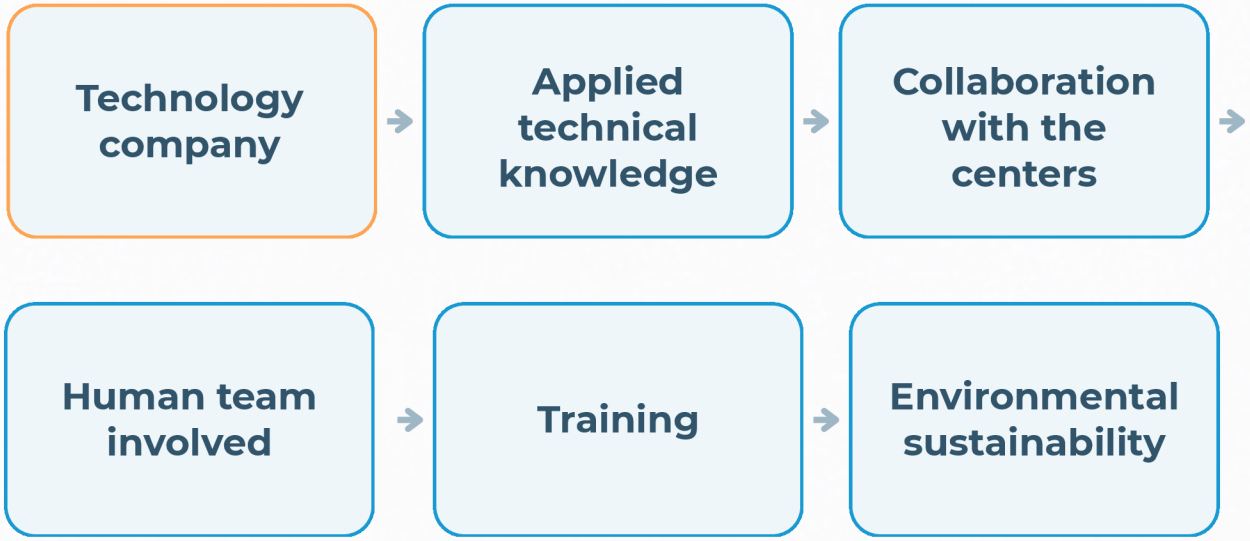
The WOMEN IN SCIENCE CAMPAIGN was created with a clear objective: to inspire high school girls to discover the potential of women in science and technology fields. Unlike other initiatives focused on women throughout history, this campaign focuses on the present, showcasing the vital role women play today, leading pioneering research centers, directing and working on research projects that will change the future of Europe and the world.

The collaboration of technology companies is especially important in the development of initiatives like the Women in Science Today campaign, as it allows students to be introduced to current female role models from research centers, universities, and innovative companies. Thanks to the direct participation of these professionals, students can identify relatable and real-life role models that help break down stereotypes and foster their interest in STEM careers.

Topic 3. Collaboration between technology companies and educational centers for the implementation of a TechLab

Collaboration between technology companies and educational institutions is one of the cornerstones of the Techlab methodology. For a technology company, implementing a Techlab doesn't mean "becoming a teacher," but rather collaborating with the educational institution based on its area of expertise.

HOW THE TECHNOLOGY COMPANY CONTRIBUTES



Applied technical knowledge

Techlabs are based on the idea that technology companies contribute their scientific and technical expertise. On the one hand, these companies can provide students with knowledge about technological advancements and real-world applications of science and technology. On the other hand, they can offer training on technological equipment for teachers, supporting them in the implementation of the Techlab.

Collaboration with educational centers

Collaboration between technology companies and educational institutions can take many forms. Key examples include the design and creation of extracurricular activities led by company technicians, presentations at schools to promote science and technology among secondary school students, and initiatives like the Women in Science campaign. We will explore these initiatives further in Topic 5 as a way to motivate students.

Human team involved

The company's employees (technicians, researchers, engineers, etc.) participate as advisors, mentors, etc. Their role is not to teach classes or replace teachers, but to accompany students in the process, collaborate in the development of activities, and bring science and technology closer to them.

Safety training

Thanks to their experience using cutting-edge technology, technology companies can advise teachers and school administrators on implementing protocols and guidelines to ensure risk prevention in the classroom when using 3D printing equipment or other advanced technology in Techlabs. While it's important to keep in mind that the official manuals for this equipment should be used as a reference, it's also crucial to understand the main risks that can arise and how to prevent them to guarantee a safe environment for students and teachers.



Environmental sustainability

We consider the incorporation of sustainable practices in Techlabs a priority, not only to reduce the ecological footprint but also to teach students to be more environmentally responsible and develop a critical awareness of environmental issues. The main sustainable practices we recommend implementing in Techlabs are the following:

- Selection of printing materials. There are certain more sustainable materials that use recycled or biodegradable materials, such as PLA.

- Efficient design of each part. We recommend grouping several parts into a single print, reviewing the designs beforehand to reduce thickness and support as much as possible, and calculating filament consumption before printing.

- Recycling printing materials. There are practices that help recycle 3D filaments, such as separating and storing the scraps in a box or container in the lab, taking them to recycling centers, or contacting organizations that collect 3D printing plastics for recycling (municipal services, universities, etc.).

- Efficient energy use and responsible machine maintenance. Turn off the printer when not in use, analyze the estimated printing time...

Topic 4. Pedagogical Concepts for Technology Professionals

Although many researchers, laboratory technicians, technicians or workers in technology companies and research centers have knowledge and experience in educational contexts, this is usually especially in the university setting.

When training is aimed at secondary school students, especially those facing various obstacles, it is essential to understand and analyze how they learn, what motivates them, and how we can bring science and technology closer to them through "Techlab" technology laboratories.

Learning in Techlabs requires innovative methodologies, distinct from traditional education focused on transmitting knowledge. In this sense, it is based on pedagogical principles in which learning science and technology is conceived as an active process, where secondary school students acquire knowledge by doing, exploring, and reflecting.

This approach is related to constructivist pedagogy, which conceives of learning as an active process in which knowledge is acquired through direct experience and interaction with the environment (Piaget, 1970; Fosnot, 2005)[1][2]. Thus, instead of teaching concepts in a traditional and passive way, students learn by exploring, experimenting, and observing, as well as reflecting on what they do. Thanks to this, they gain a better understanding of STEM concepts.



Learning experiential

In Techlabs, this approach translates into learning sessions where students transform abstract concepts into tangible experiences through hands-on experimentation and construction. This not only facilitates understanding but also fosters motivation.

01 TO POSE CHALLENGES

In this context, the role of the technician or researcher is not to explain concepts theoretically, but in a dynamic and practical way that facilitates students' understanding through experimentation.

This involves posing challenges

02 OBSERVE AND EXPERIMENT

Guide them in their observation, ask questions that spark their curiosity...

03 DEVELOP AUTONOMY AND CRITICAL THINKING

In this way, we will foster autonomy, critical thinking, motivation, and curiosity, while involving them in their own learning.

