Università degli Studi di Ferrara

DOCTORAL COURSE IN

"PHYSICS"

CYCLE XXXVI

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Development of an innovative "Hands on Physics" methodology for teaching Physics at high school level

Scientific/Disciplinary Sector (SDS) FIS/08

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Years 2020-2023

"Education shall be directed to
the full development of the
human personality and to the
strengthening of respect for
human rights and fundamentals
freedoms"
(Piaget, 1973)

ABSTRACT

Traditional methods of teaching and learning often embrace a transmissive approach, where the teacher is seen as the sole or primary repository and source of knowledge. Students typically learn about historical discoveries, with limited interaction among themselves and few opportunities to express creativity or to discover their potential and limitations. Their educational process is measured through structured assessment tests. How can this learning experience educate and prepare a new generation of inventors and innovators capable of successfully navigating societal changes and transitions in the job market? Pedagogical studies dating back to the last century have highlighted that active student participation in their own learning process can enhance their motivation and, consequently, short- and long-term learning outcomes and skills.

This research thesis aims to document two educational experiences within a Liceo Scientifico (a STEM oriented High School in Italy), one integrated into the regular curriculum, and the other extracurricular. Both experiences focused on active, collaborative, hands-on, and learning by doing approaches to learning physics. These methodologies are inspired by models adopted for decades at the Massachusetts Institute of Technology. Students are actively engaged in the conception, research, design, and collaborative construction of their STEM projects, through which they gain a deeper understanding and learning experience. This approach, in line with recent Italian Ministerial Guidelines for STEM education, not only improves students' attitudes toward Physics and STEM disciplines in general, as well as their academic performance, but also fosters the creation of inclusive learning environments, reduces gender gaps, and develops lifelong learning skills, as recommended by the Council of the European Union.

Contents

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

1.1 Reflections on Traditional Scientific Teaching Methodology and the Need for an Innovative Approach: A Critical and Proposing Perspective

The Scientific High schools (Licei) in the Italian school system allow students to attain advanced levels of knowledge in various thematic areas (MIUR, DM n. 211 , 2010, p. All.F).

My three-decade experience as a Mathematics and Physics teacher, predominantly in Scientific High Schools, has allowed me to observe students extensively in classroom settings and witness their changes over time. My observations over the years have prompted me to question the effectiveness of the more traditionally used teaching (and learning) method.

Why, in general, do students find themselves stuck when asked to analyze something different from what has already been presented in class? Why do they struggle to apply what they've studied in textbooks to real-life situations? Why do they lack the spontaneity, imagination, and curiosity that would lead them to ask new questions and proceed independently in their lifelong learning journey? How can we ensure that students, at the end of their educational journey, can develop new ideas and solve continually evolving real-world problems, leveraging appropriate use of changing technology and the tools that empower collaboration? What school activities can accustom students to carry out their tasks collaboratively, sharing knowledge and skills in conditions of mutual respect, as expected in contemporary and future society and the working world, especially in the scientific field? Is it possible through traditional methodology to shape a creative, independent, and critical mind in children and adolescents, preparing them to become active and conscientious citizens?
These and other questions have led me to reflect on the traditional teaching and learning methodology in the scientific field, the one most used in secondary schools. I refer to the unidirectional transmissive teaching and learning methodology (broadcasting), where, in general:

- The teacher is (almost) the sole repository and source of knowledge.

- The student must understand and memorize what the teacher explains or what is written in textbooks, exercising their memory to recall and apply concepts to "standard" exercises.

- Students are generally not encouraged to interact with peers through collaborative activities or discussions during the resolution of exercises or problems.

- Student learning is mostly individual and competitive, as is the evaluation process which is based on repeating what others have written or stated and solving problems that have little to do with the real world around us.

Yet, studies on these topics highlight that students engaged in cooperative activities achieve higher academic results compared to those who learn individually, with no significant disparities related to gender, age, socioeconomic class, cultural background, sample size, group size, examined discipline, or the environment in which the research was conducted (Johnson D. W., 2013) (Crouch & Mazur, 2001).

The latest publications of international research, PISA (Program for International Student Assessment) (OECD, 2023), and TIMSS (Trends in International Mathematics and Science Study) (IEA, 2019), highlight high percentages of Italian high school students with low levels of competence in Mathematics and Science. It is not surprising, therefore, that Physics university professors, when interviewed, note difficulties in first-year students primarily related to a lack of autonomy, the ability to recall and apply knowledge acquired in high school, awareness in using technology, and knowledge of its potential.

Seymour Papert, a mathematician and computer scientist, collaborator of Jean Piaget at the University of Geneva and Marvin Minsky at MIT, focused his research on learning methods with the goal of helping students build their knowledge in an engaging and meaningful way. Building on Piaget's constructivist theory, Papert developed his learning theory known as constructivism (Stager, 2016). He argued that the active construction of knowledge through the processing and realization of something that can be shared constitutes the most effective way of knowledge construction. In the '80s, during a conference dedicated to educators, Papert, regarding the learning of mathematics, stated (Papert, 1980):

"I think part of the trouble with learning mathematics at school is that it's not like mathematics in the real world. In the real world, there are engineers, who use mathematics to make bridges or make machines. There are scientists, who use mathematics to make theories, to make explanations of how atoms work, and how the universe started. There are bankers, who use mathematics to make money -- or so they hope.

But children, what can they make with mathematics? Not much. They sit in class and they write numbers on pieces of paper. That's not making anything very exciting. So we've tried to find ways that children can use mathematics to make something interesting, so that the children's relationship to mathematics is more like the engineer's, or the scientist's, or the banker's, or all the important people who use mathematics constructively to construct something."

Personally, I believe that this holds true not only for learning mathematics but also for all STEM disciplines, especially physics, which is closely tied to the interpretation of the real world but is typically taught solely through books, chalkboards, pencils, and exercises that are distant from people's daily lives.

Even the recent STEM guidelines issued by the Ministry (Att. 2) (Ministry of Education, STEM Guidelines, 2023) suggest that " *as Maria Montessori said*, *to teach, one must excite*", and that to "*generate passion for STEM disciplines*," we need "*not only boring procedural tests but also applications, laboratory experiments, games, and challenges*". Therefore, according to the guidelines, there is a need for an *"integrated approach to teaching STEM disciplines*" through "*the dissemination of innovative didactic methodologies based on problem-solving, real-world problem resolution, content interconnection for the development of mathematical-scientific-technological skills*."

Today's students will undertake jobs and professions throughout their lives that currently do not even exist. How can we prepare them for such a changing future if we don't provide them with current knowledge but, more importantly, tools to develop skills that allow them to apply and expand this knowledge autonomously?

Is it possible, within the school environment, to create opportunities and learning environments that allow students to interact with each other, promote socialization and empowerment, to discover their curiosities and passions in STEM, even if they sometimes go beyond the traditional topics of the curriculum for the academic year? In this way, students, driven by personal interest, would develop greater motivation for learning, be inclined to research, delve deeper, delve deeper independently (learning to learn) and become lifelong learners. Additionally, they would learn the importance of mutual respect and collaboration in carrying out an activity and achieving a goal. Finally, they could gain more confidence in themselves by learning to be resilient, capable of managing and facing errors as a necessary part of a learning path oriented towards the discovery and creation of the "new and innovative," which goes beyond what a teacher, with their education, degree and experience, can transmit.

This thesis aims to present innovative approaches to Physics learning (and STEM in general) in high schools, to be carried out both during regular curriculum hours and extracurricular activities.

The research is primarily based on:

A. A case study of an extracurricular program of PCTO (Paths for Transversal Skills and Guidance) in the STEAM (Science, Engineering, Arts, Mathematics) field conducted within a high school (Scientific High School "A. Roiti," Ferrara, Italy; HoPE Program, chap. 3). This proposal is based on collaborative activities involving groups of students from different classes and ages.
B. A case study of activities carried out during regular Physics classes in third, fourth and fifth year in the same High School.

In both cases, the effectiveness of the "*active learning*" methodology was experimented with, developed through "*hands-on*" and "*learning by doing*" activities (Dewey, 1916), carried out collaboratively (collaborative learning) and through peer collaborative teaching and learning (peer education). Both proposals align broadly with the ministerial STEM guidelines (Ministry of Education, STEM Guidelines, 2023), aimed at making learning more engaging and meaningful through student-centered active learning methodologies, capable of developing the knowledge and learning skills required by the European Union Council's Recommendations (EU, 2018).

The research followed an "action research" approach, as emphasized by Elliot (Elliott, 1991): "*Both product and process need to be jointly considered when attempting to improve practice. Processes need to be considered in the light of the quality of learning outcomes and vice versa. This kind of joint reflection about the relationship (...)* (is what people) *have termed action research*".

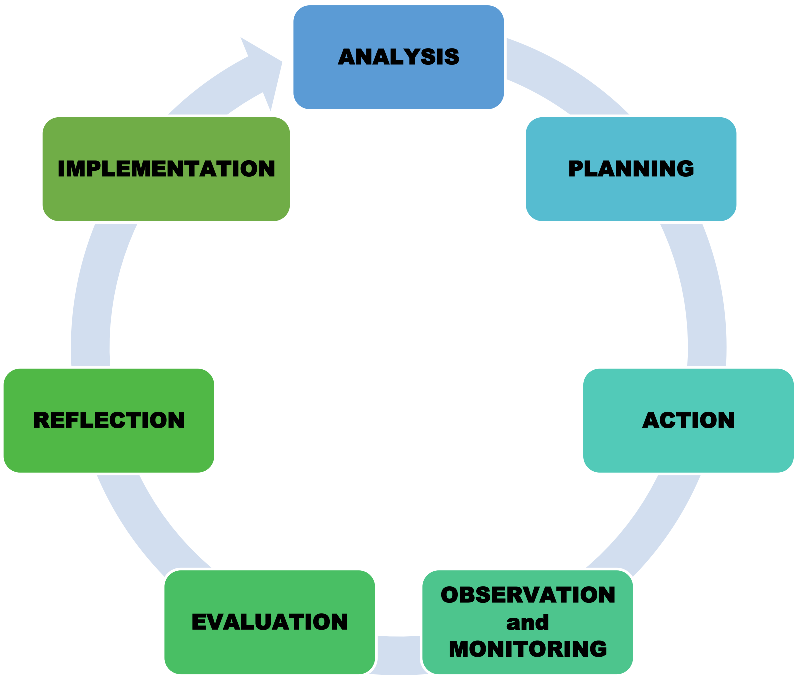

Fig. 1.1: The action research cycle

The cyclic process followed during the research I conducted was characterized by the following steps (Fig. 1.1):

- Needs **analysis** obtained through
  - **Identification of issues** and learning patterns observed in students during traditional activities.
  - **Critical reflection** on the needs of 21st-century students to consolidate and/or develop knowledge and skills relevant to further studies, social integration, and the world of work.
- **Planning**
  - Educational interventions to be implemented in relation to set objectives.
  - Tools to be used for monitoring the process and evaluating results.
- Implementation of the planned **action**, through the direct experimentation of innovative learning methodologies in both curricular and extracurricular contexts.
- **Observation** of students and **monitoring** of the progress of the educational activities.
- **Evaluation** of learning outcomes.
- **Reflection** on the implemented process and the learning outcomes obtained at the end of the educational action.
- **Implementation** of educational action through a new needs analysis considering the reflection carried out.

The research process was made more enriching through the opportunity to engage with teachers who have been applying innovative teaching methodologies in Physics at MIT for decades. This collaboration allowed me to delve into these approaches through direct research experiences at MIT.

In this journey, I had the chance to investigate the pedagogical principles that underlie active learning methodologies, an opportunity that had not presented itself in my previous academic training. However, most of the research was focused on practical action, following an iterative process where students were not just beneficiaries but active participants alongside teachers (myself in the curricular experience, and me with some colleagues in the extracurricular experience) in its planning, implementation, evaluation, and reflection for continuous improvement.

I believe that methodological innovation, which allowed students to attain the best possible results from educational action, was achieved primarily through their empowerment and participation in the various phases of the process. This enabled:

- Teachers to adapt teaching methods to the specific characteristics of the class or group of students involved, achieving set objectives.
- Students to be not just recipients but active, engaged, and aware participants in the educational action.

The results of the experiments were assessed through:

- Systematic observation of dynamics among students during collaborative activities and the skills developed.
- Results achieved in terms of acquired knowledge and skills.
- Observation of skills used during activities and in moments of "stress" for students, such as presentations for assessment purposes or during public events.
- Administration of surveys and analysis of student feedback.

The thesis is organized as follows:

- Chapter 2 outlines the pedagogical underpinnings of the research pathway.
- Chapter 3 presents a case study of an extracurricular PCTO program for active, hands-on, collaborative STEM learning.
- Chapter 4 presents a case study of a collaborative hands-on active learning model of physics within the curricular activity in high school.
- Chapter 5 presents models of collaborative hands-on active learning of physics within the curricular activity at the Massachusetts Institute of Technology (MIT), which I had the opportunity to study and experiment with during my research activities.
- Chapter 6 is dedicated to discussion and outlook.

1.2 Discovery of a New Teaching Approach: Active, Investigative, Experiential, Collaborative Learning at MIT. Description of Personal Experience at MIT

In the academic year 2014/15, my school, the Scientific High School "A. Ròiti" in Ferrara, provided me with the opportunity to participate in the Global Teaching Labs (GTL) program managed by MISTI at the Massachusetts Institute of Technology (MIT, Cambridge, United States) (MIT International Science and Technology Initiatives, (MISTI, 2023)). GTL allows MIT students to undertake international teaching experiences related to their studies with a focus on "Learning through teaching." Students participating in the GTL program are supported by a school tutor with whom they collaborate to share methodologies and knowledge. These students come into contact with different cultures and teaching approaches of the host country while simultaneously promoting the experiential learning approach "Mens et manus" (Director MIT, 2009) typically adopted at MIT.

The approach I followed with the assigned student, aimed at integrating the MIT methodology with what I had known and practiced until then, allowed me—based on the subsequent report prepared by the student—to secure a scholarship to participate in the Science and Engineering Program for Teachers (SEPT) international course held at MIT in the summer of 2015.

The SEPT-MIT 2015 experience (MIT SEPT, 2023) had an enlightening effect on me. For the first time, alongside sessions dedicated to understanding the frontiers of scientific-technological research, I had the opportunity to participate in teacher training workshops through hands-on activities.

Fig.1.2: The room 4-409 at MIT

One laboratory activity, in particular, caught my attention: the "Hands-on Physics" workshop at the Edgerton Center of MIT (Edgerton Center, 2023). The room (Fig.1.2) was entirely different from the labs I had frequented until then: few cabinets for storing materials, many previously completed projects hung on the walls to inspire new ideas, numerous photographs of smiling students at work, as well as tools available for anyone to shape their own idea. The environment created by the instructor Mr. Edward Moriarty aimed more at stimulating curiosity and unleashing creativity in students than just having them carry out a pre-packaged activity. He interacted with us in a way that showed genuine interest in our well-being within the laboratory, making us feel welcomed and integrated with each other, ensuring that we were involved and intrigued by what we were working on, encouraging us to ask questions and interact with others, discussing, finding answers together, and above all, formulating new questions.

My academic background helped me justify physical phenomena theoretically, but my ability to design and build an object that translated what I knew into reality was limited. I discovered that my mind retained formulas that I could skillfully use to explain an event, pages and pages of textbooks that appeared to me before I had the chance to reflect on the physical modeling of the phenomenon. I realized that, as a teacher, this was not what I wanted for my students. I understood how much more engaging it was to analyze a phenomenon by also constructing a simple device that made the phenomenon "real," how much more interesting it was to discuss it with classmates before even approaching the teacher, and that, by working together and with each person's contribution, I could achieve things I had never expected.

Back in Italy, I was enthusiastic about sharing what I had experienced—this active, engaging, and collaborative "learning by doing." So, I made every effort to try to organize a program inspired by this approach in my school, the Scientific Lyceum "A. Roiti." The School Principal, the Director of the of the Physics and Earth Sciences Department of the University of Ferrara, Prof. R. Calabrese, the branch of Ferrara of the National Institute of Nuclear Physics (INFN), along with some my Colleagues, supported this idea, leading to the collaboration between these local entities and the MIT Edgerton Center. The resulting educational program, included in the Paths for Transversal Skills and Guidance (PCTO) and active since January 2018, initially borrowed the name of the workshop it was inspired by: "HoP, Hands-on Physics with MIT." During the COVID-19 pandemic, its collaborative nature, even conducted remotely through the Zoom platform, helped maintain relationships among students and between students and teachers, providing new sources of learning stimuli. Teachers and students then decided, given the program's significance during challenging times, to change its name to "HoPE, Hands-on Physics Experience" since, according to the Cambridge Dictionary, the expression "Hands-on experience" means "*knowledge or skill that someone gets from doing something rather than just reading about it or seeing it being done*" (Cambridge Dictionary, s.d.).

HoPE is described in detail in Chapter 3.

CHAPTER 2

PEDAGOGICAL UNDERPINNINGS OF THE RESEARCH PATHWAY

2. **PEDAGOGICAL UNDERPINNINGS OF THE RESEARCH PATHWAY**

My research journey, characterized by the experimentation of an innovative teaching methodology for physics learning within both curricular and extracurricular activities in high school, has allowed me to engage with contexts where such approaches were already established, such as the those at MIT.

The research, structured as action research, involved direct field experimentation at my school and MIT, forming the predominant part of my work. However, the focused reflection aimed at developing a methodology integrable with the more traditional approach of the Italian school system provided the opportunity to explore the pedagogical foundations of approaches that, through direct experience, I found particularly effective for student learning.

The framework was identified through reflection on active learning methodologies, with key words guiding my theoretical research: active learning, collaborative learning, peer education, learning by doing, hands-on learning. These methodological constructs better captured the experience I was developing.

Active learning methods are not new at the national and international levels. The current experimentation found numerous points of connection, especially with the pedagogical activism of John Dewey, Maria Montessori, Jean Piaget, Seymour Papert, the Johnson brothers, and educators like Baden Powell, who developed active learning educational approaches even in an extracurricular context, such as the scout movement.

John Dewey, a progressive pedagogue, vigorously criticized the traditional individualistic and competitive learning methodology, emphasizing the importance of practical experience in the educational process (learning by doing). His vision of school as a model of democracy capable of providing equal opportunities provided a pedagogical foundation for the described experiences, with the idea that "what is communicated becomes mere words if and to the extent that it cannot be organized in the actual experience of the student" (Dewey, 1916).

The opportunity to experiment with peers without fear of making mistakes, but rather learning from them, reflects Dewey's approach, advocating that schools should guide students to discover their talents, allowing them to "understand and perceive their own limits through the experience of consequences."

The research also found points of connection with the idea of experiential learning and Maria Montessori's concept of autonomy and self-direction. Montessori promotes the use of sensory educational materials to facilitate practical and tangible learning, emphasizing the importance of students actively engaged in their learning and with a degree of autonomy in choosing educational activities: "Our students are used to exercising their will and judgment freely, guided by imagination and enthusiasm" (Montessori, 1943).

The experiences described in the thesis differ from the Montessori method, as the latter has a defined pedagogical structure with specific activities and materials prepared for certain educational tasks.

Piaget's constructivism, contributing to the theory of cognitive development by highlighting the importance of students' active interaction with their learning environment, raises the question of whether it is possible to form autonomous personalities through techniques involving intellectual and ethical constraints.

Seymour Papert, a student of Piaget, inspired the research with the comparison between "Instructionism and Constructivism," promoting the learning of mathematics through practical applications and the use of technologies like computers to enable students to actively create, experiment, and solve problems.

An in-depth analysis of collaborative methodologies used in the research experiences was provided by the contributions of David W. Johnson and Roger T. Johnson (Johnson & Johnson , 2018). Their studies characterized cooperative learning, distinguishing it from simple group activities through criteria such as positive interdependence, individual accountability, promotive and direct interaction.

Other studies related to peer collaborative learning have demonstrated, in addition to improved academic performance (Johnson, 1986), a positive change in students' attitudes and beliefs regarding physics and its learning, especially concerning the female gender (Mazur, Zhang, & Ding, 2017).

Finally, Howard Gardner has sparked awareness regarding the significance of laboratory activities, asserting that humans possess various forms of intelligence (iconic, synesthetic, numeric, logical, verbal, ...) (Gardner H. , 1988), influenced by environmental factors, which contribute to the understanding and application of concepts. Subsequently, neuroscientific research has supported Gardner's theories, highlighting how our brain undergoes modifications through the activation, construction, and organization of synaptic connections between neurons in response to environmental stimuli and lived experiences. This research has affirmed the importance of engaging sensory-motor brain systems to enhance students' comprehension of scientific concepts. The results have not only demonstrated a significant improvement in short-term test scores but also an increased ease in reasoning about learned concepts, correlated with the activation of sensory-motor brain areas (Kontra, Lyons, Fischer, & Beiloc, 2015) . This mechanism underscores the essential role of laboratory practice as an integral element in the learning process (Holmes & Wieman, 2018).

The research on the pedagogical foundations of active learning methodologies has been conducted not only through the consultation of texts but, in line with the experiential approach to Physics and STEM outlined in the thesis, also through direct experiences, especially at MIT.

With a specific focus on Physics, I had the opportunity to explore and directly experience the TEAL methodology (Technology Enabled Active Learning) as a form of active, collaborative, hands-on learning, mediated and enhanced by the use of technology. Additionally, I deepened my understanding of the ESG methodology (ESG, 2023), from which inspiration was drawn for the curricular experiment discussed in Chapter 4. Both these methodologies, TEAL and ESG, will be further elucidated in Chapter 5 of the thesis.

The Edgerton Center provided me with a unique professional development opportunity, where I experienced the significance of hands-on learning and collaboration among adults for the first time during a program for teachers at MIT in 2015 (MIT SEPT). This was made possible through the professional development workshops led by instructor Mr. Ed Moriarty. He also provides a summer school for High School students called "EDW, Engineering Design Workshop" (MIT Edgerton Center, 2023). I've got the chance to attend it and that was particularly inspirational for me, because I discover a new way to teach and learn STEM for students: they were encouraged to conceptualize, design, and execute STEAM projects in groups, with the sole support of near peer mentors. This experience served as an inspiring example for the development of my HoPE project, as described in Chapter 3. The methods, sequence of activities, and objectives of the workshop fully embody the philosophy of empowering students in their own learning process, a distinctive feature of EDW. At Edgerton Center, I also have the chance to appreciate Makerspaces for the education and training of students and teachers. The use of Makerspace for educational purpose has recently been emphasized by the European Commission (EU Commission, Ferrari, Punie, & Vuorikari, 2019).

Finally, I had the opportunity to interact with the research group "Lifelong Kindergarten" at the MEDIA_LAB (MIT_MEDIALAB, 2023), led by Prof. Mitchel Resnick, focusing particularly on the fundamental principles of 'Creative Learning,' known as the 4Ps ('Project, Passion, Peer, and Play') (Resnick, Give P's a Chance: Projects, Peers, Passion, Play, 2014). Although this group's research is primarily linked to peer-mediated technology-based learning (Scratch), the 4Ps and the concept of Tinkering (Resnick & Rosenbaum, Designing for tinkerability., 2013) derived from it found numerous points of contact with the extracurricular experience described in Chapter 5 and have been suggested as methodological guidelines for STEM learning by the National Digital School Plan (PNSD) (MInistry of Education & PNSD, 2022) of the Italian Ministry of Education and their STEM Guidelines (Ministry of Education, STEM Guidelines, 2023).

CHAPTER 3

A CASE STUDY: HOPE (HANDS-ON PHYSICS EXPERIENCE), AN EXTRACURRICULAR PROGRAM FOR ACTIVE, HANDS-ON, COLLABORATIVE LEARNING IN STEM

3. A CASE STUDY: HOPE (HANDS-ON PHYSICS EXPERIENCE), AN EXTRACURRICULAR PROGRAM FOR ACTIVE, HANDS-ON, COLLABORATIVE LEARNING IN STEM.

"Non-formal and informal learning play an important role in supporting the development of essential interpersonal, communicative and cognitive skills such as: critical thinking, analytical skills, creativity, problem solving and resilience that facilitate young people's transition to adulthood, active citizenship and working life. Establishing better cooperation between different learning settings helps promoting a variety of learning approaches and contexts "
(EU Council Recommendation on Key Competences for Lifelong Learning, (EU, 2018)*)*

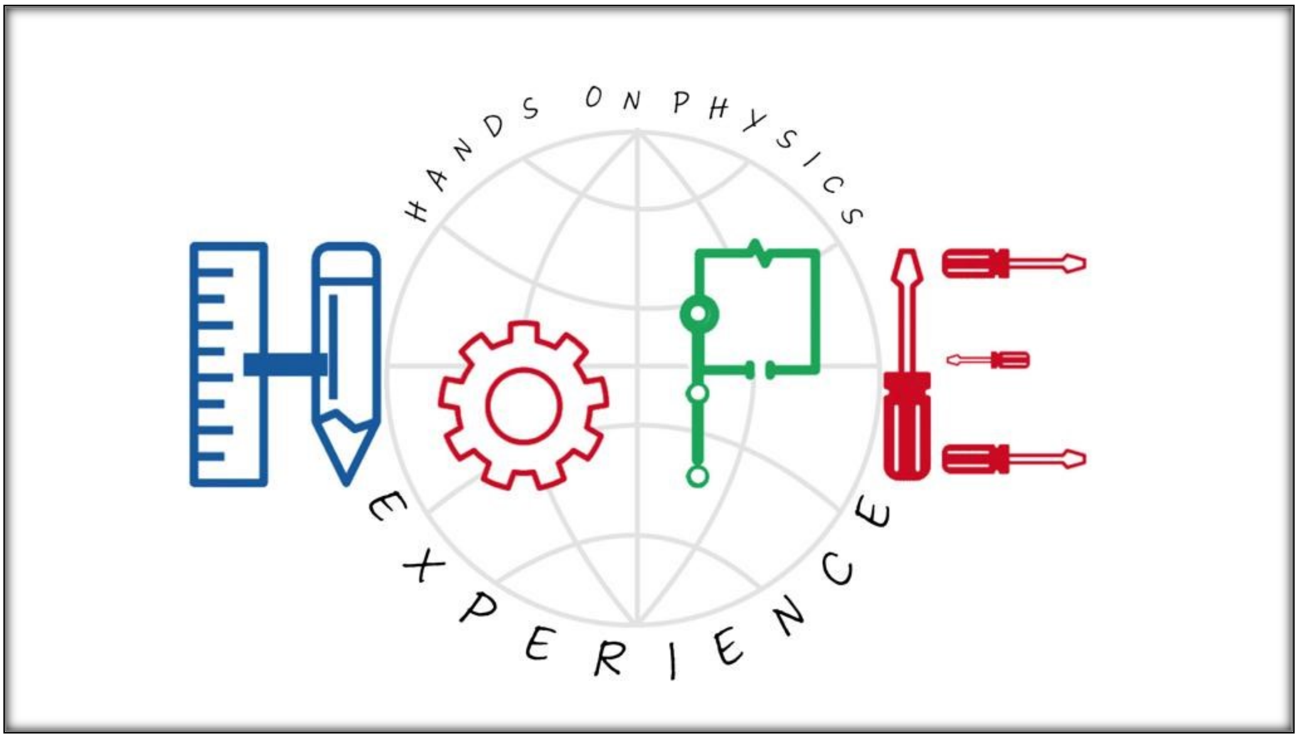

Fig.3.1: The HoPE logo

3.1 Context

The "A. Ròiti" Scientific High School in Ferrara (Italy) (Ministero dell'Istruzione & Liceo Roiti, s.d.) is a STEM oriented high school located in a quiet provincial city of approximately 130,000 inhabitants, renowned primarily for its historical and cultural beauties.

At its inception in 1923, the institute had only four classes and followed a four-year curriculum as established by the Gentile Reform of the same year. Today, it hosts around sixty classes with more than fifteen hundred students, over one hundred teachers, and dozens of administrative and technical support staff (ATA).

The students, mostly residents of the city but also a significant percentage from the province or neighboring provinces, are typically well-supported by their families, with whom the school has always maintained a relationship of dialogue and collaboration. The response of students and families to the school's curricular and extracurricular teaching proposals is usually excellent.

The teaching staff is largely part of a stable workforce. Recent competitions and retirement opportunities have facilitated the entry of personnel who graduated in the last decade into permanent positions.

The High School, initially characterized by a single curriculum, has diversified over the years, adapting to the demands of its user base and changes in society and the world of work, thanks mainly to the opportunities offered by laws on school autonomy (DPR n. 275/1999, 1999) (MIUR, Autonomia). Due to these laws, the "Course in Sciences for the Conservation of Cultural Heritage and the Environment" and the "Sports Course" were established. After initially participating in the didactic experimentation "National Plan for Computer Science" (PNI) and linguistic autonomy that allowed the inclusion of a second foreign language in the curriculum, since the academic year 2011/2012, the high school has seen the creation of numerous tracks in the "Applied Sciences" field. In the academic year 2014/2015, the Ministry of Public Education assigned the school a track of the "Scientific High School Sport oriented". Finally, from the academic year 2022/23, the "Biomedical Course" was activated within the path of the Standard curriculum, and the "Four-year Course" within the Applied Sciences path (see Fig. 3.2).

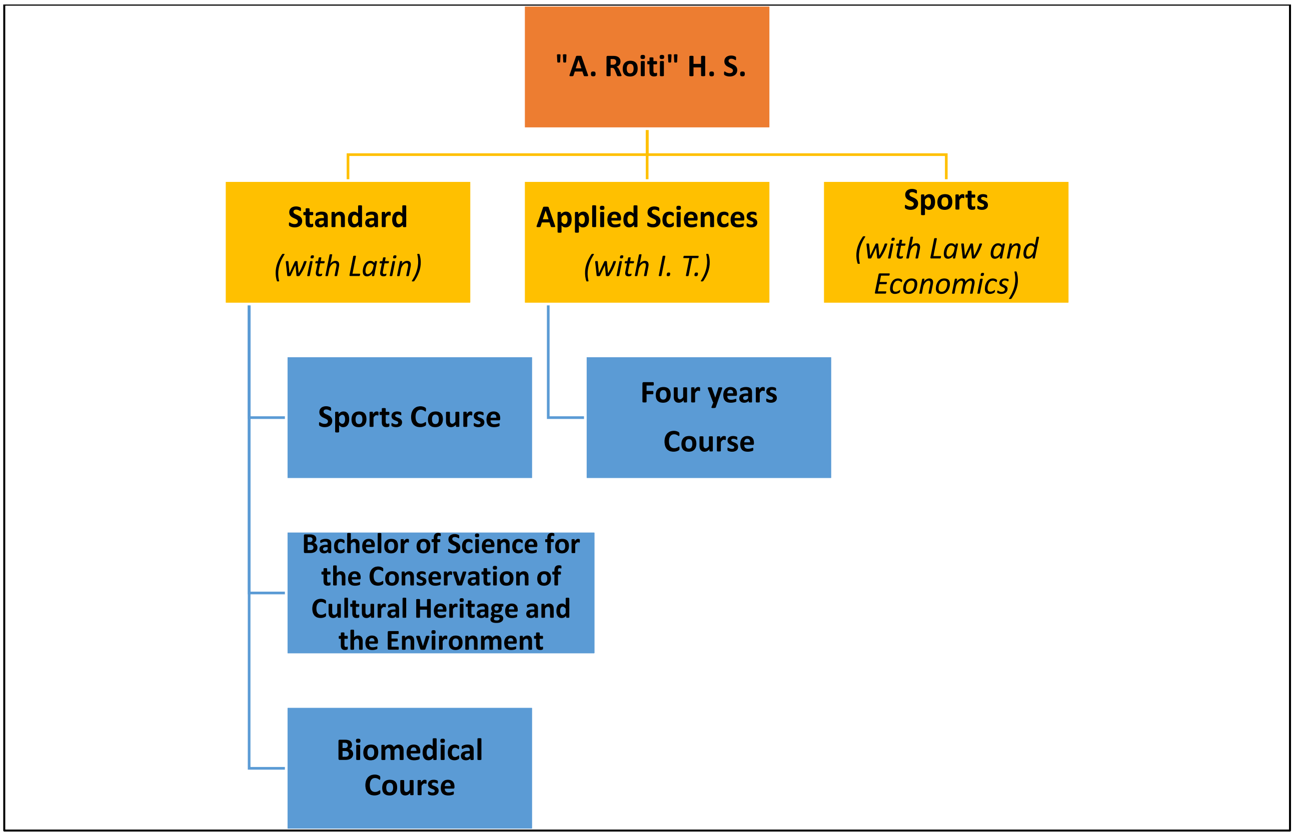

Fig. 3.2: Structure of the courses offered at the "A. Roiti" Scientific High School (school year 2023/24)

What mainly characterizes and distinguishes the various course structures is the study of Latin in the Standard curriculum, Computer Science in Applied Sciences, and Sports Law and Economics in the Sports curriculum, which is not part of the standard curriculum.

Unlike the American or other European school systems, in Italy, each student, at the beginning of their path in upper secondary school, chooses the type of school and course they intend to attend. It is important to note that each course has a predetermined curriculum and does not offer the possibility of individual customization.

The classes at "A. Roiti" High School are distributed between two nearby buildings: the central headquarters and the branch. The central location is currently undergoing renovations due to damage from the 2012 earthquake.

The laboratories are currently distributed between the two locations as in Tab 3.1:

	MAIN BUILDING	BRANCH
Physics	1	1 (shared with Biology)
Chemistry and Biology	1	0
Microscopy	1	1
Computer Science	2	3
Languages	1	1
Multimedia	1	0

Tab. 3.1: Laboratories at "A. Roiti" Scientific High School (academic year 2023/24)

The high school has always maintained a strong connection with local primary and lower secondary schools through support and guidance activities, primarily in the STEM field. These activities are mainly led by students using peer education methods.

The school also has an established relationship with the local University, particularly with STEM (Science, Technology, Engineering, and Math) degree programs. These programs typically involve high school students in activities mostly related to the Scientific Degrees Plan (PLS) and, more recently, integrated into the "Paths for Transversal Skills and Guidance" (PCTO) (Ministry of Education & PCTO). However, in recent years, there has been an increase in the number of students who, upon completing their secondary education, leave the city to enroll in universities in larger urban centers (often Milan, Rome, Bologna). The reasons for this trend can be varied, including a desire for autonomy and perhaps a lack of complete understanding of the needs and opportunities for employment in their local area.

3.2 The HoPE Program

In January 2018, with the support of the Department of Physics and Earth Sciences at the University of Ferrara (Università di Ferrara, 2023) and the Ferrara Section of the National Institute of Nuclear Physics (INFN, 2023) , it became possible to launch the "HoPE, Hands-on Physics Experience" program (Fig. 3.1) within the "A. Ròiti" Scientific High School, in collaboration with the Edgerton Center (MIT

Edgerton center, 2023) at the Massachusetts Institute of Technology (MIT) located in Cambridge, United States.

HoPE is a STEAM (Science, Technology, Engineering, Arts, and Math) program, where, in accordance with MIT's motto "Mens et manus" ("Mind and Hand") (Director MIT, 2009), knowledge and hands-on skills integrate and contribute together to the comprehensive education of the individual. Furthermore, HoPE emphasizes interdisciplinary components that combine sciences, computer science, and technology with art, architecture, music, and civic education.

The HoPE program is a Path for Transversal Skills and Guidance (PCTO) (Education, 2019) where voluntary students from the third, fourth, and fifth years of the high school meet weekly throughout the academic year to design and implement their own STEAM projects. Activities are carried out in heterogeneous teams, considering age, gender and skills.

The birth of the program is detailed below.

In January 2018, responding to my interests in sharing with my students the experience I had when I visited his workshop, Mr. Moriarty, who had 13 years of experience running high-school and college classes and workshops both locally and in China and remote villages in Alaska, arranged a trip to Roiti for a 1-week program of activities with himself, and experienced MIT students and alumni. In the mornings they offered (16) 1-hour class sessions (Fig. 3.3), providing 400 students with many different, engaging demonstrations and experiments over a range of physics and STEM in general concepts that teachers could select.

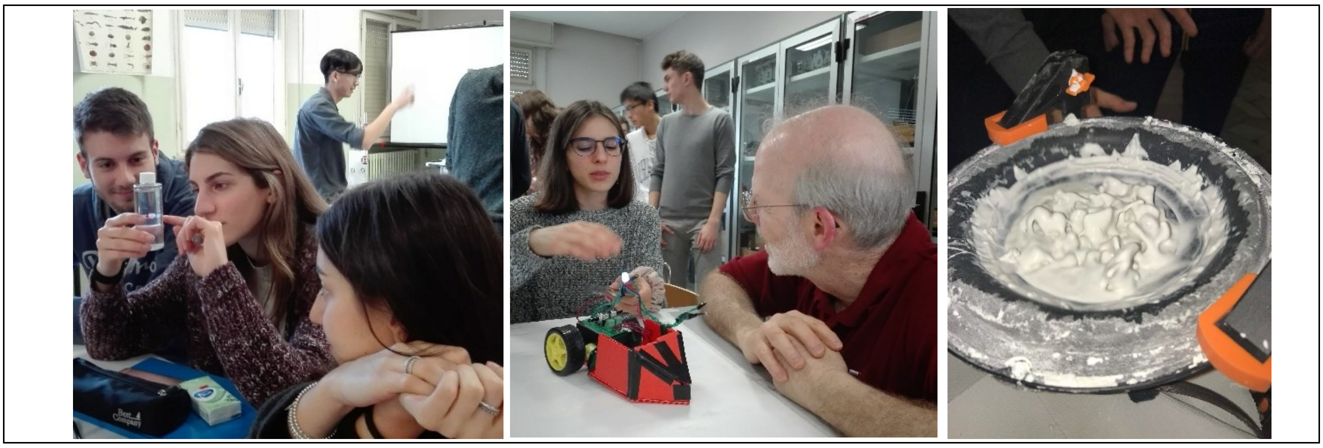

Fig. 3.3: STEM activities

In the afternoons there were (4) 3-hour workshops that allowed 100 students to have a more hands-on experience with the activities and concepts. Finally, there was a long workshop for 25 students that lasted 5 days, a workshop where, as a group, they decided to attempt a challenging engineering project to compare auditory and visual pattern recognitions of the pendulum's oscillations. The results were beyond anything that could have been predicted. In the long workshop most of the students had never used a screwdriver, programmed a computer, stripped a wire, or worked on a team project. Nevertheless, they dreamed up an intriguing project, divided into teams and managed to build an amazing multi-stage device involving 15 pendulums, lasers and break-beam sensors, and a glockenspiel that was played by an Arduino driven set of solenoids (Fig. 3.4). The project, titled

“Pendulum waves”, features a series of different-length pendulums with lasers at the top and light sensors at the bottom, all suspended from a lintel and integrated with a tuning system. When a pendulum blocks its laser, it triggers an electrical signal to an Arduino board, which then activates a solenoid to strike a corresponding glockenspiel bar. Thus, each pendulum corresponds to a musical note, converting their motion into a melody. The students, working in teams, built the structure of the set of pendulums, of the glockenspiel and set up the electronic part controlled by an Arduino.

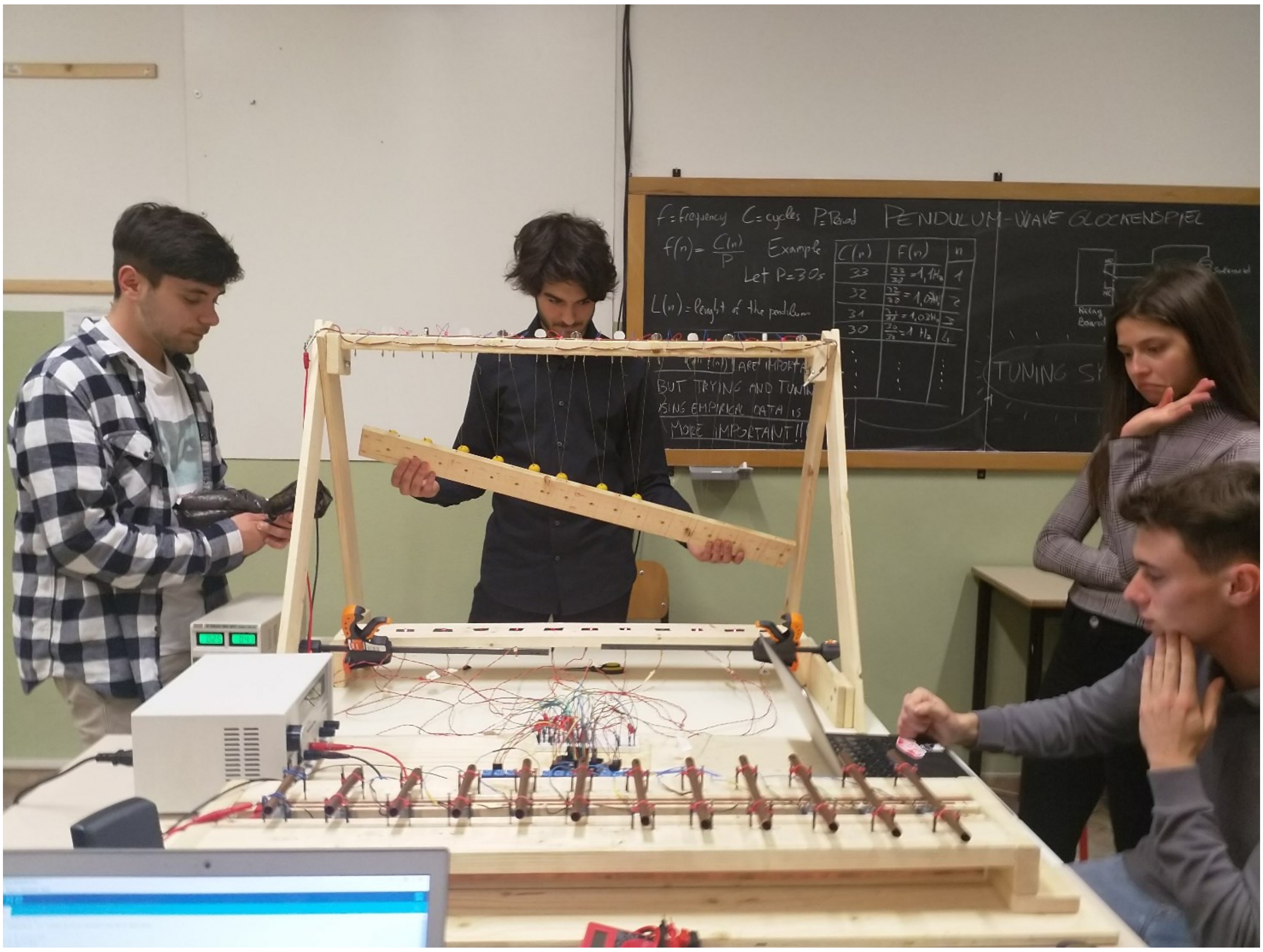

Fig. 3.4: The Pendulum wave

Students experienced the excitement of the challenge, the team spirit, mutual support, the dedication, and the sense of achievement. The shared experience brought them together and many are friends to this day. They felt the excitement of collaboration in a creative endeavor, and the sense of pride in themselves and their team. They asked if they could continue with their efforts, and Mr. Moriarty agreed to provide remote help and to return if it would be helpful. Some students volunteered to help me run a weekly workshop.

The HoPE program itself has grown as a collaborative effort with MIT staff, students and alumni, and with Roiti, INFN and University of Ferrara staff, students and alumni.

Below are some examples of projects and related videos produced by students during the HoPE program (Fig. 3.5- 12).

Fig. 3.5*: Wind tunnel*: https://www.youtube.com/watch?v=CcqayRJphrw

Fig. 3.6: Laser harp: A harp with laser beams of light and light sensors instead of strings (electronics governed by Arduino) https://youtube.com/shorts/ubdfEj-yUdU?feature=share

Fig. 3.7: Kundt 's tube to study sound waves
https://www.youtube.com/watch?v=bqGS0T3GlIc

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Fig. 3.8: Tensegrity table to study forces: https://www.youtube.com/watch?v=fxMhk4_PIoo

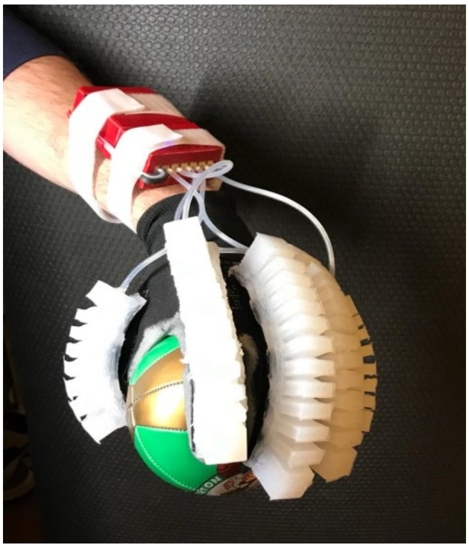


Fig. 3.9: Softrobotic glove: a glove with softrobotic actuators controlled by an air pump, capable of helping to open and close a hand
https://youtu.be/1JPcmn5rvNY

Fig. 3.10: Musical glove: a glove with sensors, which plays music when the fingers bend (designed to promote rehabilitation) https://www.youtube.com/watch?v=ZWut7Ps-4mE

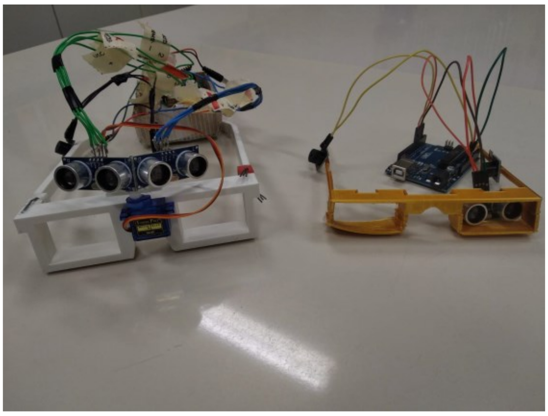


Fig. 3.11: Glasses with obstacle sensors for the visually impaired
https://www.youtube.com/watch?v=th-HRrFznJ0

Fig. 3.12: Radio controlled drone with immersive headset
https://www.youtube.com/watch?v=srscqWEv6eQ

3.3 Objectives and Specific Goals of the HoPE Program

The overall objectives that the HoPE program aims to achieve are:

- **Guidance:** To help students discover their personal inclinations, encouraging them to cultivate curiosity and interests while providing space for personal creativity.
- **Encourage Inclusivity in STEAM:** To encourage and support students, particularly females or minorities, in acquiring knowledge and skills in STEAM disciplines through hands-on activities. These activities involve direct engagement, enhancing their motivation and desire to pursue further studies in these disciplines in the future.
- **Link Theory and Practice in STEM:** To create meaningful connections between theory and practical application in STEM disciplines, demonstrating to students how acquired knowledge can be applied in the real world. This involves learning through the creation of projects that model real-world phenomena (*learning by doing*).
- **Develop Creative Problem-Solving Skills:** To cultivate students' ability to creatively tackle complex problems (problem-solving, creative thinking). This is achieved by applying scientific, technological, engineering, and mathematical principles, promoting the development of integrated skills in STEM disciplines and helping students understand how different areas intersect in solving real-world problems.
- **Facilitate Collaborative Learning:** To foster collaboration and mutual learning among students (collaborative learning) through peer-to-peer teaching, enhancing disciplinary skills, promoting the development of democratic values, social skills (listening, respect for others), autonomy in knowledge construction, and formation (*learning to learn*).
- **Connect Students from Different School Levels:** To bring students from different school levels together (*near peer education*), promoting alignment and optimization of educational paths.
- **Build Student Responsibility and Self-Esteem:** To empower students by increasing their self-esteem through assuming roles and responsibilities that make them aware of their potential.
- **Encourage Freedom of Research and Exploration:** To encourage students to freely research and explore without fear of judgment, emphasizing the importance of stepping out of their comfort zone. The program aims to convey the understanding that managing failures and correcting mistakes are essential elements of the learning process, enabling the acquisition of understanding, even of new and complex concepts, **creating new knowledge**.
- **Connect with the Academic World:** To offer students the opportunity to connect with the academic world and a center of excellence like the Massachusetts Institute of Technology, providing them with stimuli from environments characterized by research and innovation.
- **Promote Language and International Collaboration:** To promote collaborations with foreign institutions and schools, encouraging the use of the English language for a deeper understanding of its importance as a means of communication, exchange, and knowledge and experience building.

- **Develop and Evaluate Key Competences:** To promote the development and evaluate the achievement level of the eight key competences for lifelong learning (Recommendation EU, 2018) (Att.1) (Fig. 3.13)

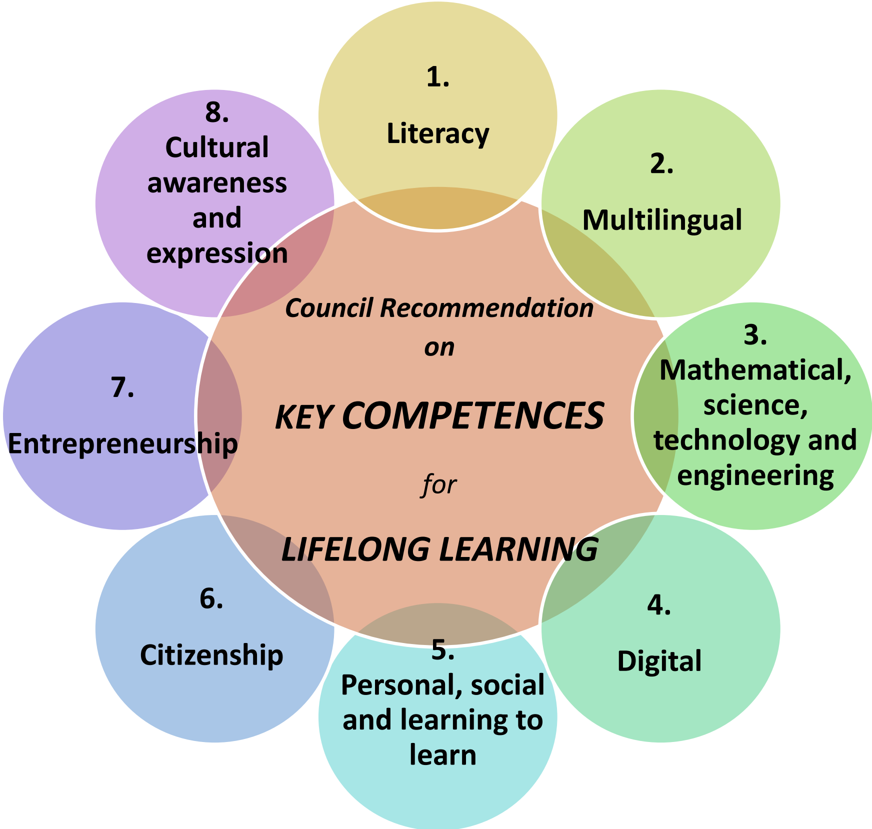


Fig. 3.13: EU Council Recommendation on key Competences for Lifelong Learning

In the context of these objectives, the specific goals of HoPE that students should be able to achieve at the end of their experience are:

- Develop autonomous and conscious research and learning skills (*learning to learn*) (*critical thinking*).
- Understand the phenomena analyzed through their project and learn the connected physical, mathematical, computer science, technological, and engineering content.
- Develop ideas and strategies for problem-solving (*problem-solving*) using computational thinking and conscientiously and critically utilizing technology.
- Acquire basic knowledge of electronics, computer science, and programming necessary for building a circuit, using Arduino, or CAD design.
- Collaborate with peers, sharing knowledge and skills, being active, respectful of others' opinions, helpful, open to new ideas, and inclusive (*collaborative learning*).
- Understand the role of socialization and collaboration, both within and outside the institute, in constructing collective knowledge and, more generally, in achieving a goal (*collaborative learning*).

- Use the English language as a means of communication, exchange, and knowledge and experience building.
- Have developed the eight key competences for lifelong learning (Recommendation EU, 2018).

The above objectives align with:

- The right of every individual "*to quality and inclusive education, training and life-long learning, in order to maintain and acquire skills that enable them to participate fully in society and manage successfully transitions in the labor market*", as promoted by the "Recommendations of the Council of the European Union for the development of key competences for lifelong learning" (Recommendation EU, 2018).
- The National Guidelines for High Schools, which state that "the high school paths provide students with the cultural and methodological tools for a thorough understanding of reality, enabling them to approach situations, phenomena, and problems with a rational, creative, project-oriented, and critical mindset. Students acquire knowledge, skills, and competencies suitable for further higher education, integration into social life, and the workforce, all aligned with their individual abilities and choices" (MIUR, DM n. 211 , 2010).
- The STEM Guidelines issued by the Ministry of Education and Merit (Ministry of Education, STEM Guidelines, 2023).
- The need for the development of STEM skills (especially among females, aiming to reduce the "gender gap") and entrepreneurship education in the local community and society at large.

3.4 Organizational Design of the HoPE Program and Its Rationale

The HoPE program, due to its structure and the activities it comprises, can develop the lifelong learning competencies recommended by the Council of the European Union (EU, 2018) and fostering interest in STEM disciplines.

HoPE involves voluntary participation from students in the second biennium and the final year of the "A. Roiti" Scientific High School (ages 16 to 19), representing diverse classes and orientations within the institution. University students can also participate as mentors. For these reasons, HoPE is an extracurricular program and follows the structure outlined in paragraph 3.6.

HoPE stems from a collaboration with the MIT Edgerton Center, aiming to integrate traditional Italian methodology with MIT's "Mens et Manus" philosophy (Director MIT, 2009) and replicate the Center's decades-long high school student training experiences (Edgerton Center, 2023), aligning with the guidelines for United States schools in the "Next Generation Science Standard" document:

"*Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world. Engaging in the practices of engineering likewise helps students understand the work of engineers, as well as the links between* *engineering and science. Participation in these practices also helps students form an understanding of the crosscutting concepts and disciplinary ideas of science and engineering; moreover, it makes students' knowledge more meaningful and embeds it more deeply into their worldview*" (NGSS, 2023).

Empowerment, promotion of personal initiative, autonomy, critical thinking, creativity, and motivation in STEM fields are foundational to the program's objectives and methodology. Accordingly, following MIT-Edgerton Center's motto "*Build it, Learn it, Share it*", students undergo the following stages represented in the cycle of Fig. 3.14, with each part of the process guided by peer mentors (*peer education*):

- **Define the PROJECT or the PROBLEM.** At the beginning of the school year:
    - They propose the projects they want to build or the issues they want to delve into.
    - They discuss together and select the projects to build or issues to resolve for the current school year.
    - Autonomously form working teams based on common interests and motivations, without class or age restrictions determining team composition.
- **IMAGINE**. Conduct a group brainstorming of ideas related to the project or issue and collaboratively arrive at possible shared solutions.
- **RESEARCH**. Conduct research to support their goals (information on what others have done or discovered, theoretical foundations, materials and tools to use, etc.).
- **PLAN & DESIGN.** Plan and design the work they intend to carry out, including:
    - Defining objectives.
    - Planning necessary activities (available resources, timelines, budget, materials, etc.).
    - Assigning roles and responsibilities within the group.
    - Drawing a project sketch.
- **CREATE**. Following the planned steps:
    - Produce the prototype or identify the solution to the problem.
    - Research practical solutions to encountered problems, learning not to fear potential errors or failures, which can sometimes limit personal initiative but, instead, learning from them (Dewey, 1916).
- **TEST**. Test the prototype or the identified solution, collect and analyze the obtained data:
    - Reflect together on what was learned, the development process, and the obtained product.

If problems arise, **REFLECT** on possible **IMPROVEMENTS** through new brainstorming and restart the cycle.