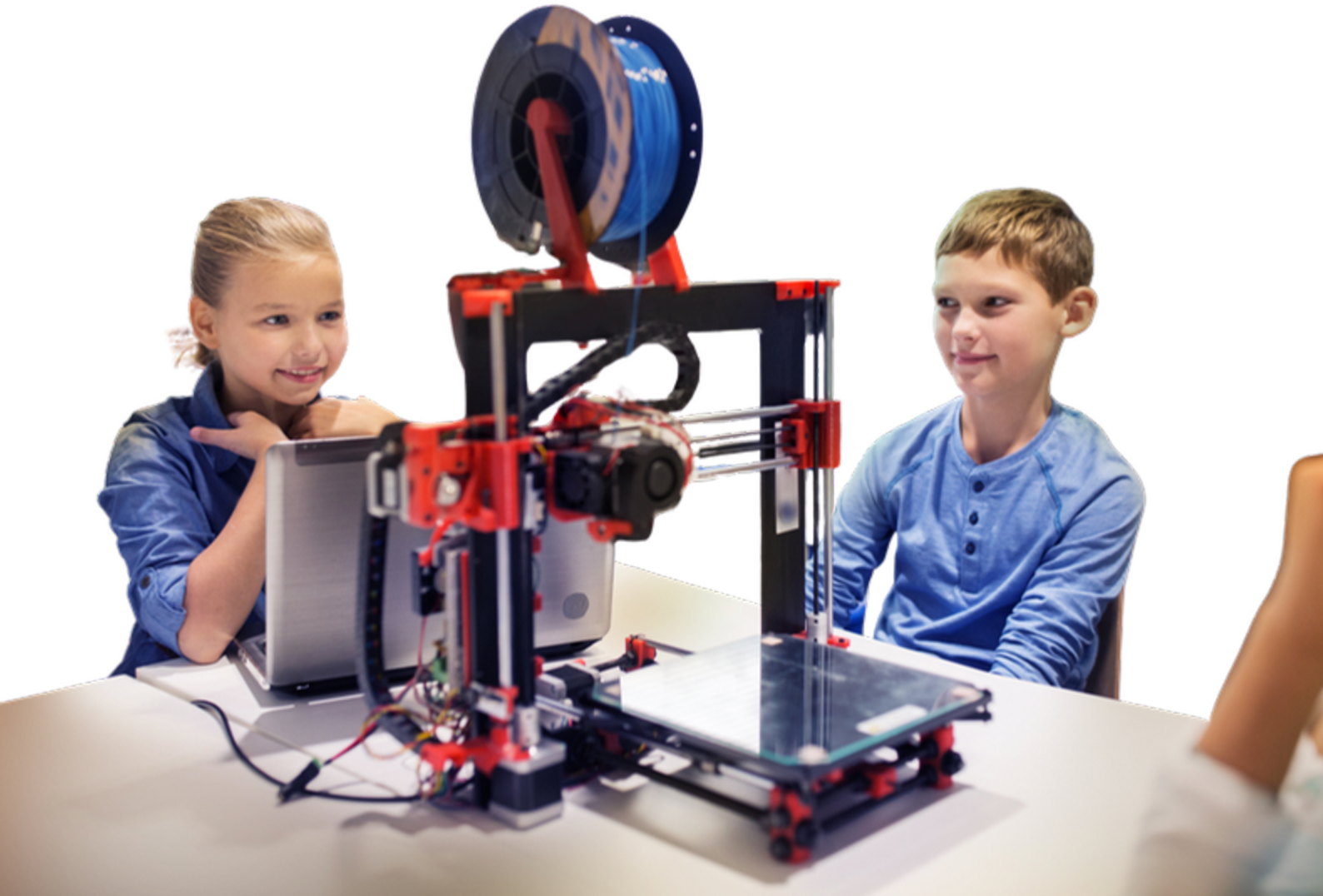
Furthermore, this methodology and pedagogical principles allow activities and learning to be adapted to the needs of the students.

4.1. Pedagogical Foundations of the Techlab Methodology

With this topic we do not seek to establish a teaching model, but to explain the pedagogical foundations of the Techlab methodology that support researchers, technicians and workers of technology companies in their role in the creation and implementation of Techlabs both inside and outside the classroom.

Experiential technological learning

In the development and/or design of activities to be developed in the Techlab, we have the ability to facilitate scientific and technological learning through interaction and experimentation, allowing students to work directly with 3D printers or make use of materials created with these printers to build while acquiring STEM knowledge.



FOR EXAMPLE: THE CHEMICAL BOND

For centuries, chemists were like cooks who had the list of ingredients but not the recipe. They knew, for example, that water had two hydrogens and one oxygen (H_2O), or that methane gas had carbon and four hydrogens (CH_4). But for a long time, no one knew how those ingredients were connected in real space. Were they in a line? Did they form a square? A pyramid?

Because scientists worked with paper and blackboard, which are flat, they made the easiest assumption: that molecules were also flat. For decades, they drew methane as a flat cross, with 90-degree angles, just as we sometimes do today when drawing Lewis structures in our notebooks. But something didn't add up. If molecules were flat, the world wouldn't work the way it does.

The big change came in 1874, when two young chemists (Van't Hoff and Le Bel) proposed a then-revolutionary idea: atoms do not exist in two dimensions. They suggested that carbon did not form a flat cross, but a pyramid with a triangular base (a tetrahedron), occupying all three dimensions of space.

The 'serious' teachers of the time ridiculed them, but history proved that 'childhood imagination' was reality. The 3D model is key to everything: how medicines work, why water is liquid, and how things smell. Today, you are going to repeat that historic leap.

Methodological innovation

Techlabs promote creative educational environments, far removed from traditional classrooms, where we encourage experimentation, the use of innovative technologies, and critical thinking. We have created a completely innovative space that will change the training processes in secondary schools thanks to:

01 The direct involvement of entities that are developing cutting-edge technological innovation projects capable of transforming European society in the medium term, where world-class experts participate.

02 Establishing unique synergies between private enterprise and education in disadvantaged areas not only results in high-impact scientific education for users, but also provides under-resourced primary schools throughout Europe with free educational resources generated in TECHLABs.

03 To meet the challenge of modernizing educational centers while combating school dropout rates among students facing obstacles, especially women, by relieving teachers of their workload through the involvement of expert technicians from technology companies.

04 Establish a holistic strategy that transforms STEM processes, with training for teachers in innovative technologies, with teachers' internships in companies, and with scientific experts who collaborate in the development of their classes.

05 To create TECHLABs, technology-based manufacturing workshops, where high school students are involved in the production of high-quality educational resources for under-resourced primary schools. A space where students discover the value of technology in helping other primary school students and fosters their educational success.

Competency development

Techlabs empower high school students to acquire key online STEM skills. Specifically:



Literacy skills

The European Commission defines literacy as “the ability to identify, understand, express, create and interpret concepts, feelings, facts and opinions orally and in writing, using visual, sound or audio and digital materials in different disciplines and contexts. This implies the ability to communicate and connect effectively with other people, in an appropriate and creative way”[1].

This skill is developed in the Techlab, both in classroom and extracurricular activities, through the exchange of ideas, the formulation of hypotheses, giving opinions...

[1] Recommendation of the Council of the European Union of 22 May 2018 on key competences for lifelong learning (2018/C 189/01). Annex. Key competences for lifelong learning. A European reference framework.

Mathematical competence and competence in science, technology and engineering

The European Commission defines mathematical competence as “the ability to develop and apply mathematical reasoning and perspective in order to solve various problems in everyday situations. Building on a good command of calculation, the emphasis is on process and activity as well as knowledge. Mathematical competence entails—to varying degrees—the ability and willingness to use mathematical modes of thinking and representation (formulas, models, constructions, graphs and diagrams)” [1] and competence in science, technology and engineering as “the ability and willingness to explain the natural world using the body of knowledge and methodologies employed, including observation and experimentation, in order to ask questions and draw evidence-based conclusions. Competence in technology and engineering means the application of such knowledge and methodologies in response to perceived human wants or needs. Competence in science, technology and engineering entails an understanding of the changes caused by human activity and the responsibility of each individual as a citizen” [2]

[1] Recommendation of the Council of the European Union of 22 May 2018 on key competences for lifelong learning (2018/C 189/01). Annex. Key competences for lifelong learning. A European reference framework.
[2] Recommendation of the Council of the European Union of 22 May 2018 on key competences for lifelong learning (2018/C 189/01). Annex. Key competences for lifelong learning. A European reference framework.

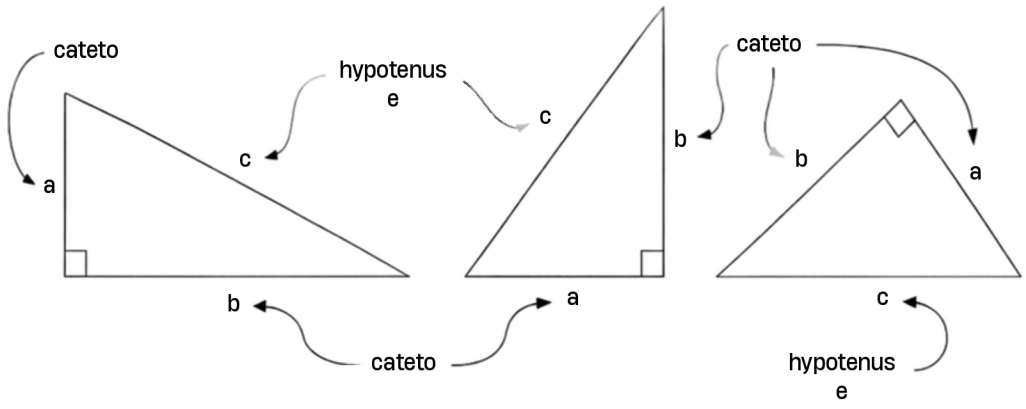
Techlabs are a fundamental learning space for working on STEM subjects through 3D printing, as they allow students to move from the abstract to the tangible. For example, mathematics ceases to be just numbers and becomes designed objects, technology is learned through innovation, and subjects like biology, physics, and chemistry are learned with three-dimensional models that students can manipulate and understand more easily.

FOR EXAMPLE: "PYTHAGORAS" MATH ACTIVITY

This activity is a geometric visualization and deduction exercise designed to transform an abstract formula into a tangible reality.

The starting point is the physical manipulation of a triangle and three squares of different sizes. The challenge is for participants to discover the physical relationship between the sides of the triangle and the areas of the squares, fostering the transition from concrete thinking (touching the pieces) to abstract thinking.

$$a^2 + b^2 = c^2$$



Once the visual relationship is established, the activity evolves towards arithmetic verification, using the measurements of the printed pieces to verify that the sum of the areas of the smaller squares is exactly equal to the area of the larger square, but only under certain geometric conditions (right triangle).



Digital competence

The European Commission defines digital competence as “the safe, critical and responsible use of digital technologies for learning, at work and for participation in society, as well as interaction with them. It includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), security (including digital wellbeing and cybersecurity-related competences), intellectual property issues, problem-solving and critical thinking.” [1]

The use of innovative 3D printing equipment, modeling software, and digital tools for the implementation of Techlabs makes these technology laboratories a fundamental environment for digital literacy and the acquisition of this skill.

In some cases, the activities you design will use pre-printed 3D models, while in others you can involve the students in designing these pieces. However, when the activity involves them designing 3D models, we must consider the time available in each session, as well as the number of computers available at the school, in order to create groups and adapt to the school's situation.

[1] Recommendation of the Council of the European Union of 22 May 2018 on key competences for lifelong learning (2018/C 189/01). Annex. Key competences for lifelong learning. A European reference framework.

Personal, social and learning-to-learn competence

The European Commission defines personal, social and learning-to-learn competence as “the ability to reflect on oneself, manage time and information effectively, collaborate constructively with others, maintain resilience and manage one’s own learning and career. It includes the ability to cope with uncertainty and complexity, learn to learn, contribute to one’s physical and emotional well-being, maintain physical and mental health, and be able to lead a healthy and future-oriented life, express empathy and manage conflict in an inclusive and supportive context.” [1]

To promote critical thinking, the ability to learn how to learn, make decisions, and seek answers, we recommend posing key questions in each of the experiments or parts of the activity that we design.

FOR EXAMPLE:

The activity will consist of lifting the same weight and asking the key questions: Is it much easier than before? (Yes). How many ropes are holding the weight (the moving block)? Key concept: Force is divided by the number of ropes holding the moving block. F = Weight / n. In this case, n = 4. (If the weight is 1 kg (approximately 10 N), the force required is only 2.5 N.)

On the other hand, we can design activities in which the class is divided into groups, promoting teamwork.

[1] Recommendation of the Council of the European Union of 22 May 2018 on key competences for lifelong learning (2018/C 189/01). Annex. Key competences for lifelong learning. A European reference framework.

Civic competence

The European Commission defines civic competence as “the ability to act as responsible citizens and participate fully in social and civic life, based on an understanding of social, economic, legal and political concepts and structures, as well as sustainability and world events.” [1]

Techlabs are inclusive and discrimination-free spaces designed to ensure the equitable participation of all students, especially those facing barriers. The implementation of Techlabs promotes equal opportunities and responsible participation in the educational community, contributing to an education based on diversity and equity.

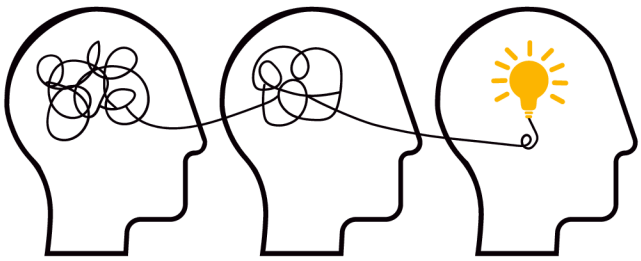
[1] Recommendation of the Council of the European Union of 22 May 2018 on key competences for lifelong learning (2018/C 189/01). Annex. Key competences for lifelong learning. A European reference framework.



Entrepreneurial competence

The European Commission defines entrepreneurial competence as “the ability to act on opportunities and ideas and transform them into value for others. It is based on creativity, critical thinking and problem-solving, taking initiative, perseverance and the ability to work collaboratively in the planning and management of projects of financial, social or cultural value.” [1]

In the Techlab and 3D printing, students learn to identify problems, formulate hypotheses, and propose solutions, fostering initiative, decision-making, and resource management. Thanks to this, they acquire the necessary skills to develop an entrepreneurial attitude geared towards innovation.



[1] Recommendation of the Council of the European Union of 22 May 2018 on key competences for lifelong learning (2018/C 189/01). Annex. Key competences for lifelong learning. A European reference framework.

Competence in cultural awareness and expression

The European Commission defines competence in cultural awareness and expression as “the ability to understand and respect the way in which ideas and meaning are creatively expressed and communicated in different cultures, as well as through a range of arts and other cultural manifestations. It involves striving to understand, develop and express one’s own ideas and a sense of belonging to society or of playing a role in it in different ways and contexts.” [1]

Techlabs allow high school students to acquire scientific and technological knowledge in a dynamic and creative way.

FOR EXAMPLE: OPTICS AND LIGHT: THE CAMERA OBSCURA

Optics is the branch of physics that studies the behavior of light. Although we are surrounded by screens and digital cameras today, the physical principle that allows us to capture an image hasn't changed in centuries: light travels in a straight line. The Camera Obscura project allows us to travel back in time, to the era of Aristotle and Da Vinci, to understand how a real image is formed. By building this device, students will discover why our eyes see inverted images and how the brain processes them, as well as understand concepts such as focal length, sharpness, and aperture (diaphragm). It's pure magic: seeing the outside world projected onto tracing paper without any electronics involved.

[1] Recommendation of the Council of the European Union of 22 May 2018 on key competences for lifelong learning (2018/C 189/01). Annex. Key competences for lifelong learning. A European reference framework.

Multilingual Competence

The European Commission defines multilingual competence as “the ability to use different languages appropriately and effectively for communication. Broadly speaking, it shares the same dimensions of competence as literacy: it is based on the ability to understand, express and interpret concepts, thoughts, feelings, facts and opinions orally and in writing (listening, speaking, reading and writing) in various social and cultural contexts according to one's wishes or needs.” [1]

In some cases, the designed activities involve students searching for information on the internet, consulting manuals in different languages, and resolving doubts with the support of scientists, allowing them to become familiar with technical, scientific, and technological vocabulary in English.

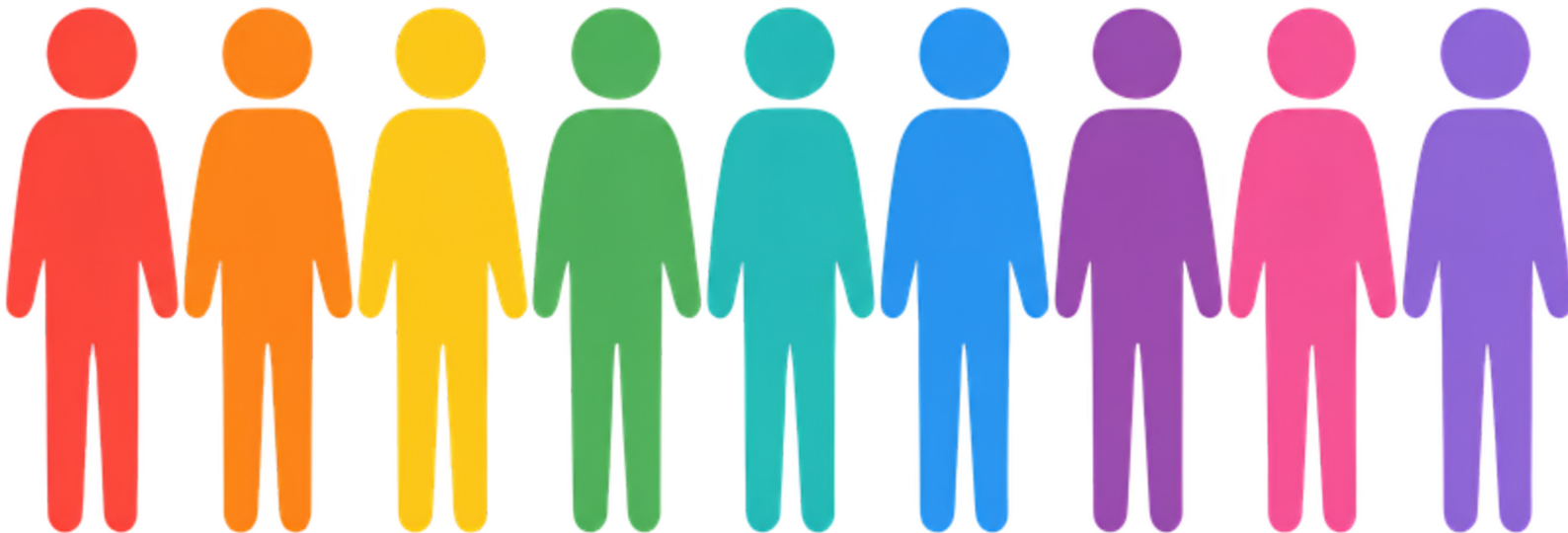
[1] Recommendation of the Council of the European Union of 22 May 2018 on key competences for lifelong learning (2018/C 189/01). Annex. Key competences for lifelong learning. A European reference framework.