Otherwise,

- **DOCUMENT and SHARE.** Produce DOCUMENTATION and SHARE the obtained results or created prototypes, collect feedback for potential new implementations.
    - Document the various steps of their project's realization, organizing materials to make them shareable online (Instructable, https://www.instructables.com). Some examples at the following links:

- https://www.instructables.com/Car-Men/
- https://www.instructables.com/Laser-Harp/
- https://www.instructables.com/SoftGlove/

- Organize the setup and actively contribute to the management of local, national, and international events. During these events, students have the opportunity to present their projects, interact with attendees, and receive feedback, which may lead to further project enhancements.

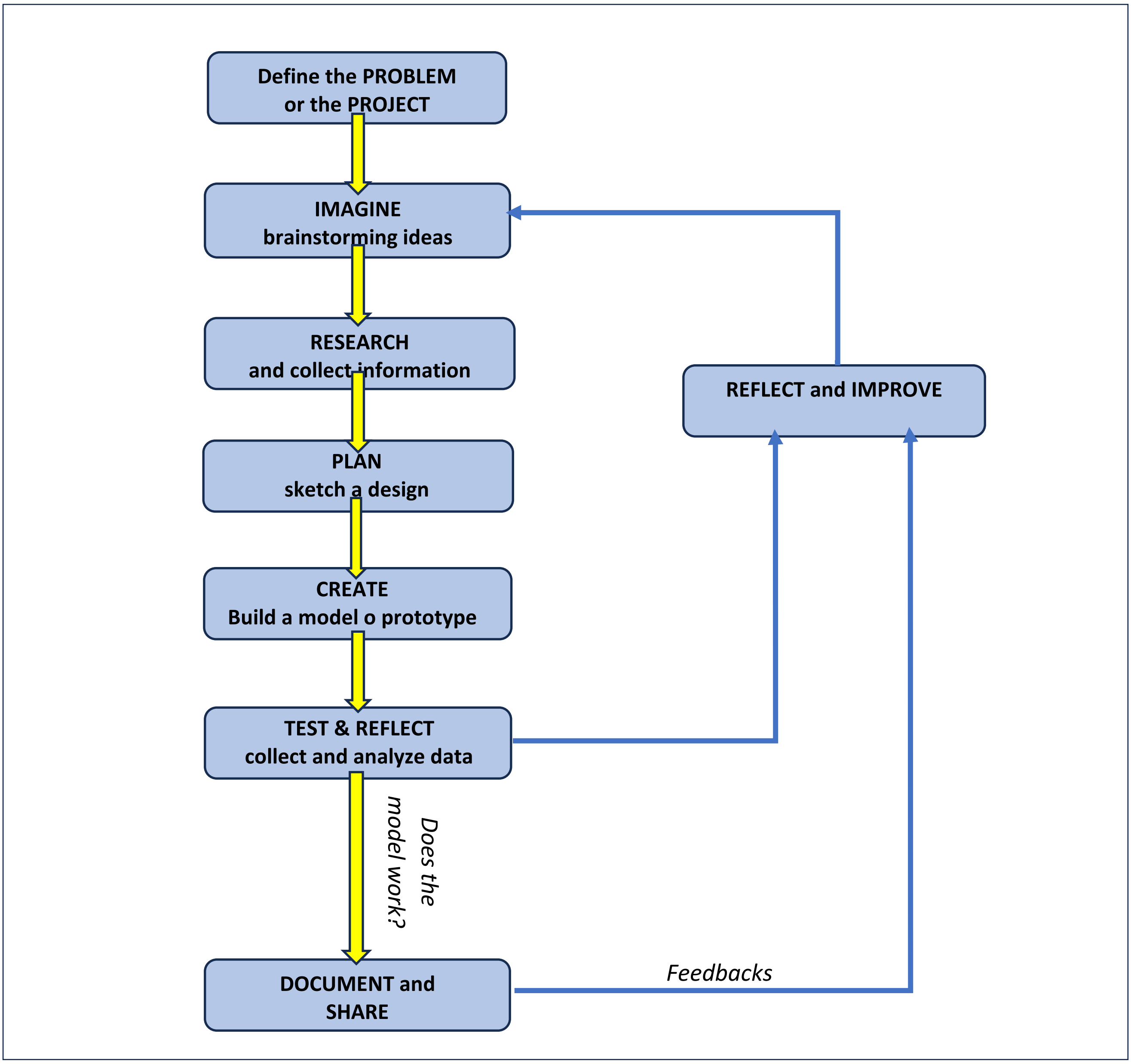


Fig.3.14: Cycle of HoPE

HoPE's objectives are achieved by overcoming:

- Some rigid boundaries between different disciplines: Students' free choice regarding the product to be created allows them to explore Science, Technology, Arts, Engineering, and Design, realizing the integrated approach to disciplines suggested by ministerial guidelines to promote STEM learning (Ministry of Education, STEM Guidelines, 2023, p. 6).
- Age differences among participants: The learning community consists of students aged 16 to 26.
- Traditional school spaces and times as traditionally understood in the Italian school system:
    - Every area of the school (classroom, laboratory, atrium, garden) can become a place for experimentation and learning.
    - The activity's duration, understood as the "life of the project" from idea inception to realization and sharing, has no temporal limits typically associated with regular teaching modules. It is dictated by the project itself. As highlighted in Fig. 3.14, each product should never be considered final and concluded because with "HoPE," there is always room for improvement, fostering creativity, research, and experimentation even in subsequent school years and by students not belonging to the original team that conceived and executed it (implementation).

In the program's first year, the organizational structure of HoPE involved:

- Three teachers and two laboratory technicians (physics and computer science) handling the organization and management of activities entirely.
- Students joining HoPE, from different classes within the institution, being selected exclusively by their respective teachers.

Starting from the following school year, to encourage students' informed and responsible participation in activities and program management:

- The choice was made for student participation to be exclusively voluntary.
- A structure was established in collaboration with students, involving the identification of a certain number of Mentors and three "Coordinators responsible for coordination between students and teachers" (Fig. 3.15).

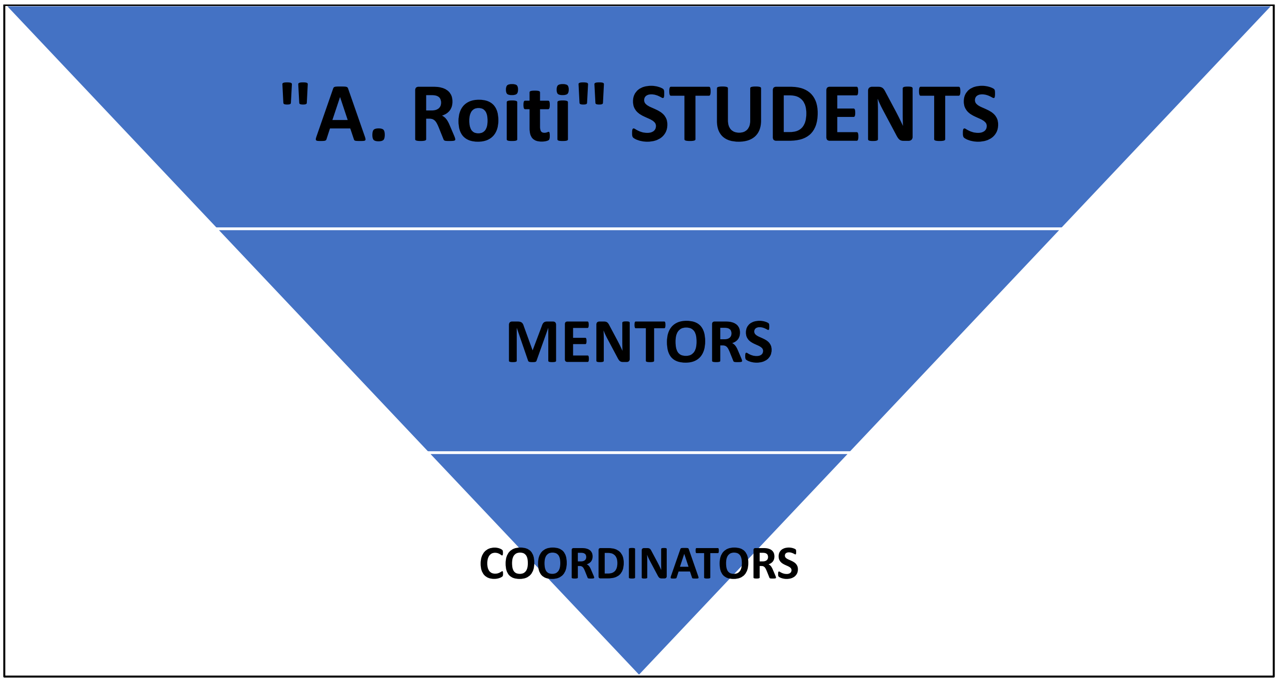


Fig. 3.15: Organization of Students Participating in the HoPE Project

The number of students applying almost always exceeds the available spots. In these cases, selection is made through the analysis of the motivational application used for candidacy. The application does not request information related to academic performance in curricular lessons. It is not uncommon to find students with low academic grades who, when placed in a condition to work actively and collaboratively, even in an extracurricular program, improve their self-confidence, motivation for STEM study, and subsequently, grades in curricular scientific subjects. Given the importance of the form used, it is currently under study and improvement.

Currently, around fifty students, about fifteen mentors, four teachers, and one laboratory technician are involved in the HoPE program, in addition to the expert staff from MIT-Edgerton Center, the Ferrara section of INFN, and the Department of Physics and Earth Sciences.

Mentors can be university students or high school students. The latter are proposed each year by mentors from previous years among students who have already participated in previous editions of HoPE and have distinguished themselves for their creativity, curiosity, commitment, openness to discussion and collaboration, empathy, effectiveness in managing complexities, and progress made in terms of acquired knowledge and skills. The candidacy of new mentors is then discussed and agreed upon with the teachers. Mentors are learning facilitators within each team (peer education): they support students in challenging moments, encouraging them not to give up in the face of failures and to autonomously seek alternative paths in problem-solving. They ensure the inclusion and well-being of each team member by facilitating interaction among students, making sure everyone feels an integral part of the community. Each HoPE meeting is preceded by a briefing between mentors and teachers, where any ideas, new information, and afternoon activities are shared and planned. The weekly appointment concludes with a meeting between mentors and teachers to discuss the progress and challenges of each team.

Mentors then report what emerged from these discussions to the members of their respective groups. During the design and implementation phases, mentors are also responsible for managing purchase proposals necessary for project realization. At the beginning of each school year, new mentors gather for a training session conducted by experienced mentors. During the meeting, the characteristics of a good mentor and their role, outlined in a document elaborated in the past by the students themselves (Att. 3), are analyzed and discussed.

The three "**Coordinators** responsible for coordination between students and teachers" are elected from and among mentors attending high school. These people work directly with teachers in managing the HoPE program, acting as a liaison between teachers, mentors, and students, coordinating communications, organizing activities, meetings, and events.

Despite the presence of mentors and "Coordinators", each participating HoPE **student** constitutes a significant voice ("*my voice matters*") and, due to their role within the team and the community, bears a significant responsibility for the program's smooth operation and the correct progress of activities. Each student is encouraged to make improvement proposals or raise issues that are then discussed in the joint assembly of students and teachers.
For this reason, the motto of HoPE is "HoPE IS A PROJECT OF THE STUDENTS, BY THE STUDENTS, FOR THE STUDENTS" and the picture the students like the most about HoPE is in Fig. 3.16.

Fig. 3.16: Students representing the HoPE's motto

Students also have full responsibility for managing the project HoPE website (https://hoperoitimit.com/).

Teachers are responsible for preparing, promoting, and supporting conditions that favor the effective completion of activities through careful organization of the various program phases. They support students performing mentoring functions in various project groups through dedicated briefing sessions at the end of each meeting or whenever deemed necessary. Teachers monitor the well-being of students necessary for the success of the learning process through observation, constant dialogue, and administering surveys. Furthermore, they circulate constantly among the teams to monitor the progress of the work process, discussing any difficulties or achieved results with the students. Teachers also have the role of overall project organization, namely:

- Preparing and drafting the annual schedule of activities, coordinating with the school's management.
- Maintaining relations with the headmaster and involved stakeholders.
- Making necessary purchases for the chosen projects.
- Organizing and managing events in which HoPE participates.

An indispensable figure within the school is the laboratory **technician**, responsible for:

- Initial training related to laboratory safety and tool use.
- Overseeing the correct use of safety devices and tools to prevent harm to people or property.
- Organizing laboratory materials and monitoring needs.
- Organizing the warehouse containing completed projects.

External **expert staff** is involved in various ways and at different times according to needs.

A group of MIT students and experts (varying in number) is usually present at school during intensive periods. A MIT_Edgerton Center expert, the instructor Mr. Edward Moriarty, is always present remotely (via Zoom) or in presence during activities and interacts with each team at the students' request, encouraging them to discover solutions by themselves. His role is described by students in the video at the link: https://youtu.be/x0aC-vZeyGc ("A conversation with Ed Moriarty: the role of a mentor).

The actual Director of the INFN branch in Ferrara, Professor R. Calabrese, who immediately recognized the significance of this mode of learning and teaching, has consistently championed HoPE. He encourages university students to actively participate in HoPE activities as mentors, supports the program's involvement in national and international events, strengthens HoPE's ties with MIT through initiatives involving the latter's students in university research, and promotes the dissemination of HoPE's learning approach through professional development opportunities for teachers.

Students in HoPE interact collaboratively through methodologies such as *collaborative learning*, *learning by doing*, *mentoring*, and *peer education*. Together, they form an active and inclusive learning community where individuals with different backgrounds, skills, ages, and genders come together to derive pleasure from ideating, building, discovering, understanding, and learning together.

For this reason, activities and groups are structured, considering the criteria suggested by David W. Johnson and Roger T. Johnson (Johnson & Johnson , 2018) for the successful implementation of cooperative activities.

A. **Positive Interdependence**: Responsibility for achieving the goal is distributed among all group members, who are heterogeneous in terms of age, gender, academic skills, and interpersonal skills. The failure of one individual can lead to the group's failure. There is no competition within the group that causes one to emerge at the expense of another.

B. **Individual Responsibility**: Each student in the team has a specific and different role discussed and agreed upon within the group at the beginning of the program, ensuring that each participant contributes fairly and actively to the common work. The success of the activity is linked to the individual's commitment, preventing them from delegating their work to a "more capable" peer. Roles and responsibilities of each member are explicitly outlined in the ongoing documentation ("Diario di bordo") and the final documentation of the activity ("Documentazione finale").

C. **Direct Constructive Interaction**: Each group member may have a specific role or responsibility, but the activity is structured in a way that the final product cannot be effectively and positively achieved without constant moments of direct interaction among the different group members.

D. **Development and Appropriate Use of Social Skills**: This approach facilitates the acquisition of basic relational skills, such as understanding and trusting others, the ability to listen and accept others' opinions, clear and precise communication, following a common schedule while respecting timelines, mutual support, conflict resolution skills, and taking responsibility for one's actions.

E. **Monitoring and Reflection**: The teacher, along with mentors from individual groups, monitors activities by observing, mediating, and encouraging interaction among students. Each meeting is preceded by a briefing between mentors and teachers to agree on objectives and activities and is concluded by a meeting between mentors and teachers to reflect and analyze strengths and weaknesses of a relational and operational nature within the groups. Teachers monitor all students during activities through direct observation and dialogue aimed at understanding and reflecting together on the personal or collective learning process. Periodically, all students are anonymously administered surveys reflecting on their satisfaction with the non-traditional methodology used and their emotional state during activities that may involve successes, anxieties, or failures from which to learn.

3.5 Methodologies

The adopted methodology aims to promote a more conscious and meaningful learning of Physics and STEM in general through an active learning and collaborative approach to the analysis of real phenomena, their interpretation, and understanding. Specifically, the following working methods are emphasized:

- **Student-centered** learning approaches that, breaking down temporal units, spatial barriers, and age differences, allow a fluid acquisition of lifelong learning skills (EU Recommendations, 2018), respecting the specific characteristics of the learner and their ways and times of learning.
- Organization of learning **environments and times** that serve as idea labs and forums for student interaction, promoting *collaborative learning*. In these contexts, students not only learn the value of collaboration but also explore their own identity, express their ideas, listen to, respect, and understand different viewpoints. This process includes negotiating one's own positions with the aim of reaching a common and shared arrangement ("P*ersonal and social competences"*, Competence 5 in EU Recommendations, 2018) (EU, 2018).
- The **learning-by-doing** methodology, where students are encouraged to understand physical phenomena and the surrounding reality through practical activities and hands-on experience. These collaborative activities involve analyzing concrete cases, solving real problems, and hands-on projects that students conceive, design, build, test, and implement. As these projects align with personal interests, they present stimulating and meaningful challenges for students, leading to autonomous learning and retention of acquired knowledge (*learning to learn*). This process involves taking individual responsibilities within the work group to contribute to achieving a shared result. Additionally, students develop the ability to correct and overcome any errors and failures during their journey, accepting them as integral parts of a process that leads to individual and collective improvement and the co-construction of knowledge, "Mathematical competence and competence in science, technology, and engineering" (Competence 3 in EU Recommendations, 2018) (EU, 2018), and "Personal, social, and learning to learn competence" (Competence 5 in EU Recommendations, 2018) (EU, 2018).
- Activities organized to develop **digital skills** necessary for STEM projects, empowering students not only as passive technology users but also as informed digital citizens ("Digital Competence", Competence 4 in EU Recommendations, 2018) (EU, 2018). These activities include computer literacy, basic electronics, and the use of Arduino, using CAD drawing platforms (Onshape), creating digital content, and opportunities for students to develop computational thinking during problem-solving.
- **Peer education**: Students, working in groups, share their skills and knowledge, agree on roles and responsibilities, and take turns as learners or facilitators (peer collaborative learning and teaching). Some more general activities, such as computer, electronics, or CAD training, are also carried out in peer education mode by more experienced students.
- **Organization of events** within and outside the school community, locally, nationally, and internationally, so that students learn to communicate the results of their STEM activities appropriately, even in languages other than their own, to constructively engage with people of different cultural backgrounds, and to be open to stimuli from different environments. This enables students to develop competences in "functional literacy," "multilingualism," and "competence in cultural awareness and expression" (Competence 1, 2, 8 in EU Recommendations, 2018) (EU, 2018).

3.6 Activity Description

The project involves a diversified and flexible structure that has adapted to the regulatory requirements related to the COVID-19 emergency. The articulation is divided into phases to be carried out entirely in extracurricular hours through weekly meetings of 3.5 hours each, alternating with periods of intensified activities (intensive weeks), mostly held in the presence of Massachusetts Institute of Technology experts. The table below (Tab 3.2) provides an illustrative timeline of the HoPE project within "A. Roiti" High School.

Phases	Methodologies	Periods and meetings
A) Presentation	*Peer education*	September - October n. 1 meeting
B) Initial training and team building activities	*Peer education* *Collaborative learning* *Learning by doing* *Problem solving*	October n. 2-3 meetings
C) Brainstorming of ideas. Teams form around ideas	*Peer education* *Collaborative learning* *Problem solving*	October n. 1-2 meetings
D) Implementation of projects	*Near peer education* *Project based learning* *Learning by doing* *Problem solving* *Autonomous learning* *Circle time*	From November to April n.1 weekly meeting January n. 3-5 meetings (consecutive afternoons)
E) Sharing	*Near peer education* *Learning by doing* *Autonomous learning*	When the opportunity arises
F) Summer school	*Project based learning* *Learning by doing* *Problem solving* *Autonomous learning*	June-July n. 2-4 weeks

Tab. 3.2: Timeline of the HoPE program

The HoPE program follows the sequence of activities outlined in Table 3.2, each aimed at contributing to the development of the Permanent Learning Competencies recommended by the European Union in 2018 (EU, 2018) through diversified activities described below.

A) **Presentation**: Introduction of the HoPE structure and objectives to new interested students and collection of applications.

Fig. 3.17: Plenary Presentation Meeting organized and managed by students

Fig. 3.18: Plenary Presentation Meeting organized and managed by students

This activity, conducted through a plenary meeting, is primarily organized and led by students who have participated in previous editions of the program. They introduce the project's structure, answer questions from new students, clarify work methods, and outline the goals achieved in previous years. (Fig. 3.17, 3.18)

At the end of the presentation, new students interested in participating can apply for HoPE. The GForm module used for the application includes a motivational presentation from the candidate.

In the following week, teachers select candidates based on the following criteria:

- The motivational presentation.
- Maximum number of acceptable students based on school resources.
- Diversity within the learning community in terms of gender, class representation, and age.

Competences involved: 1. Literacy competence – 2. Multilingual competence – 3. Mathematical competence and competence in science, technology, engineering – 4. Digital competence – 5. Personal, social, and learning-to-learn competence – 6. Citizenship competence – 7. Entrepreneurial competence – 8. Cultural awareness and expression competence

B) **Initial Training and Team Building**: New students, divided into small groups to facilitate interaction, undergo brief courses on:

- Laboratory safety (*)
- Arduino and coding (Fig. 3.19) (**)
- Onshape and digital graphics (**)
- Use of the 3D printer (**)
- Conscious use of tools such as soldering iron (Fig. 3.20), drill, pliers, etc. (*) (**)

(*) Conducted by the laboratory technician.
(**) Conducted by school or university mentors

Fig. 3.19: Students learn how to use Arduino

Fig. 3.20: Learning how to use a soldering iron

New students are also engaged in practical/playful activities (Fig. 3.21, 3.22) aiming to convey:

- The importance of personal contribution to achieve a common goal within a group
- The value of mutual listening
- The importance of constructive dialogue that embraces each other's perspectives with respect for mutual differences.

Fig. 3.21: Spaghetti tower competition

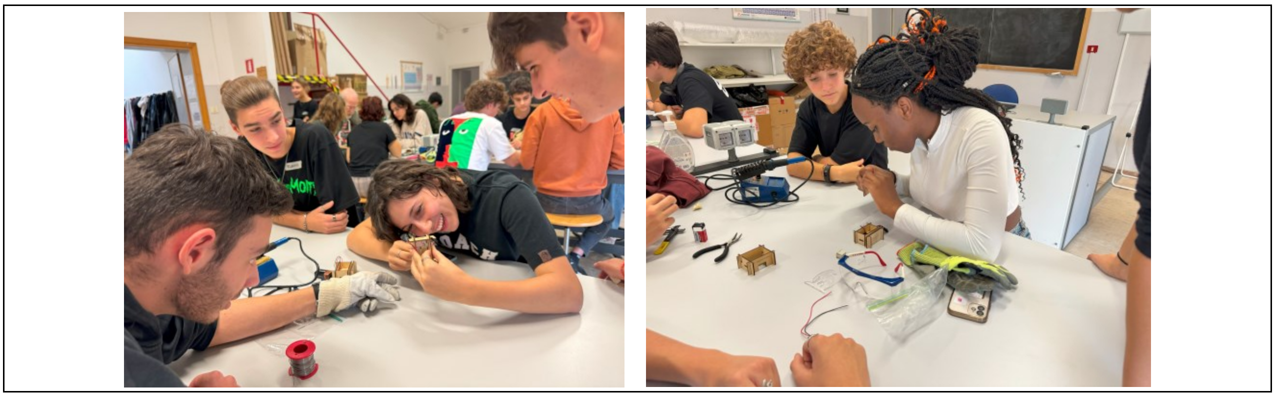


Fig.3.22: Building a project together

New mentors, together with experienced mentors, discuss a document regarding the role and characteristics of a "good mentor" (Att.3).

<u>*Competences involved*</u>*: 1.* Literacy competence – 2. Multilingual competence – 3. Mathematical competence and competence in science, technology, engineering – 4. Digital competence – 5. Personal, social, and learning-to-learn competence – 6. Citizenship competence

C) **Brainstorming of Ideas. Teams form around ideas**: Each student has the opportunity to propose a STEAM project idea (Fig. 3.23). Ideas are discussed in the assembly of all students, considering pros and cons, choice motivations, feasibility, and shareability.

Fig. 3.23: Each student can pitch an idea

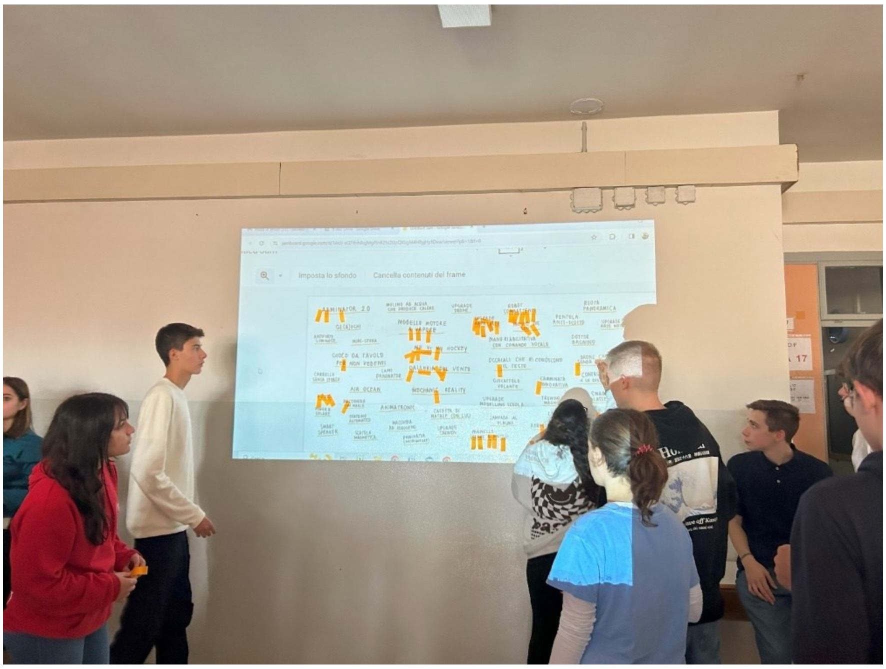


Fig. 3.24: Selecting ideas

Through a shared selection process (Fig. 3.24), a suitable number of projects is chosen, considering the available number of students and school resources. Students then select which project to join based on their personal interest. Teachers ensure that workgroups are diverse in terms of represented genders, ages, and skills, comprising no more than 5/6 students. Each team is associated with 1 or 2 mentors.

<u>Competences involved</u>: 1. Literacy competence – 2. Multilingual competence – 3. Mathematical competence and competence in science, technology, engineering – 4. Digital competence – 5. Personal, social, and learning-to-learn competence – 6. Citizenship competence

D) **Project Implementation**. The project implementation activities are organized during weekly afternoon meetings, where various groups come together to advance their respective tasks. Each team is led by a mentor chosen from experienced high school students or university students. During each meeting, students connect remotely with one or more MIT experts who stimulate them to address any emerging issues.

The activities engage students in:

Fig 3.25: Discussing and designing

1. Independent research for information/material.
2. Preparation of preliminary project documentation (design, necessary materials, costs, ...) (Fig.3.25, 3.26).
3. Creation of cardboard prototypes (Fig. 3.27 - 31).
4. Any specific training required for implementing the idea.
5. Construction and practical realization of the idea/project (Fig.3.32, 3.33).
6. Prototype testing, reflection, and potential implementation (Fig. 3.34).
7. Compilation of the logbook and creation of multimedia and shareable documentation materials for various project phases (photos, videos, technical sheets, encountered problems and choices made, ...).

Fig. 3.26: Planning and designing

Fig. 3.27: Creating a cardboard model

Fig. 3.28: Creating a cardboard model

Fig. 3.29: Creating a cardboard model

Fig. 3.30: Creating a cardboard model

Fig. 3.31: Creating a cardboard model

Fig. 3.32: Building a prototype

Fig. 3.33: Building a prototype

Fig. 3.34: Testing

Each meeting concludes with a briefing, during which all student mentors report on the progress of activities and challenges encountered in individual groups. Students form a circle, present, listen without interruption, express their ideas, and provide advice, fostering an atmosphere of mutual enrichment and discussion. Teachers facilitate the discussion and guide the resolution of any issues.

Intensive periods, during the implementation activities, may involve 3-5 consecutive days of intensified activities and hands-on physics workshops guided in person by MIT experts (teachers, students, alumni) (Fig. 3.36, 3.36, 3.37) and students from the Department of Physics at UniFe-INFN.