Educational inclusion and attention to diversity

The Techlab methodology has been designed so that all secondary school students, regardless of their needs and challenges, can fully participate in laboratory activities. In this regard, as technicians and researchers, we play a crucial role, not only in designing the activities but also in adapting explanations, providing visual and practical support, and ensuring that the activities are accessible and understandable for all students.

In the next topic we will delve deeper into the mechanisms of inclusion.



Topic 5. Student Motivation and Inclusion in Technological Contexts

5.1. Obstacles faced by students

Although Techlabs are aimed at all secondary school students, they are especially geared towards secondary school students, particularly those in more vulnerable situations who face barriers (economic, geographical, cultural, etc.). We are talking about secondary school students, especially girls, who live in rural areas, have higher rates of early school leaving, and encounter greater difficulties accessing higher education in science.

THE MAIN OBSTACLES THESE STUDENTS FACE ARE:

01

Socioeconomic obstacles.

Many of these students come from families with limited economic resources, making it difficult for them to participate in activities with additional or high costs.

02

Geographical obstacles.

Many secondary education centers are located in rural or peripheral environments where there is a limited supply of scientific activities or innovative technological workshops.

03

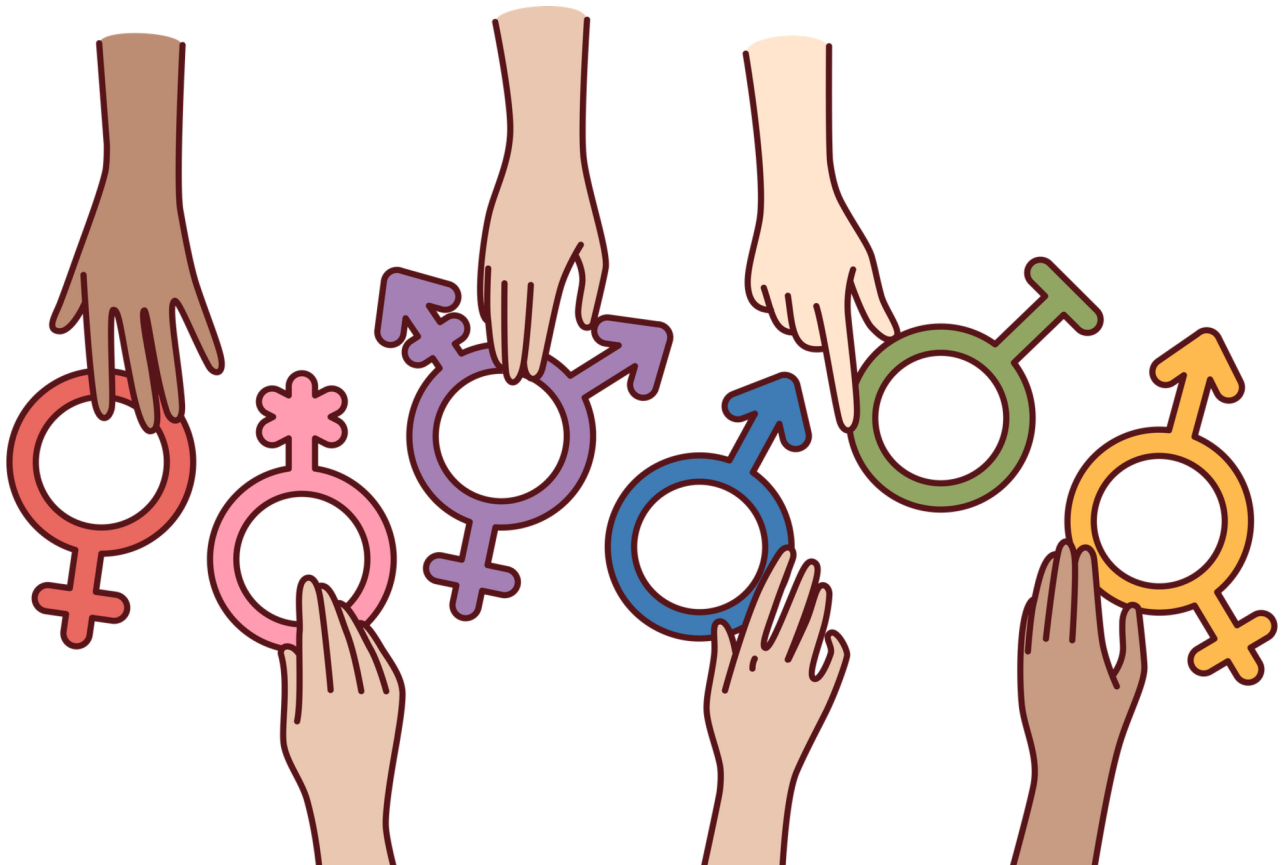
Cultural and social obstacles.

Students from migrant backgrounds or ethnic minorities frequently face hate speech such as racism. These situations, coupled with potential language barriers, hinder their social and educational inclusion.

04

Gender barriers.

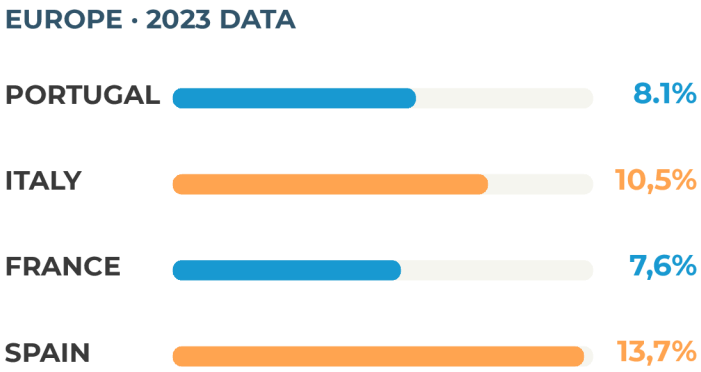
The potential of women in science is undeniable. However, the figures are worrying. According to the White Paper on Women in Technology (2019), only 16% of STEM professionals are women, and very few teenage girls (0.7%) are interested in pursuing technology degrees. This gap is not due to a lack of ability, but rather to structural factors such as gender stereotypes associated with technology and the limited visibility of female role models in science and technology during secondary school.



5.2. Motivation: the role of technology companies in combating school dropout

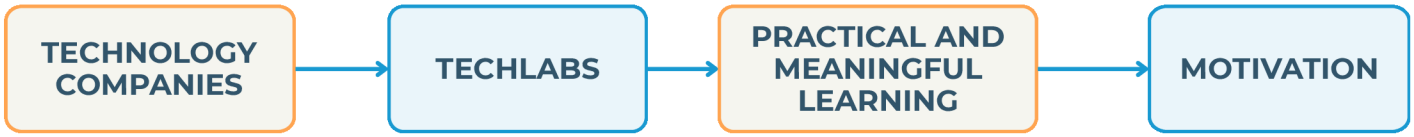
SCHOOL DROPOUT

We define school dropout as occurring when students between the ages of 18 and 24 leave their studies without completing post-compulsory secondary education and do not pursue any further training. In other words, they leave the education system too early.



Nevertheless, it remains necessary to address this issue to guarantee equal opportunities and respond to the future social and labor demands of secondary school students.

In this sense, it is important to highlight the role of technology companies in the fight against school dropout, since they have the ability to provide elements that educational centers, especially those with low resources, cannot always offer their students and which are key, such as MOTIVATION.



We believe that one of the most effective mechanisms to motivate secondary school students and reduce dropout rates is practical and meaningful learning through the "TECHLABS" technology laboratories, which we discussed in topic 4 of this course.

Many students don't see the connection between what they study and how it will benefit them in the future. Techlabs transform intangible concepts into tangible, dynamic, and meaningful learning, bringing science and technology closer to high school students facing challenges and involving them in their own learning.

The role of technology companies in Techlabs, and therefore in student motivation, fulfills several fundamental objectives:

01 IMPLICATION

To offer motivating experiences that allow students to engage in their learning in a dynamic, entertaining way that increases their interest.

02 REFERENCES

Show them relatable role models who demonstrate not only real-life trajectories, but who break stereotypes and show students facing obstacles that they too can succeed.

03 INCLUSION

Learning on equal terms, as Techlabs allow everyone to participate on equal terms, regardless of the resources available to the center or the students, or the barriers they face.