Competences involved: 1. Literacy competence – 2. Multilingual competence – 3. Mathematical competence and competence in science, technology, engineering – 4. Digital competence – 5. Personal, social, and learning-to-learn competence – 6. Citizenship competence - 8. Cultural awareness and expression competence

Fig. 3.35: Intensive period with MIT staff

Fig. 3.36: Intensive period with MIT and Unife staff

Fig. 3.37: Intensive period with MIT and Unife staff

E) **Sharing**. The following activities are usually planned: a) Open day at Liceo "A. Roiti" for the community to introduce the undertaken path and showcase the skills acquired by students. It can be scheduled at the end of the intensive period or at another time during the school year. b) Training meeting for schoolteachers, entirely managed by students, to present the projects and new approaches to STEM disciplines. c) Workshop with students from lower secondary schools in the area. d) Participation in national and international events (remote or in person). (Fig. 3.38, 3.39, 3.40).

<u>*Competences involved*</u>: 1. Literacy competence - 2. Multilingual competence – 3. Mathematical competence and competence in science, technology, engineering – 4. Digital competence – 5. Personal, social and learning to learn competence - 6. Citizenship competence – 7. Entrepreneurship competence – 8. Cultural awareness and expression competence

Fig. 3.38: Science on Stage Europe, 2022

Fig.3.39: International Maker Faire, Rome 2023

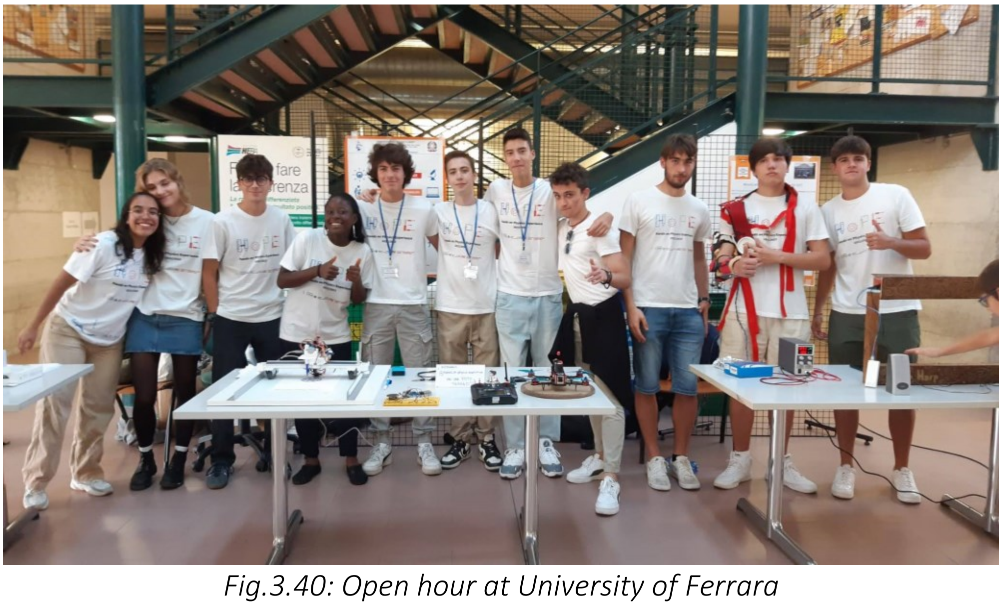


Fig.3.40: Open hour at University of Ferrara

G) **Summer School.** Training Students, on a voluntary basis, participate in laboratory activities proposed by the school (Fig.3.41) or the workshops EDW (Engineering Design Workshop) (MIT Edgerton Center, 2023) offered by the Edgerton Center-MIT (Fig.3.42) to students from different backgrounds. This experience represents an opportunity for training and interaction with peers from other countries. The activities can be carried out at their own school with remote support from MIT experts or, when possible, at MIT itself.

Fig.3.41: Summer school at "A. Roiti" High School

Fig.3.42: Summer school at MIT

<u>Competences involved:</u> 1. Literacy competence - 2. Multilingual competence – 3. Mathematical competence and competence in science, technology, engineering – 4. Digital competence – 5. Personal, social and learning to learn competence - 6. Citizenship competence – 8. Cultural awareness and expression competence

3.7 Evaluation

HoPE is a project within the framework of PCTO (Paths for Transversal Skills and Orientation) and, as mandated by the law (Ministry of Education & PCTO), it aims to promote the development of transversal skills and career guidance. For this reason, an assessment rubric for skills has been developed (Tab.3.3). Student mentors actively participate in the evaluation process alongside teachers. Periodically or at the end of each school year, teachers assess the mentors using the evaluation grid in Tab3.3…, while mentors are tasked with completing an evaluation sheet for each student in their group, assessing the degree of achievement of the expected competences. The evaluation sheets are then reviewed by teachers and may be discussed further with mentors or other team members. The assessment rubric (Tab.3.3 undergoes constant review and improvement).

TRANSVERSAL SKILLS PATHS AND GUIDANCE

CARD FOR THE EVALUATION OF TRANSVERSAL COMPETENCES WITHIN THE PROJECT " Hope WITH M.I.T."

STUDENT: ……………………………………… CLASS: ……….. School year ……………….

		LEVEL				
	COMPETENCE (Recommendation EU, 2018)	**ADVANCED (A)**	**INTERMEDIATE (B)**	**BASIC (C)**	**TO BE IMPROVED (D)**	**ASSESSMENT**
COLLABORATION	**STEM** **PERSONAL and SOCIAL** **CITIZENSHIP** **ENTREPRENEURSHIP** **AWARENESS**	Collaborate effectively and constructively, demonstrating interest and curiosity for the task assigned.	Respect your role within the group and provide input.	Do what is required, sometimes make their own contribution.	Have difficulty collaborating within the group and rarely contributes.	
INTERACTION	**MULTILINGUISTIC** **STEM** **PERSONAL and SOCIAL** **CITIZENSHIP** **ENTREPRENEURSHIP** **AWARENESS**	Interact respecting diversity and understanding the needs of the other within the group.	Listen and respect the opinion of the other or the group.	Play their role but rarely listen to the group.	Tend to act alone, without respecting the opinion of the group.	
COMUNICATION	**LITERACY** **MULTILINGUISTIC** **STEM** **DIGITAL** **PERSONAL and SOCIAL** **CITIZENSHIP** **ENTREPRENEURSHIP** **AWARENESS**	Use technical and linguistic knowledge to communicate with a correct and appropriate specific language.	Communicate using a specific language but not always appropriate for the context.	Communicate without using a specific language.	Comunicate improperly.	

		LEVEL				
	COMPETENCE (Recommendation EU, 2018)	ADVANCED (A)	INTERMEDIATE (B)	BASIC (C)	TO BE IMPROVED (D)	ASSESSMENT
CARRYING OUT THE TASK	PERSONAL and SOCIAL ENTREPRENEURSHIP	Respect schedules and deliveries to better perform task.	Respect the task with reasonable motivation.	Respects the tasks but demonstrate slow personal motivation or conviction	Does not always follow instructions	
READINESS FOR INTERACTION WITH OTHERS AND RESPECT	MULTILINGUISTIC PERSONAL and SOCIAL CITIZENSHIP AWARENESS	Work with great and constant availability and openness to a critical and constructive dialogue.	Work with a fair willingness to constructive dialogue.	Not always available for comparison but is able to respect different points of view.	Not always available for comparison and respectful of different points of view.	
COMPLEXITY MANAGEMENT	PERSONAL and SOCIAL DIGITAL ENTREPRENEURSHIP	Manage problem situations independently, critically reflect, make decisions and identify solutions.	Manage problematic situations with discrete autonomy, identifying possible solutions.	Manage problematic situations with the support of others.	Struggle to handle even simple problematic situations	
SHARING	MULTILINGUISTIC PERSONAL and SOCIAL CITIZENSHIP ENTREPRENEURSHIP AWARENESS	Always and enthusiastically make available to the group their skills and knowledge to carry out the task in the best possible way.	Usually put their skills and knowledge at the disposal of the group to carry out the task in the best possible way.	Makes their skills and knowledge available to the group only when solicited.	Struggle to contribute their knowledge and skills to the group.	

		LEVEL				
	COMPETENCE (Recommendation EU, 2018)	**ADVANCED** **(A)**	**INTERMEDIATE** **(B)**	**BASIC** **(C)**	**TO BE IMPROVED** **(D)**	**ASSESSMENT**
USE OF SOURCES	**LITERACY** **MULTILINGUISTIC** **STEM** **DIGITAL** **PERSONAL and SOCIAL**	Research and use different sources of information and study, and effectively re-process them to make appropriate use of them	Search for and independently use information sources.	If driven, search and use sources and information.	Not able to search for and use adequate sources and information.	

Tab. 3.3: Assessment rubric for skills

3.8 Results

3.8.1 STEAM Learning.

The STEAM devices produced by students encompass areas such as assistive technology, music, robotics, and other applications of physics, mathematics, electronics, and information technology. These projects and the results of the process implemented for their realization testify to how learning becomes more enjoyable and meaningful for students when it occurs through an integration of content, tools, and methods from Science, Technology, Engineering, Mathematics, and the expressive forms of Art, achieved through the use of student-centered and active learning methodologies (Ministry of Education, STEM Guidelines, 2023). Being able to engage in extracurricular STEAM activities, breaking down barriers related to the separation of individual disciplines, traditional school spaces and times experienced by students, taking responsibility for their learning path, and, above all, creating an open and inclusive learning community like HoPE often changes students' perception of their "school experience" even during regular school hours.

"*Before attending HoPE, I went to school 6 hours a day, studying tons of subjects without really caring, while now I'm happy to go to school because it feels like a second home and I'm always curious to learn new things*" (Eleonora S., 2020).

School is no longer perceived as a duty for students but as a source of pleasure because it allows them to express and recognize their potential. Increased self-confidence, linked to the achievement of complex goals that, in a collaborative manner, are more manageable than in an individual mode, translates into an increase in motivation for study even during curriculum hours.

"*When I first started this project, I was a typical insecure and shy girl who used to stay in her comfort zone in the shade of everyone else, scared of everything and living with anxiety. At the time, I was really far away from the STEM field, and I was scared also of it, so I don't really know what kind of weird force pushed me to apply for this project, but I can assure you that that choice was the best one I could ever make. In these three past years where I worked in this project, I had an incredible personal growth, starting from believing in myself and in my ability to learning difficult concepts of physics*" (Eleonora, 2020).

"*Too many times physics is considered as a difficult and merely theoretical subject that people have to study at school, there is much more about it! We wanted to show the beauty and the fun that physics can produce*" (Penelope, 2020).

Student testimonials highlight how this approach allows them to learn STEM subjects while having fun. The results of a recent survey titled "How do you feel during HoPE meetings?" produced the following outcome (Fig. 3.43), indicating the level of well-being students experience in conducting these activities.

Fig. 3.43: Survey Result: 'How do you feel during HoPE meetings?

3.8.2. Knowledge, Skills, and the 4Cs.

The educational action carried out through HoPE enables the development of knowledge, skills, and competences suggested by the Council of the European Union so that each individual can "fully participate in society and successfully manage transitions in the labor market" (EU, 2018). The STEM Guidelines (Ministry of Education, STEM Guidelines, 2023) also state that the integrated approach of STEM disciplines, as in HoPE, enhances more complex competences, such as those indicated by the term "4Cs" (*Fig. 3.44*):

- Collaboration (ability to)
- Creativity (creative thinking)
- Communication
- Critical thinking

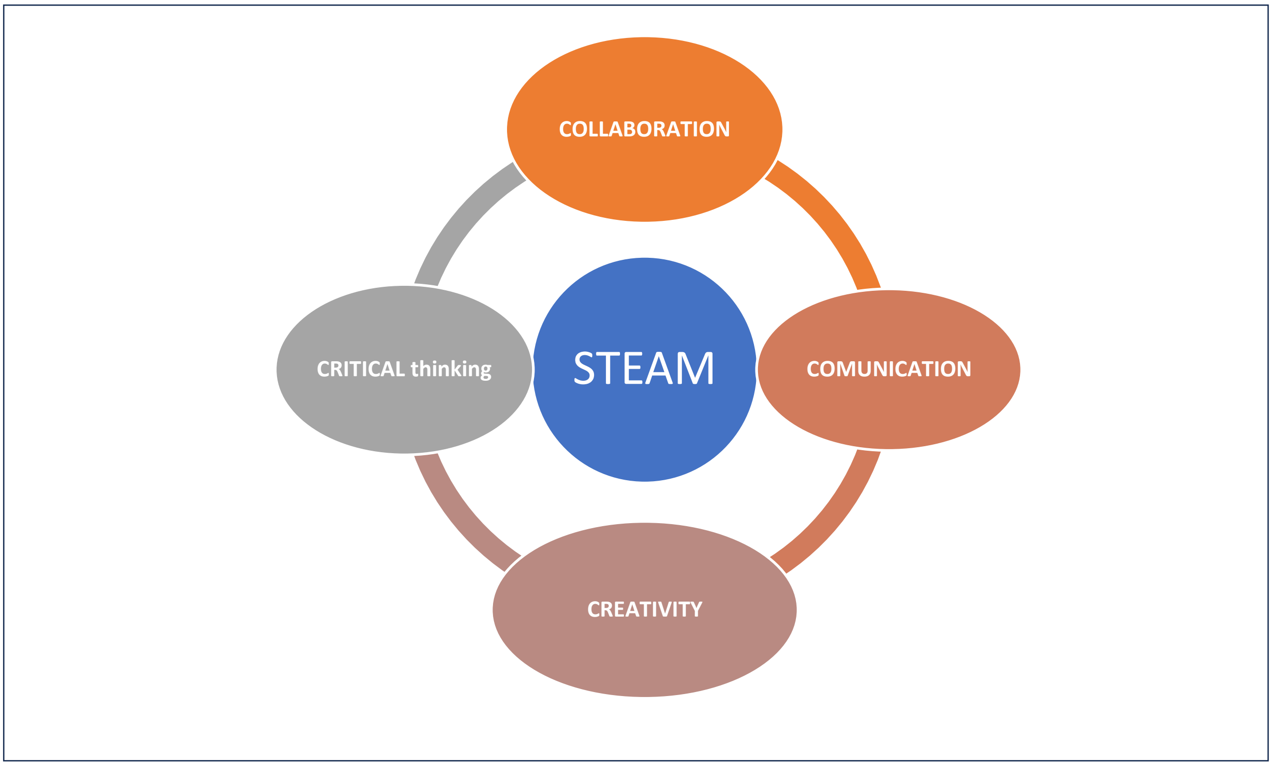


Fig.3.44: The 4Cs of learning enhanced through the integrated STEM approach

Below are some feedback excerpts provided by students during an anonymous survey titled: "Your feelings about HoPE". (Fig. 3.45, 3.46)

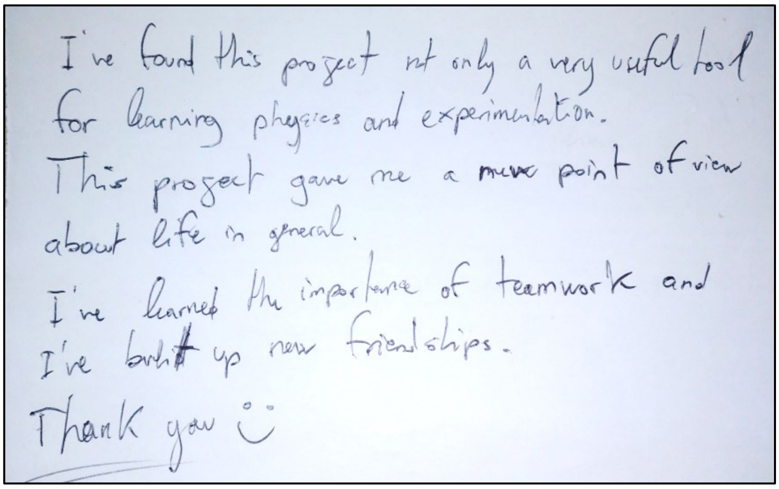
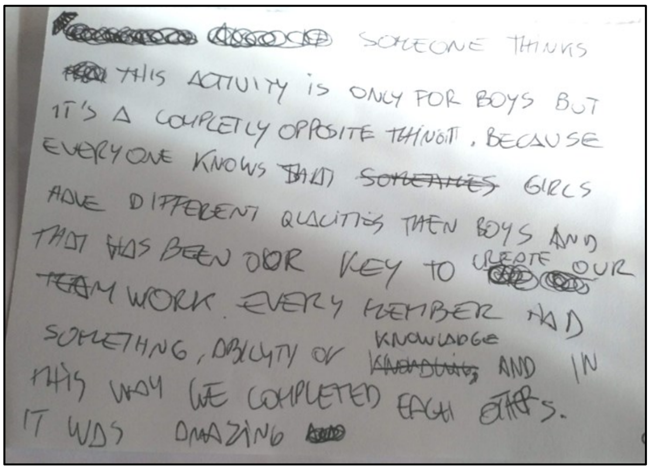

I've found this project not only a very useful tool for learning physics and experimentation.
This project gave me a new point of view about life in general.
I've learned the importance of teamwork and I've built up new friendships.
Thank you :)

Fig. 3.45: Anonymous feedback

"I've found this project not only a very useful tool for learning Physics and experimentation. This project gave me a new point of view about life in general. I've learned the importance of teamwork and I've built new friendships. Thank you"



"Someone thinks this activity is only for boys but it's a completely opposite thing. Because everyone knows that girls have different qualities than boys and that has been our key to create our teamwork. Every member had something, ability or knowledge and in this way, we completed each other's. It was amazing."

Fig. 3.46: Anonymous feedback

3.8.3 Inclusion and Gender Gap

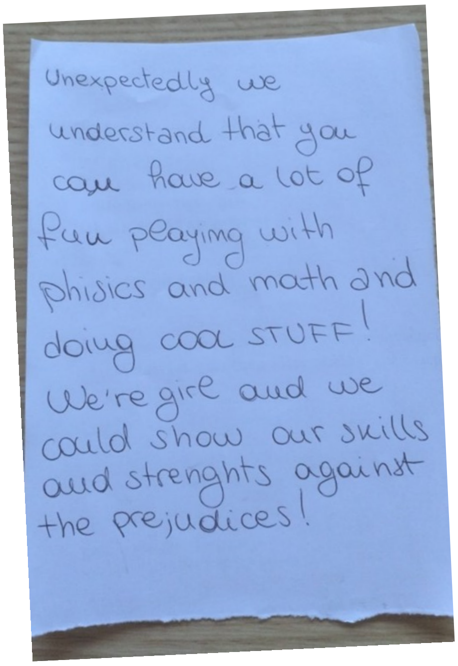
There has been a significant increase in the participation of individuals of genders other than male in recent years, initially being the most represented gender in HoPE. In the 2020/21 academic year, for the first time, and subsequently during the current academic year, the female gender has even surpassed the male representation (Tab. 3.4). In recent years, there has also been an increase in LGBTQ+ participants or first and second-generation immigrants. All of this represents a major success for a program in the STEM field, demonstrating the consolidation of an open and inclusive learning community.

SCHOOL YEAR	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Percentage of female participants in the Hope programme	14% (4 / 28)	33% (18 / 54)	34,4% (21 / 61)	**51%** (37 / 72)	42% (31 / 73)	48% (37 / 77)	**57%** (34/60)

Tab. 3.4: Percentage of female participants

The increase in the percentage of female participants has also been accompanied by an awareness of their potential in the STEM field, leading to an increase in their self-esteem, as evidenced by the feedback from Clara and the anonymous response in Fig. 3.47.

"I want to underline how this project helped me stand for my opinion and my rights, as a person and as a woman, giving me the strength to believe in myself and to get back on my feet every time I fell." (Clara)



*"Unexpectedly we understand that you can have a lot of fun playing with physics and math and doing COOL STUFF!
We're girl and we could show our skills and strengths against the prejudices!" (Anonymous feedback)*

Fig. 3.47: Having fun playing with Physics and showing skills again prejudices

3.8.4 Guidance

The opportunity to explore personal curiosities and passions through hands-on activities and the creation of self-conceived projects (learning by doing) allows students to discover their inclinations and encourages further studies in STEM fields (Fig. 3.47). Continuous and direct interaction with students and experts from the University of Ferrara (Unife), the National Institute of Nuclear Physics (INFN), and the Massachusetts Institute of Technology (MIT) makes high school students' active participants in university life, promoting a better self-awareness regarding areas of interest related to future studies.

3.9 Start-up Challenges of the HoPE Program and their Solutions

HoPE began in January 2018. At that time, the program's extensive scope over the years was not yet foreseen. The format and all requirements for its sustainability were neither prepared nor fully planned. Numerous difficulties were thus faced from the outset.

The first issue encountered was the extremely low percentage of women who had joined the program in the first year (Table 3.4). Where did this gap stem from? Perhaps the problem arose from having the Physics teacher select only one student per class? Maybe it was because female students are unlikely to join STEM programs they're unfamiliar with, especially without classmates? During this time, it was observed that even during public events, the few participating women tended to stay on the sidelines without voicing their opinions. The following school year, it was decided to open up registrations to a larger number of students who could join voluntarily. The number of female students increased year by year. Perhaps the example set by the participating girls, with their increasingly confident voices, highlighted their calmness and passion for what they were doing. Finally, the outreach events implemented over the years helped instill more confidence in new female students, resulting in a growing percentage of female participants surpassing that of males.

Another issue encountered in 2018 was the lack of a specific venue to carry out project construction activities. A careful inspection of the school revealed that the landings outside the classrooms on each floor of the school were large enough to become excellent spaces for collaborative activities, especially outside of regular school hours. These spaces were utilized until March 2020 when pandemic period started.

From the outset, the importance of sharing the journey with local stakeholders was understood. Their support was invaluable in spreading the experience through organizing local events, participating in national and international events, strengthening ties with prestigious American university such as MIT, and engaging in discussions aimed at resolving daily challenges.

Since HoPE was conducted within a public school, the project had to address the needs arising from the lack of specifically available funds. The school has always sought not to charge students any fees for participating in the project. For this reason:

- Thanks to a regional grant initially and a national one later, a laboratory was set up to conduct HoPE activities. This environment was more akin to a maker space than a traditional Italian physics laboratory. Over the years, 3D printers, a laser cutter, drill presses, screwdrivers, and tools for working with wood, plastic, and metal were purchased.

- Teachers and families of students offered to host American experts in their homes during their visits (intensive periods of HoPE). Similarly, accommodation has been found in recent years from acquaintances or at low cost for students who went to MIT during the summer.

The COVID-19 pandemic brought about the resolution of various challenges.

During the lockdown period, with schools closed and students at home connected only through video calls, it was realized that HoPE could help maintain socialization among the students, albeit remotely. This opportunity was not wasted. Forced to suspend projects being carried out at school, a new brainstorming session was held, asking students about their current desires. This led to courses in electronics, photography, video, and music editing. In collaboration with a music school, students recorded numerous voices over a common musical base, which were then edited together to become a choir. A video made entirely by the students was paired with the song to celebrate the end of the lockdown.

The return to school during the pandemic necessitated the implementation of additional safety measures, such as limiting the number of contacts. From the landings, individual groups (maximum 5-6 students each) moved into the classrooms, each of which was sanitized by students before and after each activity, along with all the tools used.

Finally, in the summers of 2020 and 2021, since no students could attend the MIT Engineering Design Workshop summer school, it took place outdoors and at school, connected remotely with experts and MIT students in various parts of the world due to the closure of the American university.

Now in its seventh edition, HoPE has not yet reached a format that ensures its sustainability. Each past year provides an opportunity for evaluation and revision aimed at improvement. Some aspects, especially, require support from institutions. This will also be discussed in Chapter 6.

3.10 Requirements for Implementations

From an organizational and logistical perspective, it is crucial, at the project's outset, to establish synergy between individuals and institutions. This involves verifying various elements and implementing specific strategies:

1. **Adequacy of Leadership Support:** It is fundamental to ensure that the school principal and the Director of Administrative Services are supportive and ready to provide the necessary backing for the project.
2. **Teachers and Technicians:** It is necessary to verify that the teachers and technical staff involved are genuinely motivated to experiment with active learning approaches within the project. Simultaneously, modes of managing teaching (and technical) staff should be evaluated to ensure the sustainability of the project through a suitable balance between curricular and extracurricular commitments.
3. **Training and Safety:** If the activity involves using equipment and/or laboratories, it becomes absolutely essential for teachers to participate in safety training in work environments, extending this training to students. It would also be desirable to provide teachers with training on the learning methodologies used in the project, possibly through connections with schools that have already experienced the program. It is also crucial for technical staff to have the necessary skills for using equipment more similar to a Makerspace (Vuorikari, Ferrari, & Punie, 2019) than a traditional high school laboratory.
4. **Student Participation:** Voluntary student participation, even outside regular school hours, can facilitate the project's success. The choice of the team to join should be self-determined by the student, although teachers should monitor that groups are balanced in terms of the number of participants, gender, age, and skills.
5. **Availability of Adequate Spaces:** It is important to ensure that there are spaces within the school that are available and/or adaptable to meet the project's needs.
6. **Guarantee of Financial Resources:** It is essential to ensure that there are adequate and guaranteed financial resources to support all stages of the project.
7. **Involvement of Entities, Institutions, Companies:** A crucial aspect for the future sustainability and implementation of the program in other schools lies in having adequate involvement and necessary support of national entities and institutions such as INFN and local universities, which are spread all over the country and can provide their support with experts to mentor students. It is also hoped that the Ministry of Education could support activities such as HoPE, which align with the STEM guidelines issued.
8. **Sharing:** Sharing activities with students' families and the internal and external community of the school, through the organization of events or via the school's website and/or its social media channels, is an additional element that contributes to reinforcing the sense of belonging to an active community. A careful evaluation and implementation of these points will contribute to creating the necessary solid foundations for the success and development of the project.

3.11 What's Next?

The results achieved through the adopted methodologies suggest the potential for spreading the experience format to other national and international schools, allowing other students to benefit from the same opportunities. This aligns with the Italian STEM guidelines (Ministry of Education, STEM Guidelines, 2023), European Union Recommendations (EU, 2018), and the American NGSS framework (NGSS, 2023).

The presence of a Scientific Technological Hub at the local university could provide a unique opportunity to establish dedicated Makerspaces for the guidance and training of high school students. These spaces could be designed as collaborative environments for project work, involving students from different types of schools, each with diverse backgrounds, training, and skills.

Finally, considering the significant impact on student education through sharing and empowerment, as well as providing training opportunities for younger individuals and community engagement, the school, if appropriately supported by external institutions and organizations, could establish an open scientific laboratory within its premises. This could follow the model of MIT's 4-409 laboratory (Fig. 3.48), which inspired the HoPE program. The "4-409" is a Makerspace for MIT students that the instructor Edward Moriarty opens every Saturday afternoon, also welcoming non-university students to work on STEAM projects, draw inspiration from existing projects, or simply experiment with available materials and equipment.

Fig. 3.48: The door of room 4-409 open to students

CHAPTER 4

A CASE STUDY: A MODEL OF HANDS-ON, COLLABORATIVE ACTIVE LEARNING OF PHYSICS WITHIN THE CURRICULAR ACTIVITIES IN HIGH SCHOOL

4. A CASE STUDY: A MODEL OF HANDS-ON, COLLABORATIVE ACTIVE LEARNING OF PHYSICS WITHIN THE CURRICULAR ACTIVITIES IN HIGH SCHOOL

“Cooperative teamwork is how practicing scientists work, so why not Science students?”
(Johnson R. T., 1986)

4.1 Transitioning to a new way of teaching

I started teaching in the spring of 1992. The pre-tenure years, waiting for a permanent position, were characterized, as for most of my colleagues, by continuous changes of schools and classes. I tried to live the uncertainty of those years as an opportunity for training, a laboratory in which to search and experiment with diverse teaching and learning methods suitable for different situations, students, and institutions, each with its own strengths and weaknesses. The permanent contract as a teacher in 2001 and the stability in the current service location in 2007 did not change my concern to maintain a channel of communication with a "wavelength" that was common to my interlocutors and that could adapt to the peculiarities of different generations. I realized how useless and often harmful to the relationship and teaching action it was to try to constantly maintain the same teaching model with students who were increasingly diverse from me in terms of age, rhythms and lifestyles, family educational systems, interests, opportunities, and demands of the surrounding world.

I carried out various teaching experiments within my curricular Physics classes. All had the common goal of developing curiosity and passions, increasing motivation and participation, interaction between teacher and students, inclusion of everyone with their characteristics and skills, student empowerment in their own learning process, and, why not, more fun and engaging learning.

The Physics laboratory has always fascinated me and has consistently been a fundamental part of the learning-teaching process in my teaching. I have always enjoyed creating simple tools with makeshift materials to help understand, whenever possible, different physical concepts.

In 2015, I had the opportunity to attend an international training course, “The Science and Engineering Program for Teachers” (SEPT) (MIT SEPT, 2023), at the Massachusetts Institute of Technology. This experience made me reflect. I experienced firsthand how physics becomes more engaging when it comes out not only from textbooks but also from the traditional laboratory. It is possible to study it through a correct integration and support of all STEM disciplines, investigating the physical phenomenon by:

- contextualizing and observing it in the surrounding reality
- asking questions and seeking answers through a conscious use of technology

- using creativity and even the language of art to design, build, and then test tools suitable for describing, understanding, and modeling the physical phenomenon, translating it into the universal language of mathematics.

I then began not only to provide experiments already "ready to use" but also to ask students to propose and build their own tools with simple and inexpensive material, even of their own invention, and that would make, when possible, the physical phenomenon under study "visible and real," allowing them to "touch it". The activity was carried out by working in teams of no more than four people, heterogeneous in gender and abilities, formed based on the common interest in the idea to be developed. Students were invited to observe, ask questions, discuss, reflect, understand, and learn through their product, but above all through the process that had led them to its final realization (researching, planning, building, testing, reflecting). I immediately observed the favorable effects of *learning by doing*, including an increase in confidence in their ability to achieve positive results and understand physical phenomena. This newfound self-esteem was the driving force for a more active and proactive participation even in moments of formalizing the topics, as well as for more autonomous and motivated study.

At the beginning, I proposed to students to try to build something of their interest in groups, understand the physics behind its operation, and explain it to the class. The students worked outside school hours, based on some schematics sent by an adult reference (Fig. 4.1), but above all by trying, retrying, testing, understanding, improving. The first important *hands-on* project was born: a wind tunnel prototype built by students independently (Fig. 4.2) before addressing fluid dynamics with the teacher (https://www.youtube.com/watch?v=CcqayRJphrw) but used later by the students involved to introduce the topic to their classmates (https://www.youtube.com/watch?v=BOvnqlUGDB8) (Fig. 4.3).

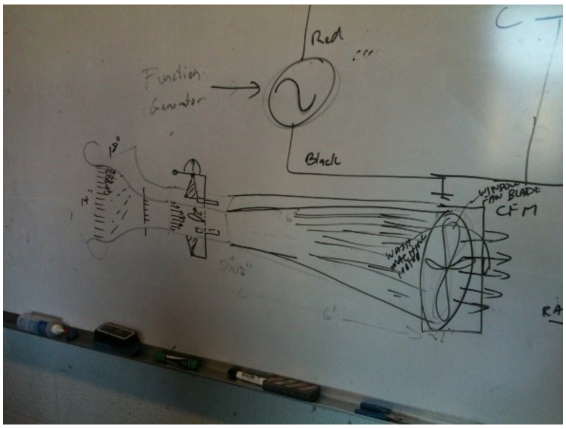


Fig. 4.1: The wind tunnel sketch


Fig. 4.2: The first prototype of wind tunnel

Figure 4.3: Students who made the wind tunnel use it to explain fluid dynamics to their classmates

The lockdown period during the 2019/20 school year led me to further research curricular methodologies different from the ordinary unidirectional transmission, which, in my opinion, is not effective through a computer screen, especially if left as the sole form of teaching and learning (Strubbe & McKagan, 2020) . The situation also required special attention to the affective-relational sphere of students, isolated first in their homes and then kept away from the place of constructing their knowledge and communities, such as school and all places of informal and non-formal education.

During periods of Distance Learning (DAD), the biggest challenge was to not let the motivation for the study of Physics wane but, on the contrary, to use it to maintain relationships with and among students. Collaborative laboratory teaching for small groups became an opportunity to come together (whether remotely or in person) and reconnect, having fun and learning even outside the school walls, as testified by the students themselves:

A) The fact that I could conceive a project, an idea together with other FRIENDS, in a period when you are mostly alone or with your own family ... helped and stimulated me. ... It was a continuous debate and comparison of ideas, criticisms, and additions, which allowed us to create a product that had a part of each of us, without judgments or a desire to prevail over each other. I believe I found the perfect group to have fun, be stimulated, and stay focused at the same time, and this gave me a moment of satisfaction in a moment of chaos and discouragement. (A.F.S., IV Scientific High School)

B) Certainly, working with peers and friends towards a common goal pushes you to give more because, in addition to the responsibility for your result, you also have a responsibility for the overall work of others, and it is important to give your best. In this period, finding optimal concentration is becoming increasingly difficult, and working in a group certainly gives you the right stimulus to do a good job. (R.M., IV Scientific High School)

C) Both this year's project and last year's have helped me a lot in finding moments of socialization with my classmates ... doing something different and more engaging, helping to overcome the difficulties of the lockdown period. (A.S., IV Scientific High School)

Physics projects were also used during the lockdown period to try to overcome the anxiety of the moment through humor, as seen in this video on the launch of a hand sanitizer: https://youtu.be/CPWdin8XnVg .

The educational experimentation I have conducted over the years has been guided by my experience, observation, reflection, and personal intuition as a teacher, but it also reflects what has been quantitatively studied in similar contexts. Research conducted has indeed demonstrated the importance of involving sensorimotor brain systems to enhance students' understanding of scientific concepts. The results have shown not only a significant improvement in test scores in the short term but also an increased ease of reasoning about learned concepts associated with the activation of involved sensorimotor brain areas (Kontra, Lyons, Fischer, & Beiloc, Physical Experience Enhances Science Learning, 2015). This mechanism highlights the importance of laboratory practice becoming an integral part of the learning process.

Additionally, research on collaborative learning within peer learning contexts have also demonstrated, in addition to improved academic performance (Johnson R. T., 1986), a positive change in students' attitudes and beliefs towards physics and its learning, particularly regarding the female gender (Mazur, Zhang, & Ding, 2017).

Continuous comparison with the Massachusetts Institute of Technology has allowed me to reflect on and adapt to Italian high school classes what was concurrently done in some Physics 1 and 2 courses (Classical Mechanics (8.01) and Electricity and Magnetism (8.02)) at MIT. The following sections present the context, motivations, methodologies, and evaluation of the experience at the "A. Ròiti" High School in Ferrara.

4.2 Context

The "A. Ròiti" Scientific High School in Ferrara is a STEM oriented secondary school that currently has approximately 1600 students. Established in 1923, the institute has consistently adapted its educational offerings over the years, responding to the changing needs of society and students. Its ongoing commitment has been to provide students with a solid education, primarily focused on preparing them for success in higher education.

When I began the educational experimentation in my Physics course, the school was divided into three main pathways (Fig. 4.4): the Scientific High School with Standard curriculum (with Latin course), the Scientific High School of Applied Sciences (with a focus on IT and more Science), and the Scientific High School with a Sports Orientation (with a focus on Law and Economics). They all contain the same core curriculum (Italian, Math, Physics, Science, Foreign Language, Physical Education).

The described experimentation took place starting from the academic year 2019/20 within my third, fourth, and fifth-grade classes in the Standard curriculum pathway.

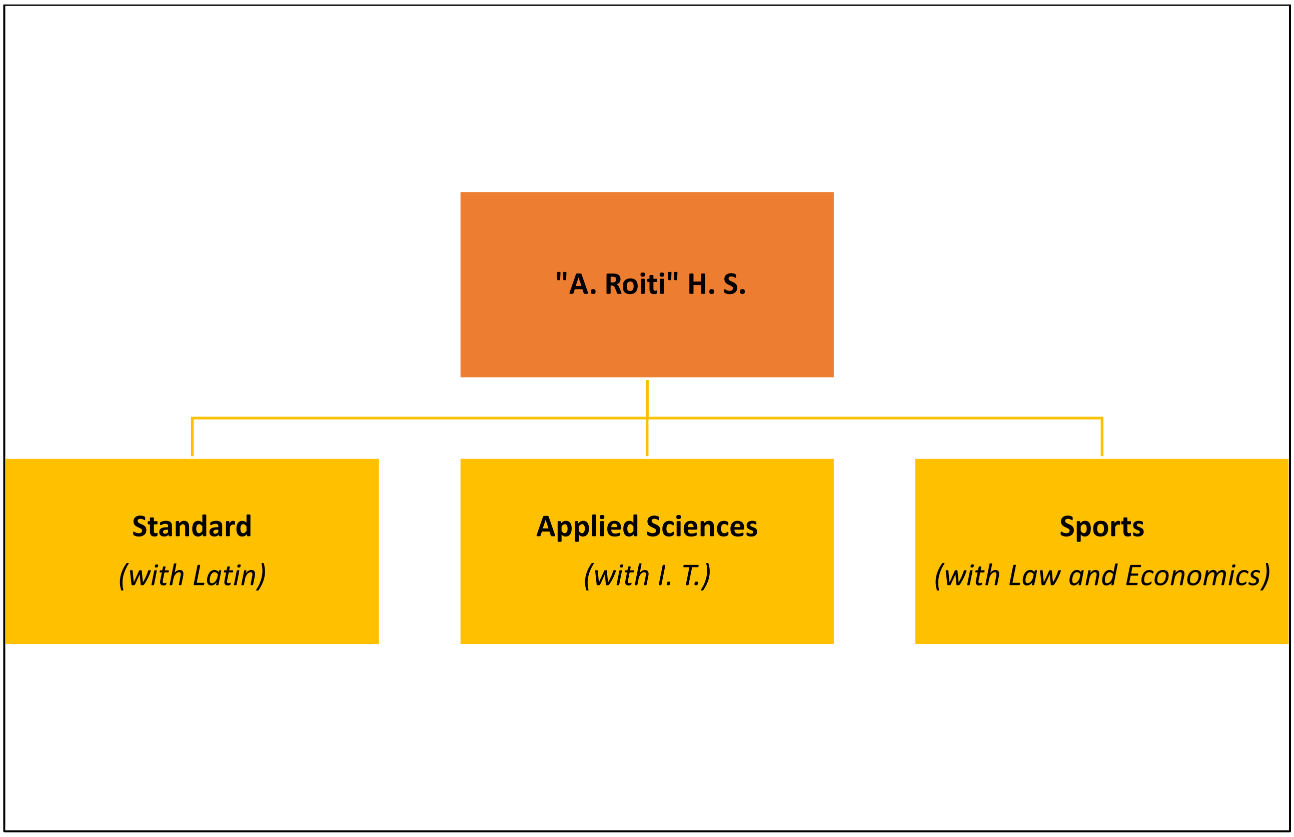


Fig. 4.4: Academic pathways at the "A. Ròiti" Scientific High School

4.3 Overall Objectives and Specific Goals

The implemented learning method actively involves students collaboratively, aiming to:

- Make learning more engaging, concrete, and meaningful.
- Promote a deep understanding of physical concepts through identifying their applications, conducting direct experiences, and building motivating projects of personal interest.
- Encourage communication, collaboration, and peer learning.
- Foster an approach where theory and practice integrate, making the educational action more comprehensive and profound.
- Incentivize creativity by encouraging students to develop original and innovative solutions.
- Develop practical, social, and cognitive skills such as experimental and technical abilities, problem-solving, collaboration, communication, and critical thinking, as well as all eight key competences for lifelong learning recommended by the European Union (EU, 2018).

As outlined in the National Guidelines (MIUR, DM n. 211 , 2010) for Scientific High Schools:

- The teaching activity aims to "*formulate and solve more challenging problems, also drawn from everyday experience, emphasizing the quantitative and predictive nature of physical laws*".
- "*Experimental activity will allow the student to discuss and build concepts, design and conduct observations and measurements, compare experiments and theories*" (DECREE of October 7, 2010, no. 211, attachment F) (MIUR, DM n. 211 , 2010).

4.4 Description of Organizational Methods and Motivations for the Path

The learning of physics in secondary schools, particularly in the Scientific High Schools where the experimentation is taking place, is based on achieving the competences and specific objectives of the discipline, as indicated in the "National Guidelines for Scientific High Schools" (DECREE of October 7, 2010, no. 211, attachment F) (MIUR, DM n. 211 , 2010).

The need to respond to these guidelines led to experimenting with new learning methods, providing students with a more motivating learning opportunity that is not solely based on the transmission of concepts by the teacher and the solving of prepackaged exercises, mostly detached from real-world problems.

Students are actively involved, collaboratively with their peers, in their learning process through practical activities such as observation, identification of phenomena in real contexts, their modeling, and the construction of STEAM projects aimed at reproducing, studying, and verifying the studied physical phenomenon.

The study of most concepts, especially in Mechanics and Electromagnetism, is approached by enhancing innovative laboratory activities alongside more "traditional" teaching methods.

Students are asked to propose their idea for creating a product that allows the direct observation, understanding, and/or in-depth study of the studied physical phenomena. Ideas are discussed among students and teachers, selected according to negotiated criteria, and then realized through collaborative activities conducted during or outside of regular hours. The product can be directly built or created using digital tools and technology. The result of each group is shared with all the classmates through multimedia presentations. Each activity is observed and evaluated by the teacher, who acts more as a facilitator than the sole transmitter of knowledge.

Groups consist of a maximum of four students to facilitate interaction among individuals and the participation of each in activities. The heterogeneity of participants in terms of skills and gender is important for the success of the activity. The division of roles and responsibilities within the groups, negotiated among the students, is essential and aimed at empowering each team member. This way, "hiding" students are avoided, and interdependence is created, stimulating relationships among them, making it impossible for each student to achieve their goal without the contribution of all classmates (Johnson & Johnson, 2013). At the same time, the team's result is not achieved without the active contribution of each: student A cannot build the project if student B has not researched the theoretical foundations; C cannot create multimedia materials without being aware of what students A and B have done and without interacting with them; the documentation and multimedia presentation of the product require the collaboration and participation of all.

Decisions are made, at various moments, through discussions among students, with constant encouragement of participation by the teacher and/or classmates.

This learning/teaching method has been carried out even during the pandemic emergency, in Distance Learning (DAD).

Section 4.10 is dedicated to the materials of some of the projects that students completed. In section 4.9, one of them is analyzed in more depth.

4.5 Working Methodologies

The teaching methodologies used are all aimed at fostering the active involvement of students in their own learning process (*active learning*). The construction of knowledge becomes more exciting and meaningful for students, allowing a deep understanding of concepts.

In particular, the following methodologies are favored:

- *Collaborative learning* and *peer education* : They promote collaboration among students and teamwork, encourage active discussion, the sharing of knowledge and skills among students to explore each other's perspectives, enrich individual understanding of concepts, and build knowledge through dialogue. They also develop social skills such as effective communication, respect for others, and collaboration.
- *Hands-on learning*, *learning by doing*, and *project-based learning*: These methodologies offer students the opportunity to integrate theory with practical application, allowing for a deeper understanding of abstract concepts. Students are encouraged to manipulate materials concretely through the practical experience of ideation, design, realization, and implementation of objects aimed at making physical phenomena observable, modellable, and more easily understandable, or at developing original and innovative solutions for concrete physical problems. This method contributes to developing students' *problem-solving*, *critical* and *creative thinking* skills, as well as experimental, mathematical, technical skills, and *computational thinking*.

4.6 Activity Description

The described activity is repeated at various times during the academic year whenever the physics topic introduced can be approached through hands-on activities or the methodologies described in the previous section.

The activity consists of distinct and interconnected moments, as outlined below.

1) **Presentation of the activity:** During this meeting, the following aspects are described and discussed ("Final Physics Project",Handout Fig. 4.5):
   a) The object and execution methods of the activity.
   b) The learning objectives of the activity and evaluation criteria.
   c) The timeline.
   d) Work and collaboration methods.
   e) Ethical conduct in comparing others' work.
   f) Modes of presenting the completed work

FINAL PHYSICS PROJECT - 2019/2020

FOREWORD: ***Recently, a Physics teacher from MIT introduced me to a project that she proposed to her students, who are roughly your age. I really liked it, and I thought it would be nice to present it to you! It's only slightly adapted from the original proposal. Some deadlines may differ by a few days due to different schedules and holidays. The students of the MIT teacher have, of course, now returned to their homes and will be working on the project during the same period as you. It would be great if we could somehow connect with them during the work. So, enjoy your work and have fun!***

WHAT?

You are asked to **develop activities** (one or more) related to everything you have learned this year. These activities should be something **fun** and **surprising** that anyone can do with what they have at home: the activity must

- be presented in a way to be **engaging** (it should, therefore, evoke the thought in those who will see it later, 'That's cool!... I'd like to try this activity too!')
- be **fun**.

The project can be inspired by existing 'materials', but each student must add their own personal contribution to them.

YOU CAN:

- Carry out and describe (in-depth) a project of your own invention (EXPERIMENTAL PROJECT 1).

- Disassemble, interpret, and describe (in-depth), based on what you've learned, the functioning of any device you have at home (EXPERIMENTAL PROJECT 2).

- Recognize, interpret, and describe (in-depth) one or more physical phenomena in the domestic reality or within your current surroundings (EXPERIMENTAL PROJECT 3). Students should be able to produce materials (pptx, docx, videos, photos, concept maps, etc.) for different levels of comprehension (elementary school level, middle/high school level, university level), always aiming to generate interest and enjoyment.

You can work individually or preferably in a group (max 3/4). To address gender inequity, it's important for girls to learn to work with boys and for boys to learn to work with girls. Therefore, heterogeneous groups are strongly preferred even if not required.

LEARNING OBJECTIVES

Your project should allow you to improve and demonstrate:

- Your **mastery of the concepts** learned during this year's physics course.
- If you choose to work in a group: your **ability to work as a team** in the current situation (identifying roles, active and proactive participation, sharing ideas, mutual respect for others' ideas, ability to synthesize each person's proposals, mutual assistance in overcoming difficulties, etc.).
- In the case of **EXPERIMENTAL PROJECT 1**: your **ability to model, experiment, construct, and/or design** (the ability to connect theory to the observable world) and **document** what you have done.
- In the case of **EXPERIMENTAL PROJECT 2** or **3**: the ability to choose objects, research, interpret the functioning or application of the physical phenomenon, and document what you have found.
- Your **ability to communicate** to others what you have accomplished and the underlying physical phenomena.

TIMETABLE

- Brainstorming will commence on **Tuesday, April 7**.
- **Wednesday, April 15**: Presentation of the initial project ideas.
- Each student or team will write and sign a team contract by **Friday, April 17**, providing a brief project description and outlining the responsibilities within the group.
- The project prototype must be completed by **Thursday, April 30**.
- From **Friday, April 17**, until the conclusion of the project, daily check-ins for project updates will be conducted through the creation of a "logbook" on a shared file within the group. Each member will record their contributions to the work.
- Students will publish their materials (short videos, simulations, and documentation in PPT, PDF, or other formats) **by Tuesday, May 12**, and subsequently present their activities on Meet/Zoom (or in presence if possible).

WORKING METHODS AND COLLABORATION

Working with other members of the class is fundamental even if you choose to undertake an individual project. Every student in the class should be open to collaboration and offering assistance to fellow classmates when requested or if difficulties are identified. Each of you is required to maintain an individual 'logbook' and share it with the group

ETHICAL CONDUCT

Do not steal ideas or work from others. If you use ideas or materials (including photos, drawings, or videos) from somewhere (websites or other sources), you must identify it (provide a bibliography or other source references) and explain what modifications you have made. Additionally, ensure that the workload is evenly divided; otherwise, you are essentially taking credit for someone else's work, which is not ethical. In the case of experimental data, do not manipulate them to fit your expectations, even if they were unexpected. In this case, try to justify any sources of experimental error and propose improvements.

Fig 4.5: Example of a worksheet provided to students (March 2020)

A concise list of the most intriguing student projects, along with their accompanying documentation, can be found in section 4.11. Additionally, section 4.10 provides an in-depth description of one project: the mechanical paradox.

2) Brainstorming of ideas (in person during curriculum hours or through a shared digital board remotely), where students are encouraged to:
   a) Generate STEAM project ideas connected to the studied physics topics.
   b) Analyze physics topics related to the projects.
   c) Identify the reasons behind proposing individual projects.
   d) Discuss collectively the positive and negative aspects of each project's realization.
   e) Select projects through a shared, conscious vote based on shared criteria and the results of the previous points.
   f) Form working groups that will carry out the individual projects: students autonomously form groups based on their personal interest in the project to be undertaken; the teacher ensures that the groups are heterogeneous in terms of gender, skills, and personal characteristics (Fig. 4.6).

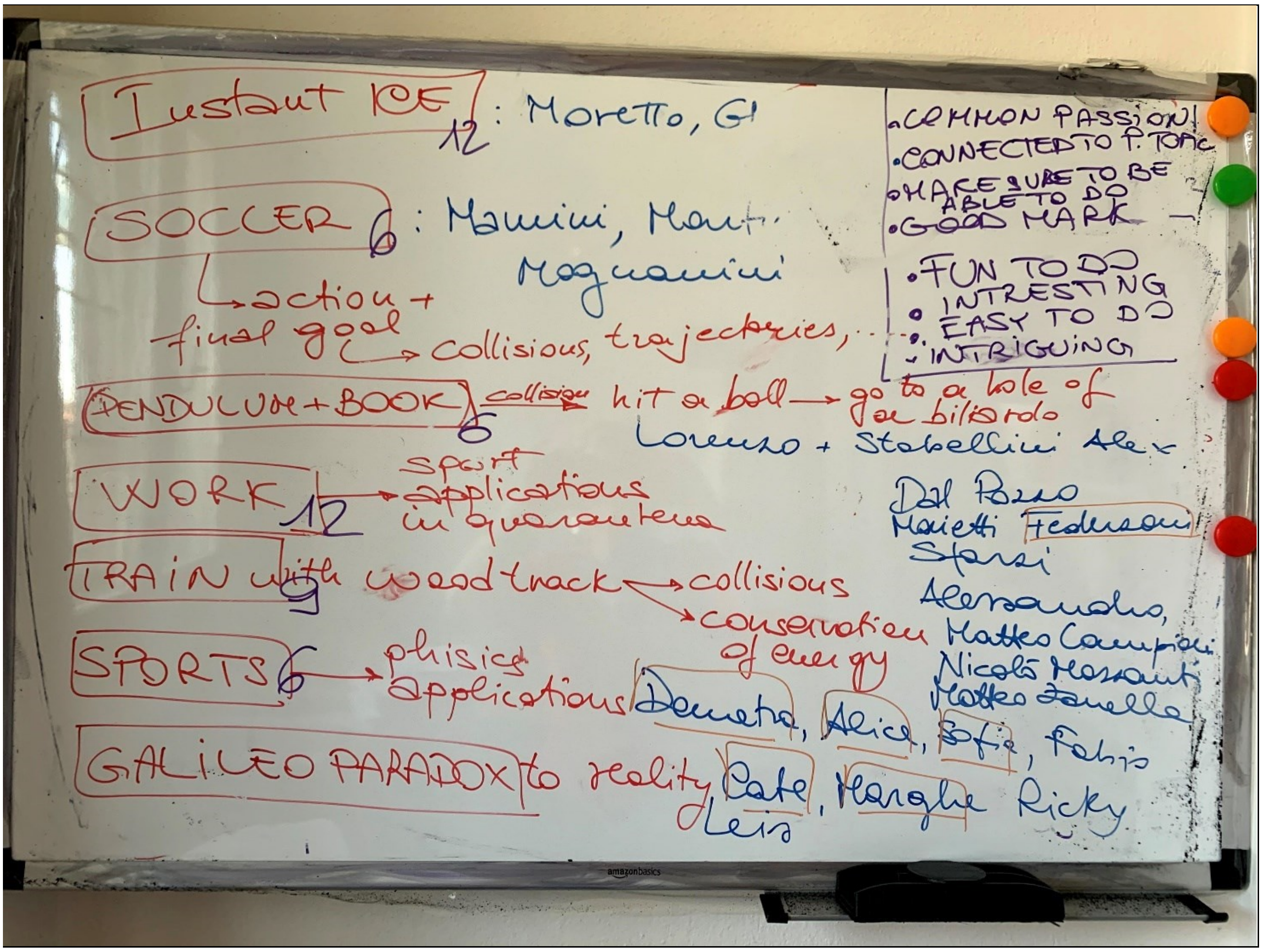


Fig. 4.6: Whiteboard for remote brainstorming and group formation (March 2020)

3) **Team Contract.** Students are required to explicitly state:
   a) A brief description of the chosen project and the motivations that led to the selection.
   b) The division of roles and responsibilities within the group.

4) **Research. Design.**
   a) Research, design, and realization of the prototype during school and/or at home.

5) **Create. Test. Understand.**
   a) Testing for correct functionality and potential improvements.
   b) Understanding and deepening of the physical phenomena related to the project, through error correction and the creation of the final product.

6) **Document:** Production of multimedia documentation material (preferably also in English).

7) **Present:** Presentation of the project to the class through:
   a) PowerPoint presentation (or other presentation software)
   b) Video, photos
   c) Concept maps
   c) Interactive tests administered to classmates to assess understanding.

8) **Feedback.** Collect feedback from classmates and the teacher.

9) **Reflection** on the work done and possible implementation.

The figure below (Fig. 4.7) schematically represents the sequence of activities.

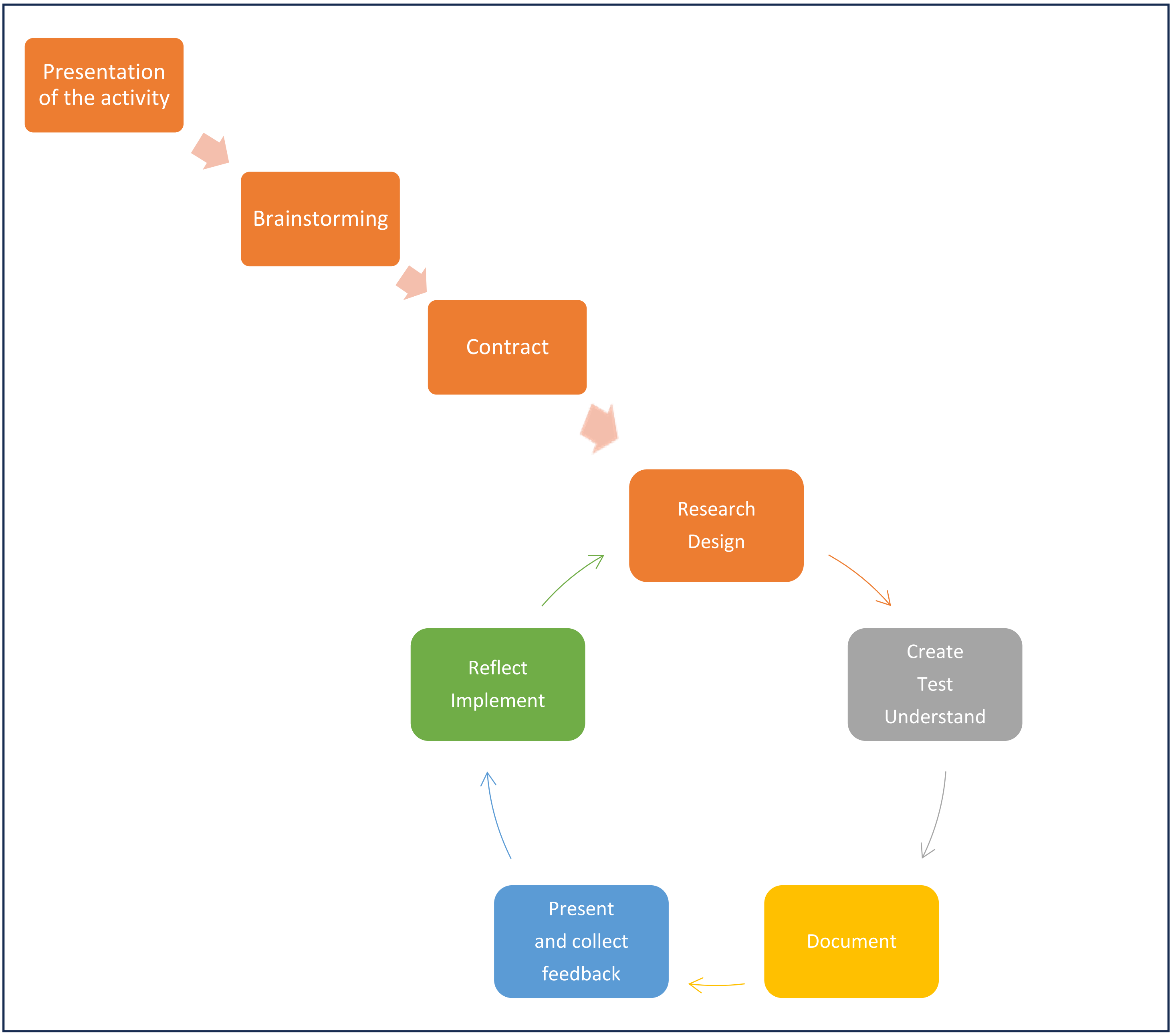


Fig. 4.7: Diagram of the activity phases

4.7 Assessment

The work is carried out collaboratively, but the assessment is individual and considers:

1. The degree of achievement of the learning objectives set and shared at the beginning of the activity (Fig. 4.5. Worksheet 'Final Physics Project')
2. The understanding and deepening of physics topics related to the project and the school program, demonstrated through responses to clarification questions from the teacher or classmates.
3. Information regarding the individual student's work deducible from the attached 'logbook.'