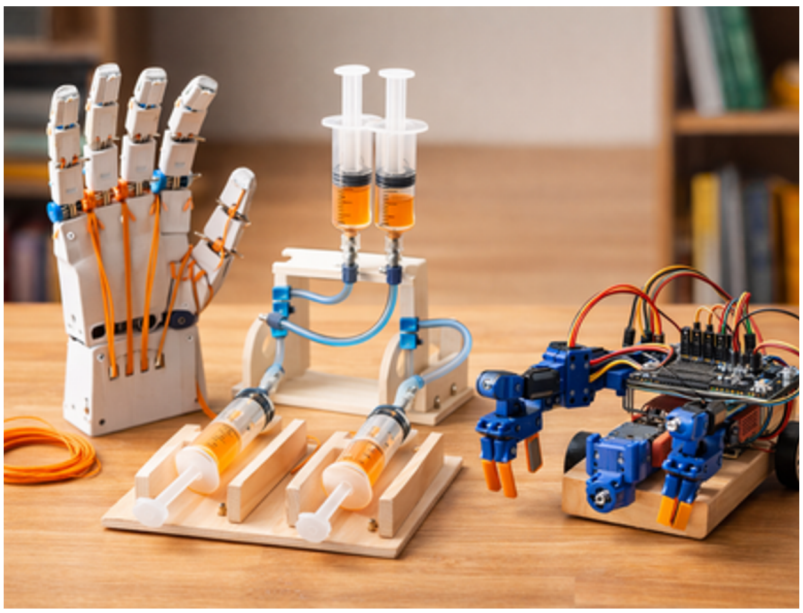
Below, we present a set of strategies to motivate students in STEM fields in which technology companies play a key role:

Design
extracurricular activities

These activities allow secondary and primary school students to learn STEM concepts in a simple, engaging, and fun way. Thanks to the experience of technology companies, you can contribute significantly to the education of secondary school students. Furthermore, a well-designed activity reduces frustration, fosters autonomy, and allows students to experiment—a factor directly related to school retention and engagement.

FOR EXAMPLE

We can design an activity where students build a simple mechanism inspired by the movement of the human hand to understand how tendons work or how force is transmitted. We're talking about something simple, visual, and that can be surprising and spark their curiosity about science and technology. This experience not only allows them to learn STEM concepts without even realizing it, but it also helps motivate them.



ANOTHER EXAMPLE

At the Techlab, we can conduct a practical exercise on molecular models in the STEM subject of Physics and Chemistry. In this exercise, we will create a model that helps explain and understand the molecular structure of very different substances, from simple molecules like water or the molecular oxygen and nitrogen that largely make up air, to extraordinarily complex molecules such as those that form the components of living systems: proteins, polysaccharides, DNA, and RNA.

The model will help us visualize not only the composition but also the internal mobility—the number of different conformations the molecules can adopt. But, of course, for that we'll need a lot of atoms, and here our 3D printing technology lab (Techlab) will allow us to grow our set of molecules as much as we want (with patience, of course).

Water



Ethyl alcohol

Butane

Glucose

In topic 7 we will see several examples of extracurricular activity proposals designed by the teams of the technology companies of the E+ “Didactech” project.

Create synergies
with educational centers

It allows us to connect them with the world of work and professional life and contribute to the motivation and learning of students through European projects, extracurricular activities...

Chats
in educational centers

Where possible, holding virtual or in-person talks at schools allows us to showcase role models to students, motivating them, inspiring them, and showing them career paths in science and technology. We can explain the research or development area we work in, how student interns work, and answer any questions they may have.



Women in Science Today

Within the framework of the Erasmus Plus “Didactech” project, the Women in Science Today campaign has been developed. This innovative initiative presents secondary school students with real-life examples of women who are contributing to scientific advancements in various fields. As technicians and researchers, we have the ability to inspire many secondary school students, break down stereotypes, and help all students naturally perceive that science is an area where gender diversity is key to progress.



5.3. Inclusion

Full participation begins in the design.



Techlabs have been created with the aim of bringing science and technology closer to secondary school students, especially those with obstacles, in a motivating and innovative way.

AN INCLUSIVE APPROACH

To achieve this goal, it is essential that the activities carried out in the Techlabs, both curricular and extracurricular, have an inclusive approach that guarantees the full and active participation of all students. If we consider the diversity of the student body and their needs from the outset of the activity design, we will be able to reduce the barriers and obstacles they face (outlined in section 6.1 of this course) and achieve their full inclusion.

Below, we present a list of inclusion mechanisms that we can implement, both in the design of activities and in the case of providing extracurricular activities in secondary schools.

Three dimensions for true inclusion

01

Equitable access

"Participation should not depend on individual resources."

To ensure the inclusion of all students, regardless of their economic circumstances, it is important that their participation in activities does not depend on resources they have to bring individually, thus preventing disparities in access and participation. Therefore, we recommend designing activities so that all necessary materials are integrated or printed within the technology lab itself (Techlab), and using free 3D design software for activities where students need to design figures.

02

Learning accessibility

"A flexible format allows for progress and participation."

The pace of learning is not always the same for all students. Therefore, we recommend designing activities with a flexible format that allows students to progress and participate regardless of their experience or prior knowledge. To achieve this, we can structure the activities into several progressive sessions with adjustable levels of difficulty to facilitate learning for everyone.

Furthermore, it is important that the activities are designed in an understandable way, using clear language that facilitates learning for all students.

03

Accompaniment and support during the activity

"Avoid frustration, gain confidence, and learn."

During the activities, it's important to offer support to the students and clarify any doubts they may have. This will not only facilitate the session but also help prevent frustration, build their confidence, and enhance their learning.



Topic 6. How to plan an educational activity using materials produced by 3D printing

6.1. What the working methods of a technology company can contribute to secondary education.

It is interesting to reflect on the added value that the participation of technology companies brings to secondary education, whether through collaboration with teachers on educational innovation projects or through a series of extracurricular educational activities taught to students by company staff. Perhaps essential aspects of the technology company's vision that we can try to convey to students are the continuous pursuit of innovation, the precision in what we produce, and its impact on society.

We can demonstrate that a thorough understanding of both the phenomena we observe and the behavior of the materials or processes involved in the technology we develop is essential for all of this. Without this deep knowledge of what we already work with, it is highly unlikely that anything new can be produced.

When we, as a company, consider developing educational activities for secondary school students, we will explore ways to maximize the benefits of experimentation. Students will observe a phenomenon, ask meaningful questions, and attempt to draw their own conclusions from their observations. To design the activity, we will utilize 3D design and printing, allowing us to create a customized experimental setup and reproduce it a sufficient number of times to ensure that all students in a relatively large group can actively participate during a session.



Although the time dedicated to teaching activities may not be enough to teach students design techniques, it will be possible to demonstrate the power of the technology and the operation of the printers, which can be very motivating: “I was able to make these pieces myself, and we can manufacture as many copies as we want using the G-code printing files.” But going back to what we said in previous paragraphs, to design and manufacture what we are going to teach them, they need to have a good understanding of the laws that govern the operation of the devices we demonstrate and the precision with which they are manufactured. We will explore this in the following sections, referring to specific examples to help clarify what we mean.

NOTICE

We observed a phenomenon.

ASK

We ask meaningful questions.

TRY IT

We design and conduct experiments with the support of 3D printing.

ANALYZE

We analyze the data and results.

FINISH

We draw conclusions and generate new ideas.

6.2. Define the concept we want to explain. Will the students understand us?

It is time to apply to ourselves what we just said in the previous section.

To implement something new in teaching, it's essential to thoroughly understand the teaching and learning process, the students' level of maturity at each educational stage—whether at the beginning or end of secondary school, or even at the end of primary school. For example, it's crucial to be familiar with the concepts in Physics, Mathematics, and Drawing that students already understand. It's certainly necessary to review how these concepts are presented in the textbooks available to students. For university graduates in our companies or for university professors, explaining concepts like velocity, acceleration, or electric field to secondary school students is far from intuitive, because there are mathematical concepts, such as the derivative of a function, that students lack. Collaboration with teachers in schools is essential to adapt the activities we propose to the level of our students.

Another aspect that we will see shortly is the great variability in knowledge, attention span, group behavior, etc. between different groups of students, even at the same educational level, coming from different educational centers or different environments, and the great variability also between students within the same group.

All of this leads us to suggest designing an activity that can be adapted to different levels of difficulty. The idea is to be able to adjust it to the specific group of students, even during the extracurricular activity itself, as we observe their individual characteristics and how the activity unfolds.