The **'logbook'** is an integral part of the activity and evaluation. It is a document shared by the group through Google Docs in the DRIVE folder. Each day, each student notes what they have done, any difficulties, and/or progress. Through writing, the student activates critical reflective and metareflective processes of their own experience. Sharing individual stories within the group, the class, and with the teacher leads to a process of collective and negotiated co-construction of knowledge (Szpunar, 2018). Each student is required to fill out their personal section of the document, but one team member is designated as the 'logbook manager' and ensures that it is consistently updated. The logbook also provides information about each student's active and proactive participation, collaborative ability, and the overall functioning of the team.

For the activity previously outlined (Fig.4.5 'Final Physics Project,' March 2020) and similar ones, the following **evaluation grid** was shared with students (Fig. 4.8):

• DESIGN: ability to model, experiment, construct, and/or design [10 points] 20%
• VIDEO: ability to document what was done, also in an original way; your ability to communicate [10 points] 20%
• PRESENTATION: your ability to communicate comprehensively and exhaustively, involving other students [10 points] 20%
• MASTERY OF LEARNED CONTENT: [10 points] 20%
• Evidence from the LOGBOOK: teamwork ability, active and collaborative participation, proactivity [7 points] 14%
• ADHERENCE TO DEADLINES: [3 points] 6%
• Additional credits for: presentations in English, Google Forms with questions for your classmates about the project and/or the presented content, ...other special personal ideas that make the presentation captivating and/or delve further into the studied physical phenomena.

Fig. 4.8: Example of an assessment grid

A draft example of the assessment rubric that I used is represented by the following table (Tab. 4.1).

Aspect to consider	Outstanding (5)	Very good (4)	Good (3)	Acceptable (2)	To be improved (1)	Comments
Mastery of the concepts	The candidate demonstrates a complete and in-depth understanding of the physical concepts underlying their project and can apply them in an appropriate and creative way.	…	…	…	The candidate shows a poor understanding of the physical concepts at the base of their project, struggling to interpret the physical phenomenon at the base of the functioning of the project.	
Teamwork skills	The candidate excels in teamwork, collaborates with team members, contributing proactively and positively to the success of the group.	….	….	….	The candidate demonstrates that they have worked only for their own benefit, without collaborating with team members and contributing proactively and positively to the success of the group.	
Ability to plan and design	The candidate demonstrates the ability to plan effectively, defining clear objectives, and implementing a detailed plan to achieve the desired result. They are able to organize their work and realize their product in an intentional, creative and efficient way.				The candidate struggles (fails) to plan effectively and to organize their work to make their product intentionally. They have difficulty in managing contingencies and evaluating	

	They are able to manage unexpected events and complexities,meeting targets and deadlines.				alternative solutions in case of difficulties. They cannot meet targets and deadlines.	
Ability to document	The candidate produces documentation clear, organized and complete, including a description of the phases, any problems encountered and their resolution, any diagrams and/ or tables. The documentation shall highlight the correct use of the sources and provide references to the relevant resources.				The candidate produces documentation unclear and incomplete: missing the description of the phases and/or problems encountered and their resolution, diagrams and/or tables are missing. The documentation shows incorrect use of sources.	
Ability to communicate	The candidate shall communicate in an understandable and effective manner with the public, demonstrating clarity in the exposure.It is able to involve the interlocutor, through their own project and an effective use of communication tools such as presentations, graphics, photos, videos.				The candidate communicates inaccurately and ineffectively with the audience. The exposure is confusing and not engaging to the interlocutor. It does not use the media effectively.	

Tab. 4.1: Assessment for skills

In the rubric presented in Table 4.1, a score from 1 to 5 is assigned for each indicator, where 1 represents an unsatisfactory performance with room for improvement, while 5 represents an exceptional performance. Specific comments can also be added for each indicator to provide detailed feedback to students participating in the project.

In the performance evaluation process, additional credits are usually assigned in the case of:

- Heterogeneous groups in terms of gender, aiming to encourage collaboration among individuals with diverse perspectives, thus promoting an inclusive and stimulating environment for all participants.
- Presentation of materials in both the native language (Italian) and English, thereby encouraging linguistic diversity and facilitating the sharing and understanding of the materials created by a wider audience.

4.8 Results

The *hands-on* activities, *learning by doing*, and *collaborative learning* among peers were occasionally introduced into the curriculum by me starting from the academic year 2017/18. However, the structure of the activity, as described in this chapter, has been experimented with in four class groups from the school year 2019/20 to the present. During the same period, I had the opportunity to teach in one or two classes each school year as I was on reduced hours for my doctorate. The research and experimentation are still ongoing, considering the new STEM Guidelines (Ministry of Education, STEM Guidelines, 2023) issued on October 24, 2023, by the Ministry of Education and Merit with Note prot. 4588 (Ministry of Education & STEM, Nota prot. 4588 del 24 ottobre 2023, 2023). The data that emerged from the study of a class group (G) consisting of 22 students where the activity was regularly conducted from the third to the fifth year (school years 2019/20, 20/21, 21/22) are as follows.

University Enrollment

Students of the reference group enrolled in the university for the academic year 2022/23, and 20 of them (90%) are still attending regularly. Of these, 10 students (50% of G) chose to enroll in STEM faculties, as shown in Tab.4.2. Two additional control classes using traditional physics teaching and learning during the same academic year yielded the results shown in Tab. 4.3.

Number of students in class	Enrolled at University	Enrolled in STEM disciplines
23	20	10 (50%)

Tab 4.2: Enrollment in STEM disciplines of the reference group

Number of students in class	Enrolled at University	Enrolled in STEM disciplines
26	24	7 (30%)
18	17	4 (23%)

Tab 4.3: Enrollment in STEM disciplines of two control groups

Achievement of Educational Goals
In all classes where the activity described with the mentioned active learning methods was used, the following could be highlighted in terms of achieving educational goals. The qualitative and quantitative results were gauged through systematic observation, assessment of curriculum outcomes, and analysis of student feedback collected via surveys.

The practical experiences realized through the independent and peer construction of chosen projects have promoted the development of practical and experimental skills, the connection between theory and application, the understanding of physical concepts through the direct observation of phenomena, their interpretation, and modeling through the correct use of mathematical language (Mathematical competence in science, technology, and engineering, (EU, 2018, p. 189/9)). Number of students in the class Enrolled in the university STEM faculty.

Students have developed skills such as *problem-solving, critical reflection, cooperation, creativity*, *imagination, computational thinking, and self-regulation,* skills strongly suggested by the European Community for the training of citizens capable of developing new ideas, theories, products, and knowledge, as required by our rapidly evolving society (EU, 2018, p. 189/2), Entrepreneurial competence (EU, 2018, p. 189/11).

Active engagement in the realization of projects useful for understanding physics has increased students' self-esteem and, with it, the motivation to learn and "succeed" even in more traditional activities, as foreseen in European Recommendations: "*Learning methodologies such as inquiry-based learning and projects, mixed, arts-based, and game-based learning, can increase motivation and commitment to learning*" (EU, 2018, p. 189/12). Through collaborative construction of projects and their knowledge, students have learned to reflect on themselves and their ways of learning, manage their time and information effectively, learn independently, and work with others constructively, remaining resilient even in moments of uncertainty and difficulty and learning from their mistakes (Personal, social and learning-to-learn competence, (EU, 2018, p. 189/10).

Peer dialogue and explanation of physical concepts, as well as research, documentation, and multimedia presentation of their product to classmates and the teacher, have improved students' digital skills and their ability to express physical concepts clearly and comprehensibly using images, graphs, and videos they created. Students have thus improved their communication skills as both presenters and listeners (Functional literacy competence (EU, 2018, p. 189/8), Digital competence (EU, 2018, p. 189/9).

Collaboration among students has improved the relationship between students. A positive learning environment has been created within each class where students felt freer to help each other and express themselves (Citizenship competence, (EU, 2018, p. 189/11). This facilitated educational dialogue and interaction with the teacher. The lesson became more participatory and interactive; questions prompted by the teacher during an explanation or problem-solving became an opportunity for constructive discussion without anyone being afraid to express their ideas or formulate hypotheses.

Finally, collaboration among students and the interdependence of the components of each group in the realization of their product has fostered relationships even at a distance between students and between them and the teacher, providing moments of fun through learning activities. This was particularly important in the emergency period, as emerges from the students' feedback. (Att. 4)

<u>*Student Feedback*</u>

At the end of the 2020/21 school year, after two years of active learning, even remotely due to the COVID emergency, a questionnaire was administered to the students of the reference class to understand their opinion on the implemented working method.

Below is the result of some survey questions in the following order:
A) Administered question.
B) Some of the most significant responses.
C) The elaboration of qualitative data deducible from all the responses to the posed question.
The complete survey (6 questions and, for each, 19 answers provided by the students present at school at the time of administration) is attached (Att. 4).

1A) *What, in your opinion, were the positive aspects of working on projects? What were the negative ones?*

1B) Positive aspects:

a) *Working on different projects allowed us to experience an alternative method of learning (more practical, less theoretical, and often more engaging). (A.P., IV Scientific High School)*
b) *Working in groups allowed us to learn through a comparison with other classmates (each contributed to building collective knowledge). (R.M., IV Scientific High School)*
c) *It was certainly a fun way to more easily learn the theoretical part of the principles of physics... I am also of the opinion that group work serves to prepare a student for a possible future "team-work" in the working world. (G.F., IV Scientific High School)*

Negative aspects:

a) *Greater emotional involvement due to the greater individual responsibility for the success of the project (fear that each may not do enough for the other group members) (M.G., IV Scientific High School)*
b) *I did not find any negative aspects. (A.S. IV Scientific High School)*

1C) Data processing

Positive aspects:

1) **Personal involvement**: Students seem to be involved and more motivated by the opportunity to work on projects. This personal involvement encourages them to explore and understand the topics more deeply.
2) **Teamwork**: Many responses mention the value of collaboration among group members and teamwork. This promotes the sharing of ideas, mutual learning, and preparation for the world of work.
3) **Diversity in learning mode**: Students appreciate project-based learning and diversity compared to traditional study. They believe it is more engaging, interactive, fun, exciting, and allows for easier learning.

4) **Well-being**: Completing a project and seeing the concrete results of their work generates a sense of satisfaction and personal fulfillment in students.
5) **Practical application**: Students note that projects allow them to apply theoretical concepts in real situations, making learning easier, concrete, and meaningful.

Negative aspects:

1) **None**: Eight out of nineteen students' responses do not highlight negative aspects or emphasize that there are none.
2) **Remote Communication**: Distance communication can pose a challenge, especially in situations like that caused by the pandemic, where in-person meetings have been limited.
3) **Time and Commitment**: Some students note that projects require additional time and effort, which can be challenging for balancing academic work, personal life, and other commitments. The need to coordinate and wait for other group members can slow down the process, especially if there are disparities in available time and commitments among students.
4) Individual **Responsibility**: Individual workload and responsibility for the project's success can increase emotional involvement and concern about disappointing other group members.

In general, it appears that students have benefited from project-based learning in groups, emphasizing its effectiveness in physics learning and practical skill acquisition. At the same time, they have highlighted difficulties related to remote communication during emergencies, challenges associated with time management, and individual responsibility within the group, perceived as negative aspects to address.

2A) *What were the positive aspects of working collaboratively? What were the negatives?*

2B)

a) I think that collaborating always yields excellent results because, naturally, in a group, there are more ideas and perspectives than in an individual. So, by collaborating, you always learn new things! (M.C., IV Scientific High School)

b) Surely a positive aspect is not closing oneself into one's own idea but ranging and confronting with group members. This allows us not to close ourselves off and to see how external people see or consider our idea. This allows us to improve the negative or lacking aspects of our thinking and combine it with others to create a more beautiful, exhaustive, and concrete one. (F.R., IV Scientific High School)

c) We had the opportunity to discuss ideas that were initially slightly discordant, making an effort to find mediation, a point of agreement. There were also playful moments that helped strengthen friendship. No negative aspects. (A.S., IV Scientific High School)

2C) Data Processing

Positive aspects:

1) **Collaborative Approach**: Experiences were described as characterized by a collaborative approach from both involved parties (students, teachers).

2) **Various Perspectives**: Working in groups led to a greater variety of ideas and insights, enriching the work with different perspectives.
3) **Constructive Comparison**: The opportunity to discuss with the group allowed for a broader personal view, improving the understanding and elaboration of ideas.
4) **Fun and Personal Involvement**: Collaboration allowed for enjoyment in learning and stimulated personal motivation and commitment.
5) **Personal Improvement**: Collaborative work contributed to personal development, improving communication skills, comparison, and sharing of ideas.
6) **Organization**: Collaboration stimulated the organization of tasks and deadlines, improving management skills.
7) **Sharing of Responsibilities**: Task division based on individual skills reduced the workload.
8) **Emotional Challenges**: The experience of working in a group was associated with greater emotional involvement, contributing to strengthening individual responsibilities and a sense of belonging to the group.

Negative aspects:

1) **Harmonization of Ideas and Organization**: Coordinating divided tasks to fit into a unified project was sometimes difficult, requiring good organization. Directing all group members toward the same direction while respecting various opinions can sometimes be complex.
2) **Difficulty in Organizing Meetings**: Finding times when all group members could participate was reported as a challenging element.
3) **Complications related to the emergency period**: The situation related to the Covid emergency made it difficult to meet and work on the project outside of school, limiting physical interactions and increasing logistical difficulties. Overall, collaborative work was seen as a positive resource, offering multiple benefits and positive results related to the work done and personal improvement, but it also presented challenges related to organization, coordination of ideas, and meeting organization.

3A) *Do you have any suggestions to facilitate your learning of mathematics and physics?*

3B)

a) Certainly, doing practical projects helps the whole class to better understand the topics (M.C., IV Scientific High School)

b) In recent years, I have understood that when I am having difficulty with a topic, I always have to try to compare it to a concrete example so that I have a better chance of understanding, and that is also why, in my opinion, projects are very useful (L.M., IV Scientific High School)

c) In the last period, both in mathematics and physics, I am really doing well, and even though they are the two subjects where I am most uncertain, I feel confident and motivated in carrying out the lessons. (F.M., IV Scientific High School)

3C) Data processing

The responses provide an interesting overview of how students perceive the learning process of mathematics and physics, highlighting suggestions and personal preferences. There are several lines of thought:

1) Practical and Applicative Approach: Many suggest the use of projects, experiments, and practical activities as a useful tool to facilitate learning. Seeking concrete examples and applying theoretical topics to the real world seems to facilitate understanding.
2) Collaboration and Group Work: Working in a group is considered an effective method to address difficulties and learn from others. Solving exercises together, comparing ideas, and doing group projects seem to be appreciated and useful approaches.
3) Use of Digital and Interactive Tools: Students prefer an interactive approach, including group exercises, laboratory experiences, and the use of digital tools (such as Geogebra in mathematics) as it makes learning more stimulating, engaging, and improves the understanding of concepts.
4) Summary and Visual Schemes: Creating visual summaries, diagrams, or concept maps at the end of a topic helps in overall understanding and visualizing connections between different concepts.

In summary, students request a variety of teaching methods that include practical learning, the use of digital tools, group work, and the opportunity to compare with concrete examples. The interactive approach and differentiation in lessons seem to be the most common requests to facilitate the learning of mathematics and physics.

These student requests and the methodologies implemented through the described activities align precisely with those indicated for effective STEM teaching in the new sent on October 24, 2023, by the Ministry of Education and Merit with Note prot. 4588 (Ministry of Education & STEM, Nota prot. 4588 del 24 ottobre 2023, 2023) to School Directors, teachers, and students in order to introduce actions dedicated to strengthening mathematical-scientific-technological and digital skills through innovative teaching methodologies. In this document, it is stated that: "*The interdisciplinary and multidisciplinary approach, together with the contamination between theory and practice, therefore constitutes the fulcrum of STEM disciplines' teaching, which are particularly suitable for promoting students' development of technical and creative skills, necessary in an increasingly technological and innovative world. To this end, teachers, whatever the school level, can refer, by way of example and not exhaustively, to the following methodologies: Learning by doing ... Problem-solving and inductive method ... Activation of synthetic and creative intelligence ... Organization of work groups for cooperative learning ... Promotion of creative thinking in the digital society ... Adoption of innovative methodologies: to develop students' curiosity and active participation, the school should overcome transmission models, also resorting to technologies, adopting an active didactic that puts students in real situations that allow them to learn, operate, grasp changes, correct their mistakes, support their arguments*." (Ministry of Education, STEM Guidelines, 2023, p. 6,10) .

4.9 Implementable phases: What Next?

"In undergraduate STEM education, we have the curious situation that, although more effective teaching methods have been overwhelmingly demonstrated, most STEM courses are still taught by lectures" (Wieman, 2014)

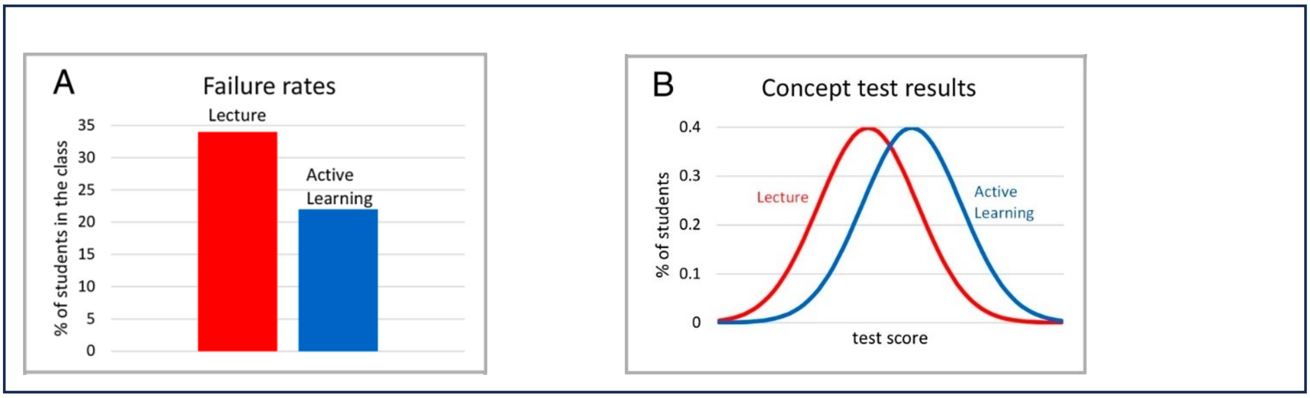


Fig. 4.9: Test results from (Freeman, et al., 2014).

Carl E. Wieman, Nobel laureate in physics and professor at Stanford University (US), summarized the results of over 200 studies comparing the effectiveness of active learning approaches to standard lectures in STEM university courses (Freeman, et al., 2014). These studies highlighted a significant improvement in learning and a notable reduction in failure rates in courses that promote the 'ask rather than tell' and 'do rather than remain passive' approach (Fig. 4.9). The most successful methodologies involved students in applying knowledge rather than merely absorbing it passively.

This, along with other studies (Johnson R. T., 1986) (Marusic, 2014), the STEM guidelines released by the Ministry for Italian schools (Ministry of Education, STEM Guidelines, 2023), and experiences at MIT, supports the continued use of hands-on active learning methodologies for physics, while continuously improving the current approach.

During my doctoral studies, I had the opportunity to directly experience some methodologies used in Physics courses for first-year students at the Massachusetts Institute of Technology: the TEAL (Technology Enabled Active Learning) methodology and the collaborative learning characteristic of ESG (Experimental Study Group) (ESG, 2023). Both stem from studies aimed at improving student learning compared to traditional transmission methods and can serve as best practices to inspire innovation in the curriculum towards student-centered active learning, as required by the Italian Ministry of Education.

4.10 Example of a Hands-on Project carried out by a group of students during Physics Curriculum activities: *"The Mechanical Paradox"*

"The mechanical paradox" was a project chosen in the 2019/20 school year by Margherita, Luca, Riccardo, and Caterina, four students attending the third class at the Scientific High School "A. Roiti" in Ferrara. The group formed based on a common interest in building the instrument and investigating a seemingly "magical" phenomenon. The mechanical paradox is not typically addressed in classic laboratory activities, nor is it usually found in high school textbooks, as its quantitative analysis requires mathematical tools beyond students' reach (Cortés & Cortés-Poza, 2011). However, Caterina and Margherita had visited the Galileo Museum in Florence, where the instrument is present (Galileo Museum), became interested in understanding the reasons behind its motion, and proposed it to the class. Riccardo and Luca joined the proposal.

The topic addressed through experimental analysis is the "motion of the center of mass" within the study of the motion of extended rigid bodies. The project presentation provided an opportunity to discuss with the involved students and the class:

- Center of mass
- Motion of the center of mass
- Conditions of stable, unstable, neutral equilibrium
- Potential energy

through their practical application in a real and concrete phenomenon.

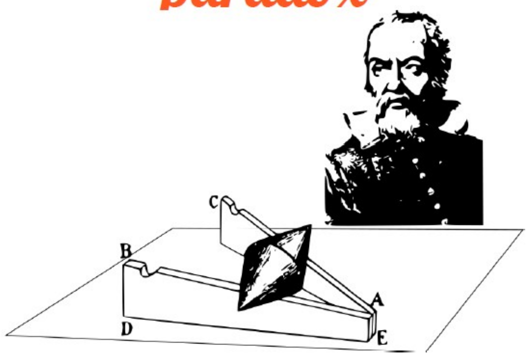
Following the presentation, the case of the motion of a sphere instead of the cone was also examined, as suggested in an article by AAPT (American Association Physics Teachers, (Gardner, 1996)) to observe analogies and differences.

<u>Structure and Evaluation Criteria.</u> In the presentation, students adhered to a negotiated basic structure that highlighted:

- Names and roles of each participant
- The phenomenon under investigation and/or the object to be built
- Minimum and maximum pre-established objectives
- Materials and tools used
- Theoretical references
- Execution of the experiment
- Interpretation of the phenomenon based on the physics concepts learned through the experience.

Additional credits were given to students who presented in English and/or made their presentation easily replicable and captivating (Fig. 4.8). The students complied with the first request (although with some errors) and agreed to the second for the materials used (can, plastic bottles) and for the final video related to a humorous anecdote about how the discovery would be made (final video). During this activity, the preparation of questionnaires to submit to classmates to assess the effectiveness of the presentation had not yet been requested. Below there are the slides of their presentations (Fig. 4.10-15)

The mechanical paradox



- Margherita
- Luca
- Riccardo
- Caterina

Instrument exhibited at the Museo Galileo in Florence (Italy) (Museo Galileo)

Index

- Working group
- Description of the project
- Goals
- Materials and tools
- How to make it
- Theoretical basis
- Description of the physical process
- Let's try…
- Fun facts
- Scheme

Fig.4.10: Slides of the Presentation "The Mechanical Paradox"

Working group

Group members	Roles
Riccardo Magri	Video editor
Caterina Sunseri	Theoretical part
Margherita Garbuglia	Practical part: construction
Luca Leis	Logbook editor

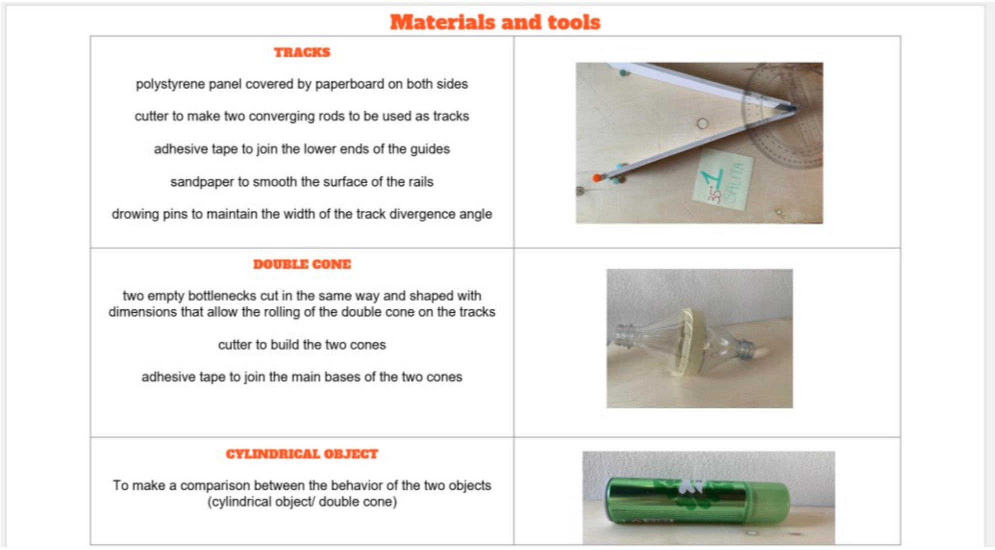
Project description

The device, positioned on a support, consists of a trapezoidal wooden frame with two brass rails on which a pair of brass cones joined by a wooden disk for their bases.

By placing the double cone on the lower part of the frame, it spontaneously begins to rise upwards, thus giving the impression of evading the universal law of gravity.

This phenomenon is therefore contrary to expectations. For this reason, the apparatus is called "mechanical paradox".

Fig.4.11: Slides of the Presentation "The Mechanical Paradox"



Materials and tools

TRACKS polystyrene panel covered by paperboard on both sides cutter to make two converging rods to be used as tracks adhesive tape to join the lower ends of the guides sandpaper to smooth the surface of the rails drowing pins to maintain the width of the track divergence angle	
DOUBLE CONE two empty bottlenecks cut in the same way and shaped with dimensions that allow the rolling of the double cone on the tracks cutter to build the two cones adhesive tape to join the main bases of the two cones	
CYLINDRICAL OBJECT To make a comparison between the behavior of the two objects (cylindrical object/ double cone)	

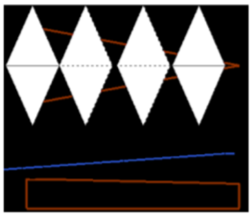
VIDEO 1: *How to build the tools* https://youtu.be/qMs8_EMPlLE

Fig.4.12: Slides of the Presentation "The Mechanical Paradox"

Theoretical basis

The apparent anomalous behavior followed by the double cone is easily explained by resorting to the physical **theorem of the motion of the center of mass (or center of gravity)**:

"The motion of a system of material points subject to external forces is determined only by the motion of its center of gravity equipped with the entire mass of the system and subject to the resulting force".



In fact, the center of gravity of the double cone lowers during the motion, even if the system apparently seems going up

! It can be observed that the double cone can be schematized as a system of material points where is the gravitational force which puts the body in motion on the inclined plane with negligible frictional forces.

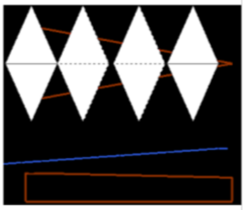
➡ The theorem of the motion of the center of mass states that what matters for the motion of an extended body is the motion of its center of gravity and not that of its parts.

Description of the physical process

There is no violation of the laws of physics

The double cone simply manifests the spontaneous rolling motion in the direction in which its center of gravity can descend, this motion apparently only appears to be uphill.

By carefully observing the motion of the double cone, with your eyes at the height of the table, **you can see how the center of gravity of the body drops during motion, although the object seems to follow the "uphill" profile " of the rails.**



The rotation axis and the center of mass of the double cone drop

How does it work ?

The center of gravity of the double cone (located on the rotation axis, where the diameter is maximum) moves downwards when a certain ratio is reached between the angle of inclination of the rails, the angle of divergence of the rails and the apex angle of the double cone.

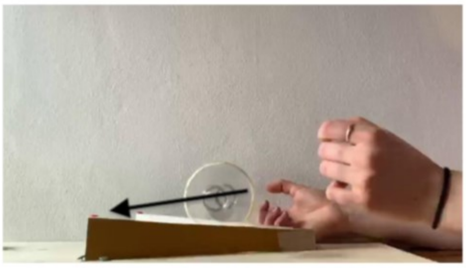
Every time the body turns, its axis of rotation moves downwards; the distance between each of the contact points of the cones with the rails and the axis of rotation increases as the body moves from the rails' convergence point. For this reason the axis of rotation (where the center of gravity is located) gradually drops gaining an height difference bigger than the inclination of the rails.

Fig.4.13: Slides of the Presentation "The Mechanical Paradox

EXPERIENCE...

By changing the inclination of the angle between the two guides, it is possible to move the object in one direction or another, or to ensure that you are in a condition of indifferent balance

For the cylinder, instead, whose center of gravity is always at the same height (equal to its radius) with respect to the guides, the "fall" motion is invariably towards the top of the guides.



VIDEO 2: Experience with the double cone https://youtu.be/wcb91oc6_cE

VIDEO 3: Experience with the cylinder https://youtu.be/YblthLTtFfA

The direction of motion of the center of gravity has an inclination contrary to and greater than the inclination of the tracks and takes on the opposite direction from the top of the tracks

The direction of motion of the center of gravity has an inclination contrary to and less than the inclination of the tracks and assumes the same direction as the inclination of the tracks

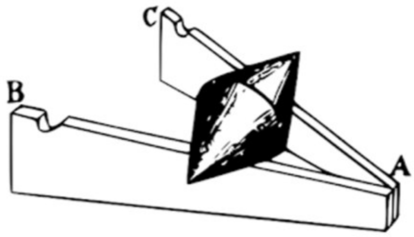
The potential direction of motion of the center of gravity has the same inclination and opposite to the inclination of the tracks - the forces balance and the body remains stationary

The direction of motion of the center of gravity of the double cone varies according to the width of the divergence angle of the rails

Fig.4.14: Slides of the Presentation "The Mechanical Paradox

ILLUSTRATIVE SCHEME

A double wooden cone and a base, consisting of two diverging wooden rods. The two wooden rods are inclined: their ends A are lower than the ends BC.



If I put the bi-cone in A and leave it, I will see the bi-cone move until it arrives (rolling) in BC. It seems impossible, it is opposite to common sense!
As soon as I change the rolling object I will notice that it will not move from A and if I put it in BC it will roll right where I had imagined (A).

Fun facts- How Galileo presented the experiment

The chronicles give us some stories of how Galileo used his discovery of the bi-cone to entertain friends and acquaintances...

VIDEO 4: A story about the Paradox https://youtu.be/5EWIDNIT0eY

REFERENCES

http://museo.liceofoscarini.it/virtuale/doppiocono_s.html

https://catalogo.museogalileo.it/oggetto/ParadossoMeccanico.html

https://robadabambini.blogspot.com/2017/10/galileo-galilei-prestigio-numero-6.html

https://it.wikipedia.org/wiki/Paradosso_meccanico

Fig.4.15: Slides of the Presentation "The Mechanical Paradox

<u>Observations</u> The students responded well to the objectives and evaluation criteria of the activity (fig. 4.8). The multimedia materials they created were original and explanatory of the reasons behind the phenomenon. The presentation, coupled with practical demonstrations using the constructed tools, garnered much interest from classmates, who particularly enjoyed the final video (Fun fact anecdote).

While the quantitative analysis of the experiment required mathematical tools beyond their reach (Cortés & Cortés-Poza, 2011), the students could have added some conjecture regarding the relationship between the opening angles of the track and the vertex angle of the isosceles triangle section of the cone. In short, they could have asked a few more "whys," perhaps by constructing cones with different openings and verifying their operation.

In the final video "Fun fact", the students seem to attribute the discovery of the phenomenon to Galileo. It was later clarified that the earliest accounts of the "strange motion" of the cone on the track can be found in a late 17th-century text, with no reference to Galileo (William Leybourn's "Pleasure with Profit" (Cortés & Cortés-Poza, 2011)).

Each student's logbook was attached to the presentation, an important element of individual evaluation, as highlighted in the fig. 4.8 grid. The logbook is a shared document among the students in the group through GoogleDoc. Below, as an example, the parts related to Caterina and Riccardo and the group's final conclusions are extracted, revealing difficulties and positive aspects of the project realization.

<u>Project Logbook for "The Mechanical Paradox"</u>

Project Logbook

Logbook of Caterina: occhiobello/ferrara 27-04 / 18-05

Monday, 27 - GROUP CONNECTION! Web research - illustrative videos, images (Original Mechanical Paradox by Galileo) ---- to get a general idea of the project and its implementation. Therefore, establish a common goal.
Tuesday, 28 - GROUP CONNECTION! General discussion - work method to achieve the preset goal - more detailed division of individual tasks - considerations/advice/opinions on working "as a group" in a fun and productive way.

Wednesday, 29 - web research - videos, documents on how to reproduce the mechanical paradox using materials available in every home.

Wednesday, 29 - web research - illustrative videos that mimic the phenomenon described by the paradox using materials/objects alternative to the 'original' ones.

Thursday, 30 - web research - project description (where does it come from/how was it born? Why specifically 'Mechanical Paradox'?) - curiosity about Galileo's discovery (historical references).

Saturday, 2 - creation of the Word document, annotation of the first identified materials - formation of an outline that includes the different points to be analyzed/developed.

Sunday, 3 - comparison regarding the work done up to that moment, opinions and useful advice to improve - sharing and collection of materials (drive). web research - videos, documents that describe and analyze the physical process, notes, diagrams, and useful drawings to understand the phenomenon +++ Comparison of materials obtained from different sources.

Wednesday, 6 - understanding the phenomenon, identifying the basic theory in relation to the previously studied topics (center of mass, gravity force, inclined plane).

Friday, 8 - collection and organization of materials according to the order dictated by the previously created outline.

Saturday, 9 - Sunday, 10 - creation of the PowerPoint, useful to give the group a more general and schematic view of the contents and for the project presentation.

Monday, 18 - group video call to review that there are no errors in the project, with any improvements on the PowerPoint, checking the language used to make it understandable to everyone, and dividing the parts for the presentation.

Logbook Riccardo:

Monday, 27 - GROUP CONNECTION! Web research - illustrative videos, images (Galileo's 'original' Mechanical Paradox) ---- to get a general idea of the project and its implementation. Therefore, establish a common goal.

Tuesday, 28 - GROUP CONNECTION! General discussion - work method to achieve the predetermined goal - further division of individual tasks - considerations/advice/opinions on working "in a group" in a fun and productive way.

Saturday, 9 - Sunday, 10 - grouping files (photos/videos) sent by the group, creating some video drafts, starting video editing.

Sunday, 10 - start converting the theoretical material (developed by Caterina) into a PowerPoint via video call and developing new ideas for the PowerPoint, discussing new ideas with the group.

Wednesday, 13 - continued video editing, selected music, and added captions explaining the materials used and how to conduct the experiment.

Sunday, 17 - completed the conversion of the PowerPoint with Caterina in a video call and finished video editing, checking for errors and adjusting the final details (text color, image color, and calibration of the exposure of video clips to ensure they are uniform and clearly visible).

Monday, 18 - group video call to review the project, make any improvements to the PowerPoint, check the language used to make it understandable to everyone, and divide the parts for the presentation.

Challenges encountered in the process:

- Difficulty in sharing the "diary of activities" via Drive, as changes were not always visible to other group members.
- Occasionally, some connection issues during the project implementation.

Positive notes from the group:

- The group worked with **great cohesion and unity**, trying to stay consistent and respecting the set dates.
- **Fun** and **passion** in the project realization

Further details of the activity

The activity introduced and studied by the students provide an opportunity to practice:

- Determining the center of mass of any object (for suspension).
- Roughly identifying the center of mass of one's own body (variations in mass distribution by changing the position of arms and/or legs, studying one's balance).

Predicting motion using the concept of the center of mass (https://en.khanacademy.org/science/mechanics-essentials/xafb2c8d81b6e70e3:why-you-cannot-change-the-result-of-a-tug-of-war-on-ice/xafb2c8d81b6e70e3:why-you-cannot-change-the-result-of-a-tug-of-war-on-ice-lesson/e/center-of-mass-exercises-ap1)

Identification of the center of mass position of a system of objects

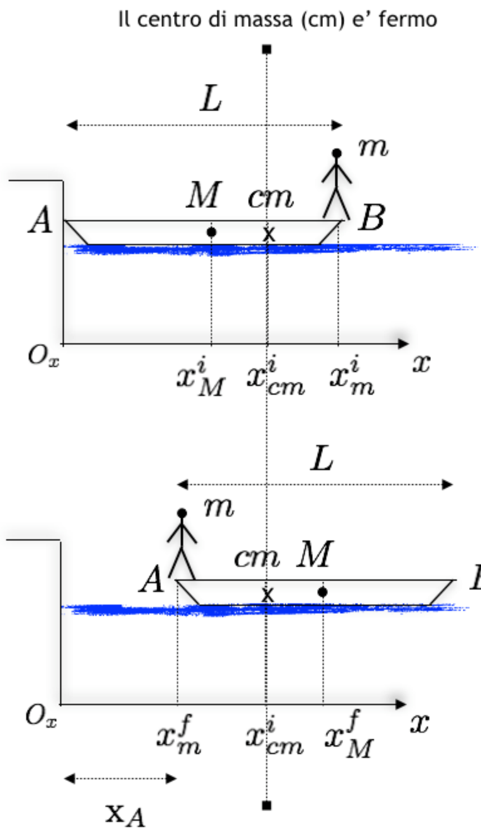
Example (taken from https://www.roma1.infn.it/~santanas/chim_ind/docs/EserciziFisica1_chim_ind_quantitaDiMoto_e_centrodiMassa.pdf):

"A raft with a mass M=150 kg M=150kg and a length L=5 mL=5m is stationary in calm waters, without any anchoring, with one end AA in contact with the wall of the pier. Initially, a person with a mass m=75 kg m=75kg is located on the raft at the opposite end BB to the pier. At some point, the person starts walking on the raft (there is friction between the person and the raft) and reaches the end AA, where they stop. Assuming that there is no friction between the raft and the water, determine:

a) the initial position of the center of mass of the raft+person system

b) the position of the center of mass when the person has reached the other end of the raft (final state)

c) the distance between end AA of the raft and the pier in the final state."



4.11 Other examples of MECHANICS and ELECTROMAGNETISM projects

Mechanics

Topic	Kind of project	Title	Materials	Language
Levers	Construction and analysis of physical phenomena	Levers of the first order"	https://docs.google.com/presentation/d/1VdogK6ewkWaydTGfNkwVB8vjhgIAKEBD/edit?usp=sharing&ouid=101847857790672296860&rtpof=true&sd=true VIDEO: https://youtu.be/dQxGHVLXtgQ	En
Review of concepts of dynamics	Recognize, interpret and describe phenomena of the surrounding reality	Launch of the disinfectant gel"	VIDEO: https://youtu.be/CPWdin8XnVg	It

Electromagnetism

Topic	Kind of project	Title	Materials	Language
Induction and electric motor	Analysis of physics in everyday life	"Physics around us"	Prezi presentation with theory, video and logbook. https://prezi.com/view/m9ZxWBcp5WM1pBdGrdPd/	It
Induction	Project construction	Induction separator	Presentation: https://docs.google.com/presentation/d/1P4jtPl3SLz4nL4VhOqnFvKqPQr0hWQsS/edit?usp=sharing&ouid=101847857790672296860&rtpof=true&sd=true VIDEO: https://youtu.be/stxpJ4IaGGM	It
Electrostatics	Project construction	Volta's electrtophorus	VIDEO: https://www.youtube.com/watch?v=l8Txolx3AIM	En

CHAPTER 5

MODELS OF HANDS-ON, COLLABORATIVE, ACTIVE LEARNING IN PHYSICS WITHIN THE CURRICULAR ACTIVITY AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT)

5. MODELS OF HANDS-ON COLLABORATIVE ACTIVE LEARNING IN PHYSICS WITHIN THE CURRICULAR ACTIVITY AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT)

5.1 TEAL (Technology Enhanced Active Learning)

<u>Motivations:</u> Studies on student learning at MIT highlighted how traditional teaching methods provided a passive learning experience where students simply listened to what the teacher explained. These classes showed low participation rates, and students had a high failure rate in the final exam. Students were required to memorize what the teacher told them as a sequence of facts that did not require questioning or experimental research. Additionally, basic physics courses almost eliminated laboratory experiments, causing students to lose the ability for physical intuition, experimentation, and problem-solving. Furthermore, it was observed that students sometimes lacked the necessary, including mathematical, requirements to master quantitative representations or formulas associated with physical phenomena needed for conceptualization (Dory, et al., 2003). For these and other reasons related to methodological innovation, in 2001, John Belcher and Peter Dourmashkin began introducing the first TEAL (Technology Enabled Active Learning) physics courses for first-year students at MIT (mechanics and electromagnetism).

<u>Sources:</u> TEAL drew inspiration from various sources, including Scale Up (Student-Centered Activities for Large-Enrollment Undergraduate Programs) by Robert Beichner (Beichner, 2008), developed at North Carolina State University (NCSU) and based on a model from Rensselaer Polytechnic Institute (RPI), as well as Peer Instruction by Eric Mazur (Mazur, Zhang, & Ding, 2017). Particularly influential were the Integrated Studies Program (ISP) (Integrated Studies Program, 2021) and the Experimental Study Group (ESG) at MIT.

The ISP program, active at MIT until 2001, provided a comprehensive curriculum for first-year students. It was an example of an innovative of hands-on active learning program at MIT. Combining hands-on learning with theoretical study, ISP aimed to equip students with practical skills and theoretical knowledge essential for success in academia and beyond. Workshops led by guests from within and outside MIT helped students understand the connections between theory and practice in various disciplines. Additionally, ISP fostered a supportive community that promoted collaborative problem-solving, critical inquiry, effective communication, and lifelong learning, laying a solid foundation for students' future achievements.

The Experimental Study Group (ESG) will be further discussed in Section 5.2.

<u>Objectives:</u> The TEAL methodology was created at MIT to help first-year physics students at MIT to:

- Overcome difficulties in learning physics related to understanding concepts and principles of the physical world that are sometimes impossible to visualize (as in electromagnetic phenomena) and often challenging to understand (Dourmashkin, Tomasik, & Rayyan , 2020).
- Improve understanding and retention of mechanics and electromagnetism concepts, experimental and problem-solving skills, and the ability to apply physical principles to model real-world phenomena.

- Enhance the learning experience through active participation in the learning process, increased motivation, and greater engagement achieved through collaborative activities among peers (collaborative learning).

Structure: The TEAL methodology involves a fusion of presentations, tutorials, simulations, and *hands-on* laboratories within an active, collaborative, and technologically advanced learning environment (Dourmashkin P. , 2013). In TEAL, both the structure of the learning environment and the method of work and materials used play a significant role, distinguishing it as an active learning approach.

The ENVIRONMENT consists of a classroom (Fig. 5.1) with:

- Round tables for collaborative learning, each equipped with stations for nine students and laptop outlets; students work in groups of three.
- Whiteboards on all available walls to facilitate interaction among students, collaborative problem-solving, teacher monitoring of learning, and the presentation of reasoning and results.
- Projectors that allow each student to view slides or multimedia material shared by the teacher or what the teacher is writing on one of the whiteboards.
- A station for the teacher, a technician, and a doctoral student used to share materials, provide insights, show larger experiments, summarize concepts, or display real-time results of concept tests administered to students to assess real-time understanding.

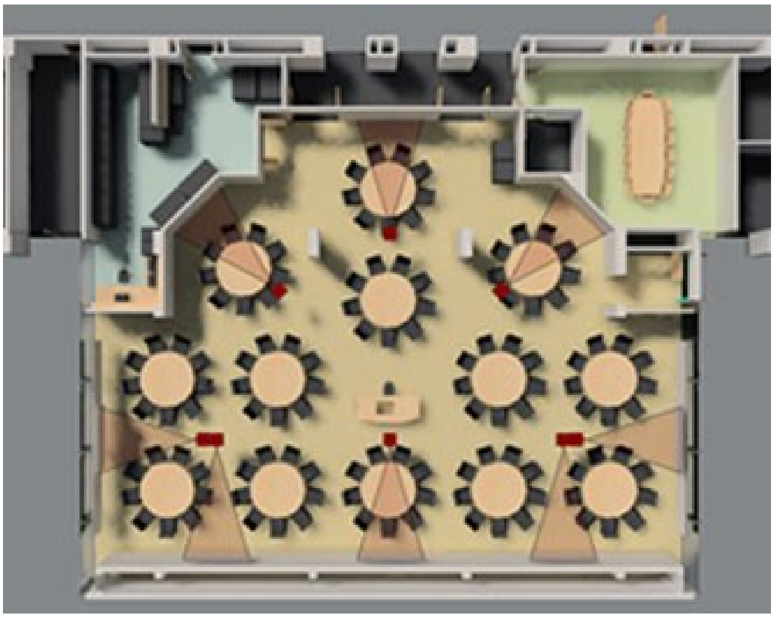


Fig. 5.1: TEAL classroom layout, top view (https://icampus.mit.edu/projects/teal/)

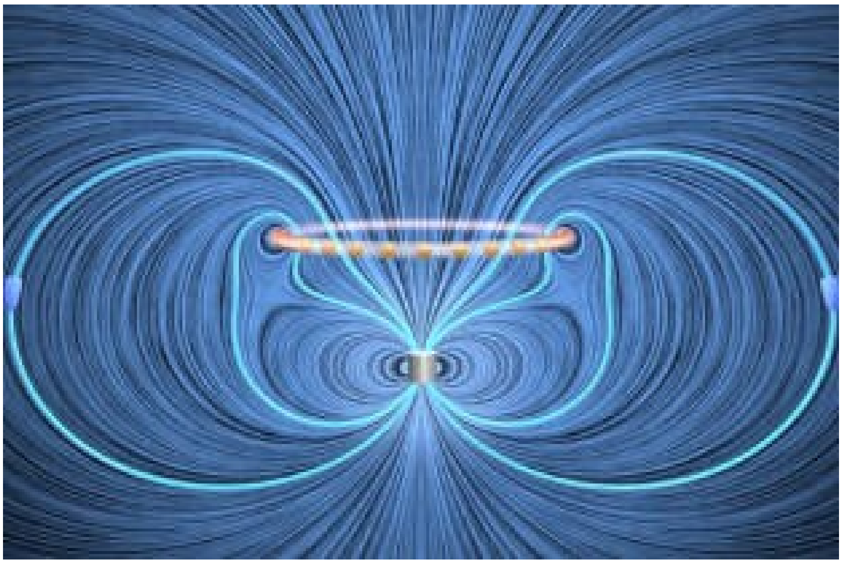


Fig. 5.2: Visualization of an electromagnetic phenomena (https://icampus.mit.edu/projects/teal/)

TEAL's characteristic elements (methods and materials) include:

- **Pre-class Learning Sequences:** Content delivered through pre-class web-based graded "activities" that include videos, concept questions, short problems.
- **Media-Rich Visualizations and Simulations**: Delivery of visually engaging content and simulations through laptops and web (Fig. 5.2).
- Assignment of **problems** to solve outside the class after the lesson (*homework "problem sets*").
- "***Concept tests***" to which students respond in class, collaboratively and/or individually, using now laptops/smartphones.
- ***Peer instruction*** through which students understand physical concepts with the help of peers or reinforce learning through explanations to peers; each table is also followed by a student from subsequent years who facilitates the discussion.
- ***Hands-on*** experiments and activity conducted on desktops by students connected to laptops for data acquisition.
- Larger **experimental demonstrations** by the technician or the teacher (Fig. 5.4).
- ***Collaborative problem-solving***: students collaborate in small groups to address problems, using whiteboards placed on all classroom walls or shared laptop computers; assistants, the technical instructor, and the teacher move between groups to provide support in solving and offer feedback.
- **Personal Response Systems**: Integration of systems that encourage interaction between students and lecturers, enhancing engagement and participation in the learning process.

The TEAL learning sequence is visualized in Fig.5.3.

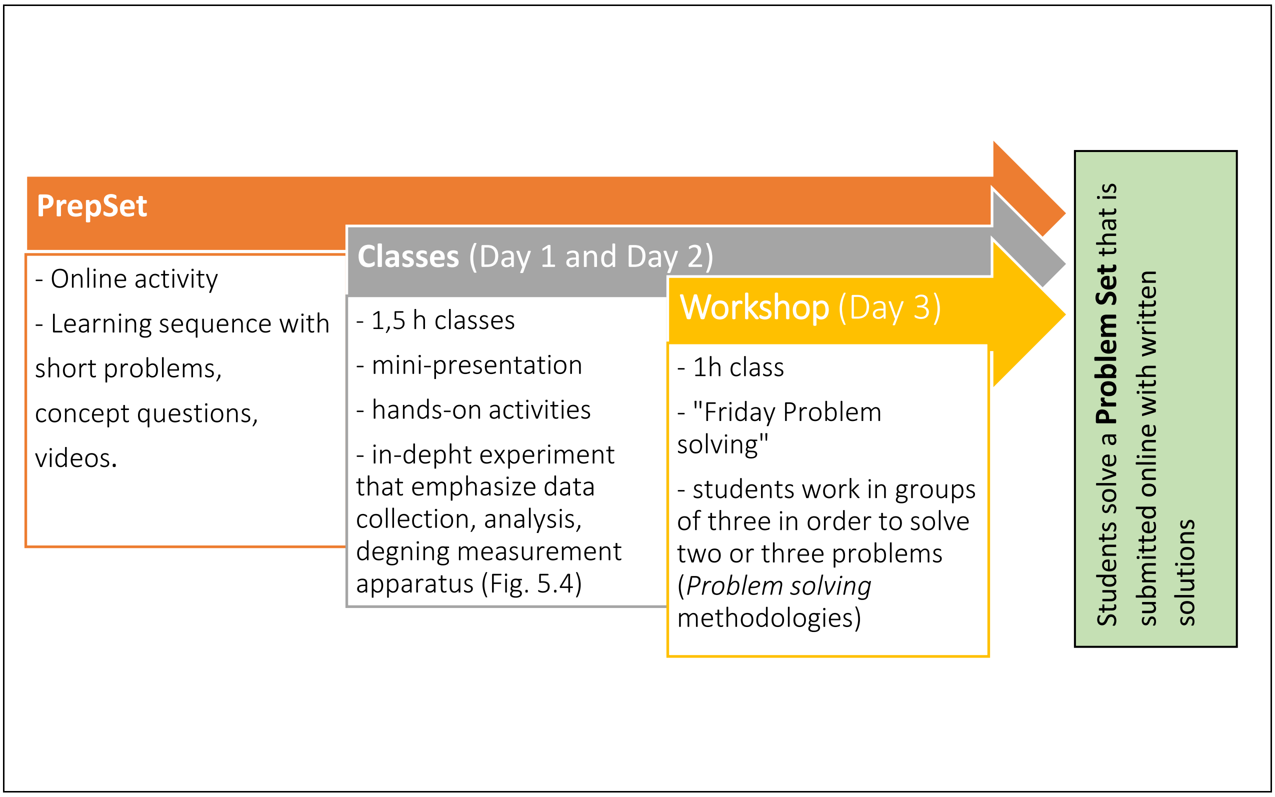


Fig 5.3: The TEAL learning sequence at MIT

Fig. 5.4 Experiment during TEAL class

Peer instruction is also based on the teaching model used by Prof. Eric Mazur in Physics courses at Harvard (Mazur, Zhang, & Ding, Peer Instruction in introductory physics: A method to bring about positive changes, 2017) (Mazur & Watkins, Just-in-Time Teaching and Peer Instruction). The sequence of the activity includes:

1. Administration of the concept test to students in class.
2. Reflection and subsequent individual response using clickers.
3. Immediate viewing of responses by the teacher only for feedback on individual student learning.
4. Discussion among students divided into small groups.
5. New response to the concept test provided this time by individual groups.
6. Teacher explanation.

<u>Teacher's Role During the Course</u>: The teacher is no longer the sole repository and dispenser of knowledge that students can only reach through their direct involvement in all phases of the process. During the course, the teacher:

- Prepares materials and establishes content to be covered based on expected learning outcomes.
- Circulates among students acting as a guide to their reasoning, if required.
- Provides the concluding explanation.

The teacher is supported by UTA (Undergraduate Teacher Assistants), students who have recently completed the course in question.

<u>Assessment</u>: The final assessment is a weighted average of points accumulated by students:

- In assignments between lessons ("learning sequences" (12%) and "problem sets"(12%)).
- In class work (7%).
- In concept tests and practical lessons on Fridays (5%) (for participation).
- In the two mid-term exams (17% each one) and final exams for the course (26%).
- In experiments (4%).

<u>Results</u>: The TEAL methodology was introduced at MIT in 2001, with modifications and adjustments over the years. Since the early academic years, the following have been highlighted:

- An increase in the percentage of students who passed courses with the TEAL methodology.
- An improvement in academic performance in terms of grades obtained and long-term topic retention (Dourmashkin, Tomasik, & Rayyan , 2020, p. 515).
- Over the years, the TEAL methodology has also spread to American and worldwide high schools (Shieh, 2012).

In Italy, INDIRE (National Institute for Documentation, Innovation, and Educational Research) is promoting the activation of the TEAL methodology in schools of all levels through Educational Avant-gardes (Avanguardie Educative) (Avanguardie Educative & TEAL).

5.2 ESG (Experimental Study Group)

<u>Motivations</u>: The academic community of ESG (Experimental Study Group) (ESG, 2023) was established within MIT in 1969 to study innovative teaching and learning methods through small groups of students (Levensky, 1973). ESG was created during a period of profound change in American society when counterculture was gaining traction, and students and staff were driven by the search for new educational approaches.

<u>Objectives</u>: ESG encourages students to take charge of their own education, discover their learning methods and passions, ask questions, collaborate with peers, consider not only what they are learning but also why and how they are doing it, and contextualize their learning.