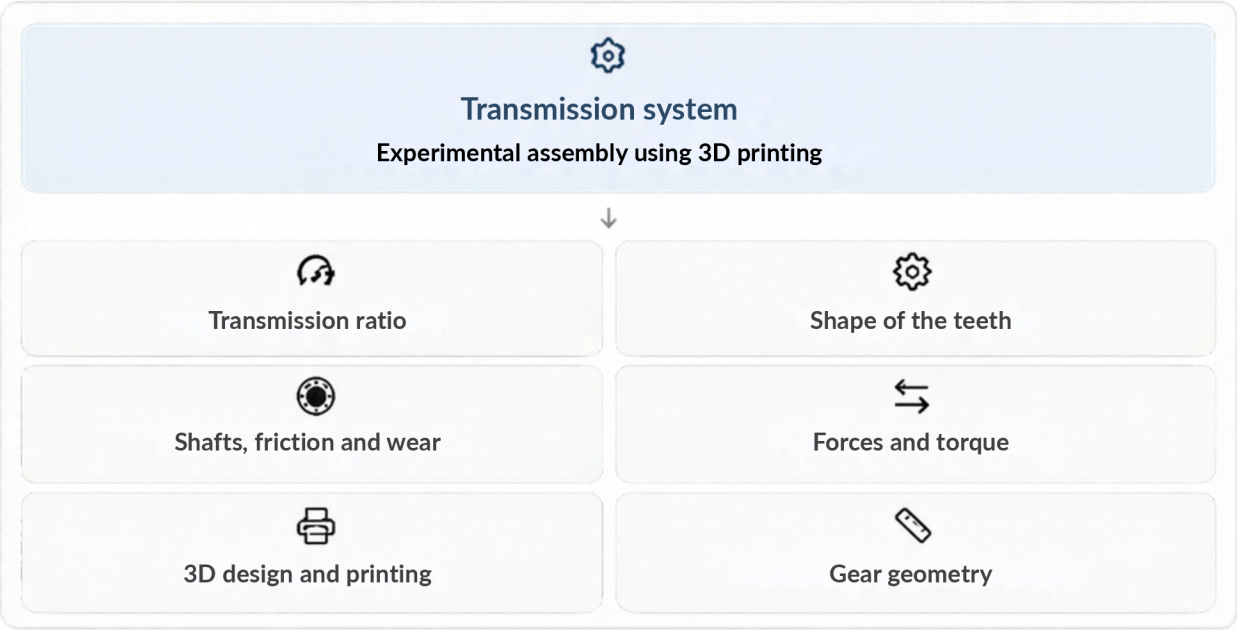
FOR EXAMPLE

Let's imagine we want to demonstrate a gear transmission system. To motivate the students, we can present it with a technological application or another: an electric motor that moves a remote-controlled toy car, where the motor rotates, for example, between 2000 and 6000 rpm, and the car's wheel axle must rotate at a much lower speed. It could also be a stepper motor that moves a joint in a robot, and many other examples.

3D printing allows us to easily create all kinds of gears. It also allows us to design the support structure with the shaft mounts for each gear at the exact distances required for each configuration and gear ratio. We only need one or two small motors for each assembly. All of this has a very low cost. The cost in terms of preparation, design, and manufacturing time is higher, but it's only a one-time expense: once the print files are ready, we can produce as many units as needed.

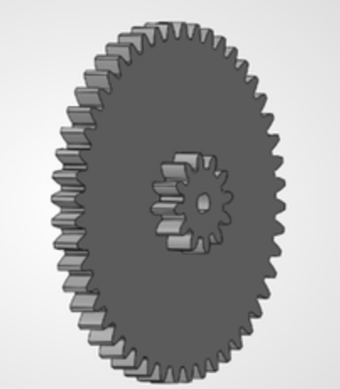
We can initially present a device in which the motor drives a 12-tooth pinion meshed with a 48-tooth gear, which in turn meshes with another 12-tooth pinion that drives another 48-tooth gear. Students will also have access to other sets of gears.

The activity can be approached in different ways:



01

The transmission ratio



Let's just talk about the number of teeth on each wheel and its rotational speed. We can see right away that the three axles rotate at different speeds, very different speeds. We can talk about the gear ratio. Could we get to the point where the last wheel only makes one revolution per day? We can tell you about that story of the merchant who asked the king (or was it the other way around?) to pay him by placing one grain of rice on the corner square of a chessboard, two grains on the next one, four on the following one, and so on until the board was filled.

The surprise comes when you realize that the last square should read 264 = 18,446,744,073,709,600,000 grains of rice. The same thing happens here: with 11 transmissions like the one in front of you, the last one completes a full cycle every day. It may or may not be worth mentioning that this is called a geometric progression and the difference between it and an arithmetic progression.

02

The shape of the tooth

A further step is to look at the shape of the teeth. Why are they made that way? We can make gears with the same number of teeth, but with triangular or rectangular teeth. What happens? You'll see that they vibrate, especially if the motor's rotational speed is high. You can talk to them about the first gears, those in windmill wheels that transmitted the rotational motion of the blades to the millstone. They can also observe the wear (for the next class, you might need to print new ones). What rule or condition defines the shape of the tooth?

03

The housing of the axles and their connection to the gears

We can discuss the friction between the shaft and its housing in the support, as well as wear if the shafts are made of plastic, even with a 3D printer, or wear on the support itself if the shafts are metal and the support is plastic. We can design a support with small, very low-cost ball bearings and observe the significant difference in the overall performance.

04

Forces

You can manually move, or try to move, the wheel that drives the motor and observe the force required to slow the last wheel in the transmission. The reverse is also true. When the transmission accelerates the rotation, the force exerted on the last wheel decreases. A car with such a transmission would be faster but wouldn't be able to climb steep hills. Conversely, a transmission that slows the final wheel allows for greater force to be applied. If deemed appropriate, the concept of angular momentum or torque can be introduced.

05

3D printing

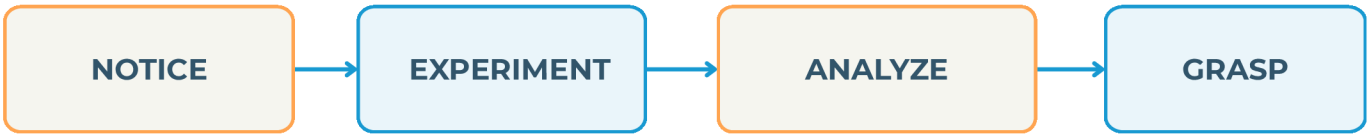
Some students may be curious about how the devices are manufactured. On a computer, we can demonstrate the design steps, showing how it's not necessary to draw each tooth individually; instead, once one is drawn, it's copied the required number of times around the circumference of the wheel. We can also show how the wheel drawing is transformed into a three-dimensional object, how the parameters are modified, and how the wheel's diameter and number of teeth are easily changed. Then we'll demonstrate the software that converts our three-dimensional model into a series of layers that the machine will build one on top of the other by depositing the molten filament. We can also explain the programming language used to communicate with the machine, to tell it what shape to create.

06

The parameters of the gear

Some students at higher educational levels might search the internet for information about the equations that define the geometry of gears, the relationship between diameter and height, and the number of teeth, for example.

This approach to the activity will allow us to adapt it to each group of students, maintaining their interest throughout. There's no point in setting overly ambitious goals or designing complex experiments if the students aren't able to draw conclusions from their observations.



6.3. Design the activity in such a way that the students are active

It's obvious that students shouldn't be mere observers, as if they were in a blackboard classroom. This means that the device they'll be working with must be modifiable to respond to the curiosity of the user. In the example we're using, the gear support must allow for the placement of wheels of different sizes and several sets of wheels. It should be relatively easy to attach the wheels to the axles and place the axles in their slots on the support. Clearly, a sufficient number of devices are needed; perhaps two or three students working with each device would be ideal. For this, 3D printing is especially useful, as it will allow us to reproduce the parts as many times as needed at a very low cost.

Furthermore, to help students acquire critical thinking skills, it's more effective to encourage them to ask questions, discuss among themselves, and draw their own conclusions than to have the instructor or teacher provide comprehensive explanations. Approaching the activity in this way is an art; it's not easy to give instructions on how to do it.



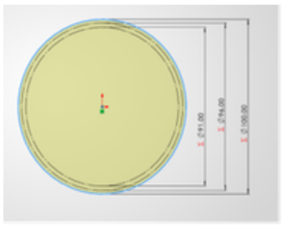
6.4. Prepare the materials.

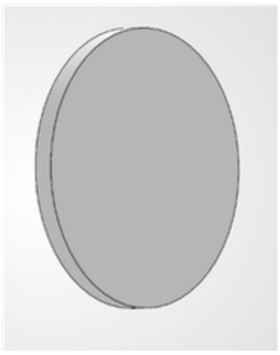
It's striking how far you can go in designing complex parts with just a basic course on 3D design software. Starting with a sketch on a flat surface, converting it into a three-dimensional object through extrusion or rotation around an axis, defining a surface in space on which to draw a new sketch, extruding a section from the original shape, creating symmetries, and so on, are actually simple operations. By combining them, you can create complex parts. Even building seemingly more complex elements, like the gears we discussed in previous sections, becomes quite manageable when you have instructions on how to do it.

FOR EXAMPLE

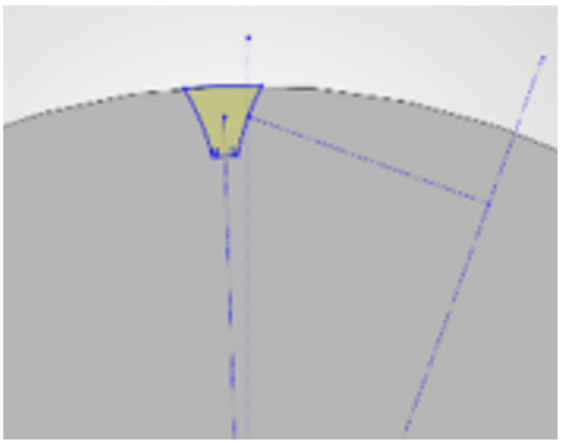
There are dozens of tutorials online showing how to draw the profile of teeth and how, once drawn, one tooth can be copied in a simple operation along the entire edge of the wheel. To illustrate this, let's continue with the example of a gear. The following figures are intended to give an idea of the process of creating the part; of course, they are not meant to be sufficient instructions for carrying it out.

We start with a selection of gear data: number of teeth and module, and pressure angle, with which we calculate the rest of the parameters that define the shape and size of the tooth: pitch diameter, outside diameter, tooth height, angle between teeth, etc.



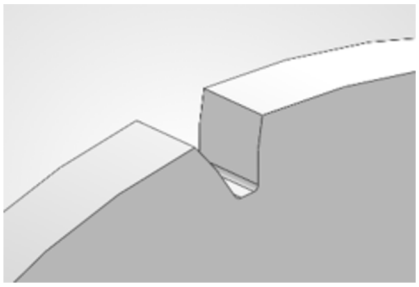


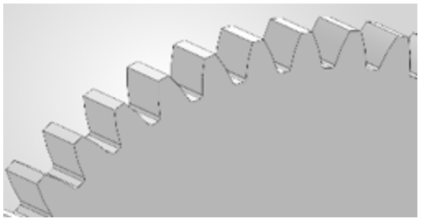
First, we draw on one of the coordinate planes: on the front view, for example, a circle with the outer diameter of the gear, in our example 100 mm. We ask the program to extrude it 8 mm and we have a cylinder. In the sketch, we have added a circle with the pitch diameter of the gear and another with the base of the teeth.



Next, we draw the simple geometric construction shown in the figure, which defines the curvature of the tooth. The figure is intended only to illustrate the simplicity of the process. It involves constructing a series of accessory lines that allow us to find the center and radius of the circle that defines the tooth's profile. Using a symmetry operation, we draw the profile of the previous tooth and thus the space between the two teeth.

We asked the program to cut out this gap between two consecutive teeth in the cylinder we had built.





And now all that remains is to copy this gap along the entire side surface, and that's it.

We can practice the shaft housing in the center, with similar operations.



What seems very complicated at first glance is actually not, although it obviously requires time and, initially, following a short introductory course or a good basic tutorial for the software being used. It's even easy to teach students to design simple parts. Once you start working with these programs, you progress very quickly, building increasingly complex structures; for example, you learn to assemble different parts with two or three simple operations.

The next step is to save the part in STL format, which captures the shape of the outer surface. This file will be used to generate the file that sends the printing instructions to the printer. If using a fused filament printer, this is the G-code file. There are free programs that perform this operation, and your 3D printer may have its own software. The program will also indicate the amount of filament needed and the printing time. The G-code file is a text file that, after a few initial lines with generic machine data and some printing parameters, tells you, point by point and layer by layer, the position of the print head and the polymer flow rate.

Thus, once we have become familiar with the operation of the Techlab's printing machines, it is simply a matter of imagination to design and produce materials that will allow us to undertake activities that demonstrate and clarify basic concepts from different subjects. These materials will also allow us to introduce students to 3D design itself, with all that this entails in terms of applying concepts of geometry, graphic representation, mechanical elements, dynamics, and so on.

Topic 7. Design of Extracurricular Technology Activities

7.1. How to design activities

Firstly, one of the main aspects we must take into account is the educational level and situation of the students to whom these activities are directed.

We recommend that the activities designed have five blocks:

BLOCK 1

Title and inspiring explanation

We recommend that extracurricular technology activities begin with a title and explanation that captures the attention of the students, since they connect better with science and technology when they feel that they are not only learning, but also discovering, building and recreating inventions.

FOR EXAMPLE

For millennia, sound was ephemeral. A spoken word vanished instantly. In 1877, Thomas Edison achieved the impossible: freezing time. He discovered that if he shouted into a diaphragm with a needle, it could "write" the vibrations of his voice into a soft metal, creating physical grooves. However, to reach the modern era, we needed to take another step: to stop relying on mechanical needles and convert the voice into electricity.

Next, we recommend explaining what the students will be doing in a simple and motivating way.

FOR EXAMPLE

“This two-day unit is a journey through the history of audio technology. Students will begin in the mechanical era, building a gramophone to play vinyl records. Then, they will experience physical recording with Edison’s phonograph. Finally, they will jump to the electrical era by building a working microphone using pencil leads, understanding how vibration is transformed into the electrical signal that travels through our wires and is stored on hard drives.”

SUMMARY

We are not trying to create a theoretical or lengthy explanation, but rather to capture your attention, awaken your curiosity, and get you to ask yourselves, "How does it work? Can I do it?"

BLOCK 2

Introduction and technological challenge

In this section, we'll explain more clearly what you're going to do and why it's important. To create it, you can answer the following questions:

- What are they going to explore?
- What are they going to build or experience?
- What will they discover and learn?

Additionally, it is advisable to indicate whether the activity will be carried out in several sessions and whether there is a progression.

FOR EXAMPLE

"The challenge is divided into two major technological blocks:

- *Day 1 (The Mechanical Age): The Gramophone. We will build an analog system to reproduce sound. We will make a passive amplifier (paper cone) and a motorized turntable to read a real vinyl record, understanding that sound is physical vibration.*

- *Day 2 (The Electric Age): The Phonograph and the Microphone. While one team physically records their voice on Edison's phonograph (grooves in metal), the rest of the class will build a Carbon Microphone (graphite and batteries) to discover how to convert their voice into an electrical current without using magnets.*

BLOCK 3

Materials needed

This section should list all the materials needed for the activity so that any instructor or teacher can prepare it without any questions. We recommend organizing it by session to make the activity easier to carry out.

FOR EXAMPLE

For Day 1 (Gramophone):

- *Electronics: DC Motor (3V-6V)*
- *Battery holder*
- *Speed controller (Potentiometer)*
- *Switch.*
- *Structure: 3D printed base or foam board for the motor*
- *A turntable (old or printed CD).*
- *Acoustics: Large cardboard (for the cone)*
- *Adhesive tape*
- *A fine sewing needle*
- *An old vinyl record.*

For Day 2 (Phonograph and Microphone):

- *3D Phonograph: Base, cylinder and crank.*
- *Plastic cup*
- *Thick needle*
- *Heavy-duty aluminum foil.*

Classroom sessions

This section is the most important, as it describes how the activity will be carried out step by step. Therefore, we recommend including the following information:

- Aim
- Explanation of each part of the session in clear language, indicating to the technician or researcher what to do to carry out the activity.
- Duration of each part.
- Expected final result of the session

FOR EXAMPLE

DAY 1: The Gramophone and the Hard Disk Theory

The goal of this session is to build a functional player and understand the analogy with computer data storage.

(0:00 - 0:15) The Physics of Vibration (Theory).
We'll begin the lesson by explaining that sound isn't magic; it's a physical impact on the air. To demonstrate this, we'll ask the students to touch their throats while speaking. We'll explain that a vinyl record has microscopic "mountains and valleys" carved into its groove. If we can get a needle to hit these "mountains," the needle will vibrate. The problem is that this vibration is very small and inaudible. Here, we'll introduce the need for "mechanical amplification": the paper cone, which acts like an inverted funnel to force more air through.

(0:15 - 0:45) Gramophone Engineering (Assembly).
We will divide the class into engineering teams. One team will be responsible for the drive system. They will need to assemble the DC motor circuit with the speed controller and batteries, attaching it to a stable base so the "plate" rotates flat. It is crucial that the motor does not vibrate excessively. The other team will build the reading system. They will roll the cardboard into a large cone and glue the sewing needle to the narrowest point, making sure it is secure (if the needle wobbles, there will be no sound). The ideal angle is to pierce the needle through the corner of the paper before rolling it up, or use strong tape.

(0:45 - 0:55) The Trial by Fire (Reading).
The magic moment arrives. We'll place the old vinyl record on the rotary motor. We'll adjust the speed with the potentiometer (vinyl records spin at 33 or 45 RPM). The students will gently bring the cone's needle close to the record as it spins. Amazingly, the music will begin to play directly from the record. There's no electricity in the cone; it's pure mechanical vibration transferred from the track into the air.

(0:55 - 1:00) Connection with the Future (The Hard Drive).
We'll close the session by showing an open hard drive. We'll point out the shiny platter and the reading needle. We'll explain that it's essentially a hyper-advanced gramophone. The fundamental difference is that on vinyl the needle physically touches the groove, while on a hard drive the needle hovers over the platter without touching it, reading magnetic fields.

DAY 2: Mechanical Recording vs. Electrical Conversion

Today we will compare two ways of capturing the voice: the old way (scratching metal) and the modern way (modifying electricity). The class will rotate between the two stations.

(0:00 - 0:10) Introduction: Graphite and Electricity.
We'll explain that to send our voice over the internet or store it on a chip, we can't use mechanical needles. We need to convert the voice into electricity. To do this, we'll use the same material inside your pencils: graphite.

(0:10 - 0:50) Rotating Activities.

Station A: The Recording Studio (The Phonograph).
Taking turns, the students will go to the teacher's table to use the 3D-printed phonograph. One student will act as the motor, steadily turning the crank, while another will shout a short message into the diaphragm. The needle, pushed by the voice, will leave a visible groove in the aluminum foil. When played back, they will hear their "mechanical" voice, demonstrating that sound can be stored as a physical texture.

Station B: The Pencil Microphone (Electrical Conversion).

The rest of the class will build a functional microphone without magnets:

- *The Base: They will use a small cardboard box (like a matchbox).*
- *The Circuit: They will glue two thick pencil leads parallel to each other on the box, connecting a wire to each one.*
- *The Sensor: They will place a third loose mine, supported transversely on the other two (forming an "H").*
- *The Connection: They will connect this assembly in series with a 9V battery and the input of some old headphones (or PC speakers).*
- *The Experiment: When you speak to the box, the vibration of your voice will slightly move the loose lead. This will change the electrical resistance of the graphite (allowing more or less electricity to pass through) in rhythm with your voice.*
- *Result: Whoever puts on the headphones will hear the voice amplified and transmitted electrically, just like on an old telephone!*

BLOCK 5

Final reflection

Finally, we will conduct a final reflection that allows students to review the concepts covered and their potential usefulness.

FOR EXAMPLE

(0:50 - 1:00) Final Reflection: Analog vs. Digital.

We'll bring everyone together to compare. In the phonograph, the voice is converted into movement (groove). In the microphone, the voice is converted into voltage (electricity). We'll explain that the modern hard drive needs that electrical signal from the microphone, which it then transforms into magnetism (zeros and ones) to store our photos and audio forever.

7.2. Template for creating extracurricular activities

TITLE
INTRODUCTION
MATERIALS

CLASSROOM SESSIONS

FINAL REFLECTION

7.3. Proposals for extracurricular activities

Activity 1

Capturing the Sound



For millennia, sound was ephemeral. A spoken word vanished instantly. In 1877, Thomas Edison achieved the impossible: freezing time. He discovered that if he shouted against a diaphragm with a needle, it could "write" the vibrations of his voice into a soft metal through physical grooves. However, to reach the modern era, we needed to take another step: to stop relying on mechanical needles and convert the voice into electricity.

This two-day unit is a journey through the history of audio technology. Students will begin in the mechanical era, building a gramophone to play vinyl records. They will then experience physical recording with Edison's phonograph. Finally, they will jump to the electrical era by building a working microphone using pencil leads, understanding how vibration is transformed into the electrical signal that travels through our wires and is stored on hard drives.

Introduction to the activity

The challenge is divided into two major technological blocks:

01 Day 1 (The Mechanical Age): The Gramophone.

We will build an analog system to reproduce sound. We will fabricate a passive amplifier (paper cone) and a motorized turntable to read a real vinyl record, understanding that sound is physical vibration.



02 Day 2 (The Electric Age): The Phonograph and the Microphone.

While one team physically records their voice on Edison's phonograph (grooves in metal), the rest of the class will build a Carbon Microphone (graphite and batteries) to discover how to convert their voice into an electrical current without using magnets.



Materials

01 For Day 1 (Gramophone):

Electronics

- Electronics: DC Motor (3V-6V)
- Battery holder
- Speed controller (Potentiometer)
- Switch.

Structure

- Structure: 3D printed base or foam board for the motor
- A turntable (old or printed CD).

Acoustics

- Acoustics: Large cardboard (for the cone)
- Adhesive tape
- A fine sewing needle
- An old vinyl record.

02 For Day 2 (Phonograph and Microphone):

- 3D Phonograph: Base, cylinder and crank.
- Plastic cup
- Thick needle
- Heavy-duty aluminum foil.

Pencil Microphone (Parallel Activity):

A matchbox or small cardboard box, 3 thick pencil leads (or carpenter's pencils sharpened on both ends), a 9V battery, a battery connector (or insulating tape), wires with alligator clips (or bare wires), and an old pair of headphones (or a PC speaker with an auxiliary input).

Classroom session

DAY 1: The Gramophone and the Hard Disk Theory

The goal of this session is to build a functional player and understand the analogy with computer data storage.

0:00 - 0:15

The Physics of Vibration (Theory)

We'll begin the lesson by explaining that sound isn't magic; it's a physical impact on the air. To demonstrate this, we'll ask the students to touch their throats while speaking. We'll explain that a vinyl record has microscopic "mountains and valleys" carved into its groove. If we can get a needle to hit these "mountains," the needle will vibrate. The problem is that this vibration is very small and inaudible. Here, we'll introduce the need for "mechanical amplification": the paper cone, which acts like an inverted funnel to force more air through.

0:15 - 0:45

Gramophone Engineering (Assembly)

We will divide the class into engineering teams. One team will be responsible for the drive system. They will need to assemble the DC motor circuit with the speed controller and batteries, attaching it to a stable base so the "plate" rotates flat. It is crucial that the motor does not vibrate excessively. The other team will build the reading system. They will roll the cardboard into a large cone and glue the sewing needle to the narrowest point, making sure it is secure (if the needle wobbles, there will be no sound). The ideal angle is to pierce the needle through the corner of the paper before rolling it up, or use strong tape.

0:45 - 0:55

The Trial by Fire (Reading)

The magic moment arrives. We'll place the old vinyl record on the rotary motor. We'll adjust the speed with the potentiometer (vinyl records spin at 33 or 45 RPM). The students will gently bring the cone's needle close to the record as it spins. Amazingly, the music will begin to play directly from the record. There's no electricity in the cone; it's pure mechanical vibration transferred from the track into the air.

0:55 - 1:00

Connection to the Future (The Hard Drive)

We'll close the session by showing an open hard drive. We'll point out the shiny platter and the reading needle. We'll explain that it's essentially a hyper-advanced gramophone. The fundamental difference is that on vinyl the needle physically touches the groove, while on a hard drive the needle hovers over the platter without touching it, reading magnetic fields.

DAY 2: Mechanical Recording vs. Electrical Conversion

Today we will compare two ways of capturing the voice: the old way (scratching metal) and the modern way (modifying electricity). The class will rotate between the two stations.

0:00 - 0:10

Introduction: Graphite and Electricity

We'll explain that to send our voice over the internet or store it on a chip, we can't use mechanical needles. We need to convert the voice into electricity. To do this, we'll use the same material inside your pencils: graphite.

0:10 - 0:50

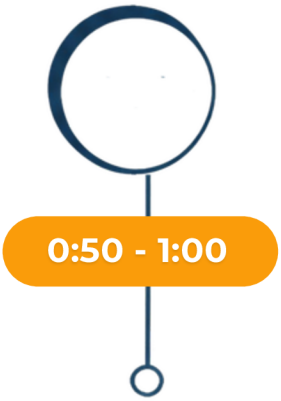
Rotating Activities

Station A: The Recording Studio (The Phonograph).
Taking turns, the students will go to the teacher's table to use the 3D-printed phonograph. One student will act as the motor, steadily turning the crank, while another will shout a short message into the diaphragm. The needle, pushed by the voice, will leave a visible groove in the aluminum foil. When played back, they will hear their "mechanical" voice, demonstrating that sound can be stored as a physical texture.

Station B: The Pencil Microphone (Electrical Conversion).
The rest of the class will build a functional microphone without magnets:

- The Base: They will use a small cardboard box (like a matchbox).
- The Circuit: They will glue two thick pencil leads parallel to each other on the box, connecting a wire to each one.
- The Sensor: They will place a third loose mine, supported transversely on the other two (forming an "H").
- The Connection: They will connect this assembly in series with a 9V battery and the input of some old headphones (or PC speakers).
- The Experiment: When you speak to the box, the vibration of your voice will slightly move the loose lead. This will change the electrical resistance of the graphite (allowing more or less electricity to pass through) in rhythm with your voice.

Result: Whoever puts on the headphones will hear the voice amplified and transmitted electrically, just like on an old telephone!



Final reflection

We'll bring everyone together to compare. In the phonograph, the voice is converted into movement (groove). In the microphone, the voice is converted into voltage (electricity). We'll explain that the modern hard drive needs that electrical signal from the microphone, which it then transforms into magnetism (zeros and ones) to store our photos and audio forever.

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