<u>Structure and Methodology</u>: ESG offers courses for first-year students in physics, mathematics, chemistry, biology, and humanities. Its main features include (ESG_MIT, 2023):

- Small class sizes (typically 5 to 12 students);
- A community of about 55 voluntary student members (if enrollments exceed this number, students are selected based on a lottery), 25-40 assistants (TAs, teacher assistants, students who have recently completed the offered courses and must attend a teaching seminar), and 11 staff members.
- Interactive learning with *collaborative problem-solving* sessions.
- Innovative, typically interdisciplinary, *hands-on* seminars.
- Various services and facilities, such as a library, study rooms, a common kitchen, and a relaxation area, shared by students and teachers to create a learning community (ESG, 2023); services and facilities are open to ESG students (or alumni) 24/7; every Friday, a communal lunch is held among students, teachers, technicians, and assistants to foster trust and solidarity among the involved parties; often, informal lunches host teachers from various MIT departments or other institutions; community activities are also organized inside and outside ESG;
- Teaching staff has offices at ESG to maximize available time for student consultations.

ESG has recently pioneered two experiments relevant to this thesis:

- Replacing final exams with projects (mostly practical but also simulations or theoretical) that allow students to apply theoretical learning to real projects of their interest and design.
- Combining basic computer science lessons with curricular physics lessons to develop computational thinking in students, enabling them to learn physics by formulating appropriate questions that can be addressed numerically.

Specifically, regarding physics courses (mechanics and electromagnetism):

a) Students are provided with pre-lesson preparation materials (theory, videos, practical/simulation activities, and preliminary questions).

b) During in-class activities, after discussing concepts and reflecting on preliminary questions, the teacher presents problems for students to solve by discussing in small groups and outlining their reasoning on whiteboards, paper, or tablets; the teacher interacts with groups, guiding their reasoning while understanding the students' learning level (formative feedback); at the end of the activity, the teacher, together with the students, presents the correct solution, reflects on the mistakes made (presented as fundamental elements for learning), and summarizes the underlying physical concepts;

c) Strong emphasis on laboratory practice:

- Physical concepts are, when possible, introduced in a *hands-on* manner, using everyday tools and direct observation of the phenomenon, to connect theory and application, concept, and reality.

Fig. 5.5: Hands on Exploration

Fig. 5.6: Hands on Exploration investigating together

- *"Hands-on* ***explorations****"* (Fig. 5.5, 5.6) (Att.5) during which students gradually:
    - Investigate collaboratively phenomena from everyday life observable through the manipulation of materials, use of common tools, observation of the surrounding reality.
    - Formulate questions based on observation and curiosity.
    - Formulate hypotheses about the model of the analyzed phenomenon, including the mathematical equations representing it.
    - Verify the model based on their knowledge and data acquired during the activity.
    - Share the results of their discoveries with the class group and the teacher.
- Throughout the semester, students are required to propose **projects** related to the study topics through brainstorming sessions, discuss their positive and negative aspects together to select some that will be realized in the last month of the lesson, documented, and presented by students grouped in twos or threes.

Assessment: The final evaluation is derived from participation and, above all, the achievement of formative objectives in different components:

- Discussion, questions, and reflections on the material introduced before the lesson;
- Intermediate theoretical exams (one or two hours);
- Hands-on explorations and final project.

Results: Due to the nature of the activities, students develop practical, social, and cognitive skills such as experimental and technical abilities, problem-solving, collaboration, communication, and critical thinking, as well as the ability to learn autonomously (learning to learn) and take responsibility for their learning. The ongoing new experimentation is also aiming to enrich the understanding of physical concepts through the development of computational competence. ESG has been a strong inspiration in the experimentation I conducted in the classes of the "A. Roiti" Scientific High School.

CHAPTER 6

DISCUSSION AND OUTLOOK

6. DISCUSSION AND OUTLOOK

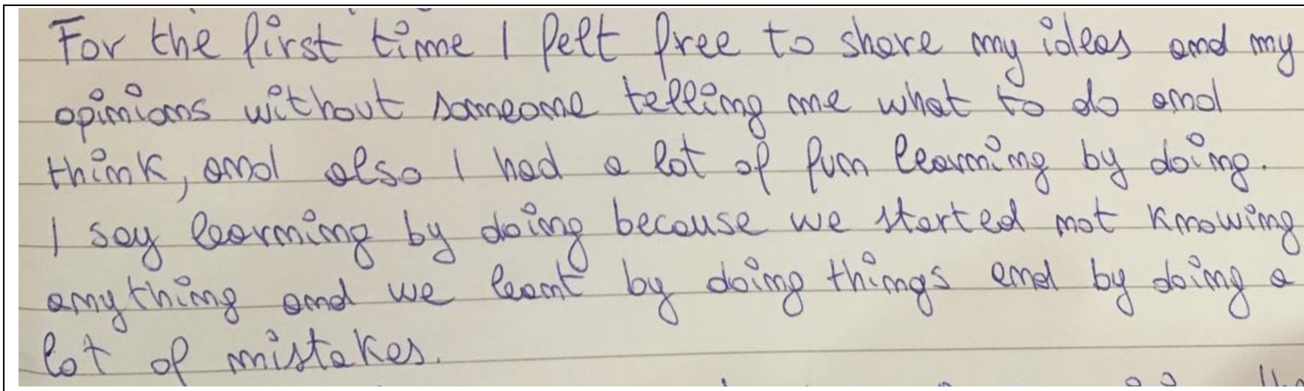
The documented research in this thesis was carried out within a single high school since, at the moment, this experience is still in the experimental phase and not shared by other institutions. It is hoped that in the future, a more extensive sample of schools can be obtained to highlight differences in results related to various types of high schools, each with its own characteristics linked to socio-economic-cultural aspects of the student body and geographical distribution across the national territory. A broader comparison will also be effective in identifying any biases in the research that may not be evident in the context used.

It is important to emphasize that this experimentation is not the result of an impromptu action but rather the integration of the traditional methodology of the Italian school system with established pedagogical approaches and practices at the Massachusetts Institute of Technology, a world-renowned university for excellence in scientific and technological disciplines.

Finally, it is important to acknowledge that the research planned at the beginning of the academic year 2019/20 was subject to limitations imposed by the long period of the COVID-19 emergency. This factor, while hindering the planned experimentation, also, by "putting the system under stress," created the opportunity to verify how, with appropriate revisions of activities, it is possible and desirable to conduct collaborative hands-on and learning-by-doing laboratory activities even with students connected remotely.

The results from the experiments, both in the extracurricular context discussed in Chapter 3 and in the curricular context presented in Chapter 4, highlight how the approach to Physics through active learning involving hands-on methodologies, learning by doing, and collaborative learning among peers not only facilitates the students' learning process by activating sensorimotor centers through direct laboratory experience but also contributes to completing their education. This approach, in fact, promotes the development of key learning skills fundamental for continuing studies, entering the workforce, and actively participating in society.

The analysis of the effects on students involved in either of the two experiments provides answers to the questions posed at the beginning of this thesis. If students are given the opportunity to act and experiment collaboratively, creatively, and without the direct guidance of the teacher but by sharing knowledge and skills among themselves, they demonstrate a reawakening of imagination, curiosity, and interest in learning Physics and STEM disciplines. They also acquire the ability to generate new ideas, design and build tools necessary for analyzing phenomena, learn through overcoming mistakes, along with critical reflection on their actions and comparison with others, as evidenced by the anonymous feedback in Fig. 6.1.



For the first time I felt free to share my ideas and my opinions without someone telling me what to do and think, and also I had a lot of fun learning by doing. I say learning by doing because we started not knowing anything and we learnt by doing things and by doing a lot of mistakes.

Fig. 6.1: Anonymous feedback, HoPE student

Beyond this, the testimonials and requests from students who have experienced such initiatives highlight the need for a broader paradigm shift in education. It is crucial to introduce a methodological innovation that allows students not to be mere recipients of information transmitted by teachers but active protagonists in the process of constructing knowledge and developing their skills. This active engagement can occur through practical experiences, discussions, and collaborative activities that extend beyond the boundaries of the classroom. When technology becomes not only a tool but also a learning objective, it can play a key role in shaping a new and more effective mode of teaching and learning.

The Ministry of Education and Merit has expressed this direction through the "STEM Guidelines" and references to best practices such as HoPE practiced within the "A. Roiti" High School, documented on the INDIRE website (National Institute for Documentation, Innovation, and Educational Research) (INDIRE & HoPE, 2021). Additionally, in these last months of 2023, it is possible within schools to structure paths of innovation, teacher training, and necessary purchases for implementing activities with innovative methodologies through the funds of the EU-PNRR (National Plan for Recovery and Resilience).

In my opinion, a National Plan with dedicated funds is essential but not sufficient to enable a change in teaching methodology or, at least, an integration of traditional methods. It is essential to ask whether the main actors in the Italian school system are actually ready for this radical change and, if they are not, how their preparation can be facilitated.

My doubts arise from the fact that schools and teachers have been tasked with structuring methodological innovations and formulating proposals for the purchase of tools and materials that are unknown to most of them. I strongly support the autonomy of the school when it aims to identify learning paths in line with the needs of the territory and the resources available. I also consider teaching freedom fundamental when it allows teachers to better express their potential in relation to the specificities of each class, achieving goals shared by the school.

However, I do not believe that autonomy and freedom are compromised if I assert the need for guidance in the process, greater institutional support to illuminate the path. I find it particularly important that, given the abundance of information and proposals that schools and teachers must confront while seeking clarification and support in this crucial transition phase, institutions, with a greater knowledge of innovative methods and objectives, can identify and propose ways and support paths for teachers in this epochal shift within the school paradigm of recent decades.

It is essential to support teachers in understanding the importance and scope of this change, also through direct experiences, as happened in my case. Workshops and training courses organized by universities or research institutions, disseminated throughout the national territory, could prove useful for this purpose. It would also be appropriate to involve teachers and students simultaneously in these experiences to encourage collaborative learning, breaking down the barriers that often separate the two parties. This way of operating would allow the teacher not to feel constrained to demonstrate competence only by answering every student's question but rather to encourage their curiosity and drive to explore.

The active learning methodologies described in the previous chapters are quite different from the traditional training and practice for teachers in Italy. They should be aided in this process through a revision of the curriculum and teaching materials, through hands-on training, and through mutual support from a growing network of teachers and students who are experienced in these practices. Although these methods are more effective than traditional ones, they could require more time, especially initially, to be effectively implemented. Content should be gradually phased in to allow teachers to become confident and proficient in this more dynamic learning environment.

On a national level, the State Exam, especially concerning Mathematics and Physics, must be aligned with the goals and expected results of the National Guidelines for High Schools and those taken up by the STEM Guidelines together with the introduction of active learning approaches. Currently the State Exam continues to require preparation with predominantly traditional methodologies and does not highlight enough the competencies that are developed with active learning methodologies. Progress will never be made if evaluation criteria and methods do not address or certify these degrees of achievement. One way could be the introduction and evaluation of projects transversal to the disciplines, as already present, for example, in the Catalan school (Diari Oficial de la Generalitat de Catalunya 2019a) (Diari Oficial de la Generalitat de Catalunya 2019b) and like those discussed in this thesis.

In conclusion, the experience gained through this research project has taught me the importance of freeing students' minds and learning to learn with them. At the beginning, it was difficult, but it is fantastic to observe their well-being at school, their joy in discovering, doing, learning, and feeling able to do it independently by collaborating with peers. At the same time, it is wonderful to be able to gain new stimuli from students and learn new things together with them, making the subjects always vibrant and "new." Students gain more confidence in themselves (my voice matters), but also in us adults. They recognize that we adults trust them, and this has positive effects on educational action. I believe that an educational synergy (students-teachers-Institutions-Entities) like the one in place at the "A. Roiti" High School can create a context that allows students to achieve the necessary goals for a more motivated and aware knowledge of Physics, and, through the innovative tools and methods used, for a complete education of the individual in the century we are living in.

HoPE, the extracurricular program discussed in Chapter 3, is an effective collaboration between students, teachers, “A. Roiti” High School, University of Ferrara, and INFN. It was inspired and continues to be supported by MIT and its “Mind, Hand, and Heart” culture of education. It has become an example of a lively, inclusive, and innovative learning community that can be established in other schools, where students are beneficiaries and disseminators of the joy produced by collaboration, discovery, understanding, and knowledge. Hopefully, at the national level, the Ministry and research entities like INFN could promote programs, like HoPE, that augment traditional teaching methods and address long needed improvements in our educational system: a system whose goal should be helping our students to lead happy, healthy, productive, fulfilling lives and to become active in creating a better world.

References

Avanguardie Educative, & TEAL. (s.d.). *TEAL (Tecnologie per l'apprendimeto attivo).* Tratto da INDIRE: https://innovazione.indire.it/avanguardieeducative/teal

Beichner, R. (2008, January). *Student-Centered Activities for Large- Enrollment University Physics (SCALE-UP).* Tratto da ResearchGate.net: https://www.researchgate.net/publication/266882822_Student-Centered_Activities_for_Large-_Enrollment_University_Physics_SCALE-UP

Cambridge Dictionary. (s.d.). Tratto da https://dictionary.cambridge.org/it/dizionario/inglese/hands-on-experience

Cortés, E., & Cortés-Poza, D. (2011). Mechanical paradox: the uphill roller. *European Journal of Physics, 32*(6), 1559–1576. Tratto da https://iopscience.iop.org/article/10.1088/0143-0807/32/6/010

Crouch, C., & Mazur, E. (2001, March 15). *Peer Instruction: Ten years of experience and results.* Tratto da Massachusetts Institute of Technology: https://web.mit.edu/jbelcher/www/TEALref/Crouch_Mazur.pdf

Dewey, J. (1916). *Democracy and Education: An Introduction to the Philosophy of Education.*

Diari Oficial de la Generalitat de Catalunya 2019a. (2021). Tratto da Gencat: https://dogc.gencat.cat/

Diari Oficial de la Generalitat de Catalunya 2019b. (s.d.). Tratto da Gencat: https://dogc.gencat.cat/ca/document-del-dogc/?documentId=507489

Director MIT. (2009). *Mens et Manus et Mundus.* Tratto da https://orgchart.mit.edu/system/files/reports/20090901_Provost_GlobalCouncilReport.pdf

Dory, Y., Belcher, J., Bessette, M., Danziger, M., McKinney, A., & Hult, E. (2003, December). Technology for active learning. *Materials Today, 6*(12), p. 44-49.

Dourmashkin, P. (2013). *L'esempio TEAL.* Tratto da INDIRE: https://www.indire.it/quandolospazioinsegna/eventi/2013/pacioli/materiali/04_dourmashkin/crema-general_talk_02.pdf

Dourmashkin, P., Tomasik, M., & Rayyan , S. (2020). The TEAL Physics Project at MIT. In J. W. Mintzes, *Active Learning in College Science* (p. 499- 520). Springer, Cham.

DPR n. 275/1999. (1999). Tratto da Gazzetta Ufficiale della Repubblica Italiana: https://www.gazzettaufficiale.it/eli/id/1999/08/10/099G0339/sg

Edgerton Center, M. (2023). *K-12 Education*. Tratto da K-12 Education: https://edgerton.mit.edu/k-12-education

Education, I. M. (2019). *Guidelines PCTO (Pathway for Transversal Skills and Orientation).* Tratto da MInistero dell'Istruzione e del Merito_Governo Italiano: https://www.miur.gov.it/ricerca-tag/-/asset_publisher/oHKi7zkjcLkW/document/id/2290917

ESG, E. (2023). *Community*. Tratto da https://esg.mit.edu/community/

ESG_MIT. (2023). *Esg-at-a-glance*. Tratto da Experimental Study Group: https://esg.mit.edu/explore/esg-at-a-glance/

EU Commission, Ferrari, A., Punie, Y., & Vuorikari, R. (2019). *Makerspaces for education and training : exploring future implications for Europe.* Tratto da European Union: https://data.europa.eu/doi/10.2760/946996

EU, R. (2018, May 22). *An official website of the European Union: EUR-Lex.* Tratto da Council Recommendation of 22 May 2018 on key competences for lifelong learning: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2018.189.01.0001.01.ENG&toc=OJ:C:2018:189:TOC

Freeman, S., McDonough, M., Smith, M., Okoroafor, N., Jordt, H., & Wenderoth, M. (2014). Active learning increases students performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of america, 111*(23), 8410-8415. Tratto da https://doi.org/10.1073/pnas.1319030111

Gardner. (1996). Physics trick of the month_The ball that rolls uphill. *The Physics teacher, 34*, 461. Tratto da AAPT.

Gardner, H. (1988). *Formae mentis. Saggio sulla pluralità delle intelligenzeFormae mentis. Saggio sulla pluralità delle intelligenze.* Feltrinelli.

Holmes, N. G., & Wieman, C. E. (2018, January 1). Introductory physics labs: We can do better. *Physics Today*, 38-45. Tratto da https://doi.org/10.1063/PT.3.3816

HoPE. (2023). *Hands on Physics Experience*. Tratto da https://hoperoitimit.com/

IEA. (2019). *TIMSS 2019 International Results in Mathematics and Science.* Tratto da IEA TIMMS&PIRLS: https://timss2019.org/reports/

INDIRE, & HoPE. (2021). *HoPE, Hands-on Physics Experience with MIT*. Tratto da Biblioteca dell'Innovazione: https://biblioteca.indire.it/esperienze-innovazione/view/442

INFN. (2023). *INFN Ferrara*. Tratto da https://www.fe.infn.it/index.php/it/

INFN. (s.d.). *Esercizi su quantità di moto e centro di massa di sistemi.* Tratto da https://www.roma1.infn.it/~santanas/chim_ind/docs/EserciziFisica1_chim_ind_quantitaDiMoto_e_centrodiMassa.pdf

Integrated Studies Program. (2021). Tratto da MIT Reports to the President 2001–2002: http://web.mit.edu/annualreports/pres02/08.17.html

Italiana, P. d. (2010). *DECRETO DEL PRESIDENTE DELLA REPUBBLICA 15 marzo 2010, n. 89* . Tratto da Gazzetta Ufficiale della Repubblica Italiana: https://www.gazzettaufficiale.it/eli/id/2010/06/15/010G0111/sg

Johnson, D. W. (2013). The impact of cooperative, competitive, and individualistic learning environments on achievement. In *International guide to student achievements* (p. 372-374). New York: J. Hattie & E. Anderman.

Johnson, D., & Johnson , R. (2018). Cooperative learning; the foundation for active learning. In *Active learning_Beyond the future* (p. 59-68). Tratto da https://www.intechopen.com/chapters/63639

Johnson, R. T. (1986). Cooperative Learning in the Science Classroom. *Science and children, 24(2), 31-32*, 31-32. Tratto da https://www.pdst.ie/sites/default/files/Cooperative%20education%20D&R%20Johnson.pdf

Kontra, C., Lyons, D., Fischer, S., & Beiloc. (2015). Physical Experience Enhances Science. *Psychological Science, 26*(6), 737-749.

Kontra, C., Lyons, D., Fischer, S., & Beiloc, S. (2015). Physical Experience Enhances Science Learning. *Psychological Science, 26(6), 737-749., 26*(6), p. 737-749. Tratto da https://doi.org/10.1177/0956797615569355

Levensky, M. (1973, March). The experimental study group: A new undergraduate program at MIT. *Interchange, 4*, p. 49-63. Tratto da Springer lilnk: https://doi.org/10.1007/BF02138792

Marusic, M. &. (2014). Students' Experiences in Learning Physics: Active Learning Methods and Traditional Teaching. *Latin-American Journal Of Physics Education, 8*(4), p. 32.

Mazur, E., & Watkins, J. (s.d.). *Just-in-Time Teaching and Peer Instruction.* Tratto da Mazur.Harvard.edu: https://mazur.harvard.edu/files/mazur/files/rep_634.pdf

Mazur, E., Zhang, P., & Ding, L. (2017). Peer Instruction in introductory physics: A method to bring about positive changes. *Physical Review Physics Education Research*. Tratto da https://mazur.harvard.edu/files/mazur/files/rep_772.pdf

Ministero dell'Istruzione, & Liceo Roiti. (s.d.). *Liceo Roiti*. Tratto da Ministero dell'Istruzione e del Merito: https://www.liceoroiti.edu.it/

Ministry of Education. (2023, ottobre 24). *STEM Guidelines.* Tratto da https://www.miur.gov.it/documents/20182/0/Linee+guida+STEM.pdf/2aa0b11f-7609-66ac-3fd8-2c6a03c80f77?version=1.0&t=1698173043586

Ministry of Education, & PCTO. (s.d.). Tratto da https://www.miur.gov.it/documents/20182/1306025/Linee+guida+PCTO+con+allegati.pdf

MInistry of Education, & PNSD. (2022). *Piano Nazionale Scuola Digitale*. Tratto da PNSD_Didattica Innovazione Futuro: https://scuoladigitale.istruzione.it/pnsd/

Ministry of Education, & STEM. (2023, ottobre 24). *Nota prot. 4588 del 24 ottobre 2023.* Tratto da Ministero dell'Istruzione e del Merito: https://www.miur.gov.it/web/guest/-/nota-prot-4588-del-24-ottobre-2023

MISTI, G. (2023). *Global Teaching Labs*. Tratto da MISTI Global Experiences: https://misti.mit.edu/your-resources/crafting-your-experience/types-programs/global-teaching-labs

MIT Edgerton Center. (2023). *Engineering Design Workshop*. Tratto da https://edgerton.mit.edu/k-12-education/summer-programs/engineering-design-workshop

MIT Edgerton center. (2023). *MIT Edgerton Center*. Tratto da https://edgerton.mit.edu/

MIT SEPT. (2023). *Science Engineering Program for Teachers*. Tratto da MIT: https://sept.mit.edu/

MIT_MEDIALAB. (2023). *Lifelong kindergarten*. Tratto da MIT_MEDIALAB: https://www.media.mit.edu/groups/lifelong-kindergarten/overview/

MIUR. (2010, ottobre 7). *DM n. 211 .* Tratto da Gazzetta Ufficiale: https://www.gazzettaufficiale.it/gunewsletter/dettaglio.jsp?service=1&datagu=2010-12-14&task=dettaglio&numgu=291&redaz=010G0232&tmstp=1292405356450

MIUR. (s.d.). *Autonomia.* Tratto da Ministero dell'Istruzione Università e Ricerca: https://www.istruzione.it/archivio/web/istruzione/famiglie/autonomia-scolastica.html

MIUR. (s.d.). *DPR n.89 (2010) Regolamento recante revisione dell'assetto ordinamentale, organizzativo e didattico dei licei.* Tratto da Gazzetta ufficiale: https://www.gazzettaufficiale.it/eli/id/2010/06/15/010G0111/sg

Montessori, M. (1943). *Come educare il potenziale umano, Conferenze tenute da Maria Montessori in India nel 1943.* Garzanti, 1970.

Museo Galileo. (s.d.). Tratto da Paradosso meccanico : https://catalogo.museogalileo.it/oggetto/ParadossoMeccanico.html

NGSS. (2023). *APPENDIX F – Science and Engineering Practices in the NGSS.* Tratto da Next Generation Science Standard: https://www.nextgenscience.org/sites/default/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

OECD. (2023). *PISA 2022 Results.* Tratto da OECD: https://www.oecd.org/pisa/publications/

Papert, S. (1980). *Constructionism vs. Instructionism.* (D. I. Harel, A cura di) Tratto da Papert.org: http://www.papert.org/articles/const_inst/const_inst1.html

Piaget, J. (1973). *To understand is to invent_The future of education.* New York: Grossman Publisher_Viking Press.

Project-manus. (2023). *https://project-manus.mit.edu/*.

Recommendation EU. (2018, May 22). *An official website of the European Union: EUR-Lex.* Tratto da Council Recommendation of 22 May 2018 on key competences for lifelong learning: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2018.189.01.0001.01.ENG&toc=OJ:C:2018:189:TOC

Resnick, M. (2014). *Give P's a Chance: Projects, Peers, Passion, Play.* Tratto da MIT_Media Lab: https://www.media.mit.edu/~mres/papers/constructionism-2014.pdf

Resnick, M., & Rosenbaum, E. (2013). Designing for tinkerability. In *Design, make, play: Growing the next generation of STEM innovators* (p. 163-181). Tratto da https://creativetech.mat.ucsb.edu/readings/resnick_rosenbaum_tinkerability.pdf

Shieh, R. S. (2012, September). The impact of Technology-Enabled Active Learning (TEAL) implementation on student performance and teachers' teaching in a high school context. *Computers & Education, 59*(2), p. 206-214.

Stager, G. S. (2016, Settembre 15). Seymour Papert (1928–2016) Father of educational computing. *Nature*, p. 308.

Strubbe, L., & McKagan, S. (2020, March 13). *I suddenly have to move my face-to-face physics/astronomy course online! What should I do?* Tratto da PhysPort, AAPT: https://www.physport.org/recommendations/Entry.cfm?ID=119906

Szpunar, G. (2018). In G. Szpunar, *Documentare per apprendere. La scrittura riflessiva come strumento di formazione (continua) del professionista dell'educazione* (p. pp. 31-41).

Università di Ferrara. (2023). *Dipartimento di Fisica e Scienze della Terra*. Tratto da Università di Ferrara: http://fst.unife.it/it

Vuorikari, R., Ferrari, A., & Punie, Y. (2019, October 11). *Makerspaces for Education and Training: Exploring future implications for Europe.* (E. Commission, A cura di) Tratto da JRC Publications Repository: https://publications.jrc.ec.europa.eu/repository/handle/JRC117481

Wieman, C. E. (2014, 22 May). Large-scale comparison of science teaching methods sends clear message. *Proceedings of the National Academy of Sciences of the United States od America, 111*(23), 8319-8320. Tratto da https://doi.org/10.1073/pnas.1407304111

APPENDIX

4.6.2018 EN Official Journal of the European Union C 189/1

I

(Resolutions, recommendations and opinions)

RECOMMENDATIONS

COUNCIL

COUNCIL RECOMMENDATION

of 22 May 2018

on key competences for lifelong learning

(Text with EEA relevance)

(2018/C 189/01)

THE COUNCIL OF THE EUROPEAN UNION

Having regard to the Treaty on the Functioning of the European Union, and in particular Articles 165 and 166 thereof,

Having regard to the proposal from the European Commission,

Whereas:

(1) The European Pillar of Social Rights [1] states as its first principle that everyone has the right to quality and inclusive education, training and lifelong learning in order to maintain and acquire skills that allow full participation in society and successful transitions in the labour market. It also states the right of everyone 'to timely and tailor-made assistance to improve employment or self-employment prospects, to training and re-qualification, to continued education and to support for job search'. Fostering the development of competences is one of the aims of the vision towards a European Education Area that would be able 'to harness the full potential of education and culture as drivers for jobs, social fairness, active citizenship as well as means to experience European identity in all its diversity' [2].

(2) People need the right set of skills and competences to sustain current standards of living, support high rates of employment and foster social cohesion in the light of tomorrow's society and world of work. Supporting people across Europe in gaining the skills and competences needed for personal fulfilment, health, employability and social inclusion helps to strengthen Europe's resilience in a time of rapid and profound change.

(3) In 2006, the European Parliament and the Council of the European Union adopted a Recommendation on key competences for lifelong learning. In that Recommendation the Member States were asked 'to develop the provision of key competences for all as part of their lifelong learning strategies, including their strategies for achieving universal literacy, and use the 'Key Competences for Lifelong Learning — A European Reference Framework' [3]. Since its adoption, the Recommendation was a key reference document for the development of competence-oriented education, training and learning.

(4) Nowadays, competence requirements have changed with more jobs being subject to automation, technologies playing a bigger role in all areas of work and life, and entrepreneurial, social and civic competences becoming more relevant in order to ensure resilience and ability to adapt to change.

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[1] COM(2017) 250.
[2] COM(2017) 673.
[3] OJ L 394, 30.12.2006, p. 10.

(5) At the same time, international surveys such as the Organisation for Economic Cooperation and Development (OECD) Programme for International Student Assessment (PISA) or the OECD Programme for the International Assessment of Adult Competencies (PIAAC) indicate a constant high share of teenagers and adults with insufficient basic skills. In 2015 one in five pupils had serious difficulties in developing sufficient reading, mathematic or science skills. [1] In some countries up to one third of adults are proficient at only the lowest levels in literacy and numeracy [2]. 44 % of the Union population have low or no (19 %) digital skills [3].

(6) Consequently, investing in basic skills has become more relevant than ever. High quality education, including extra-curricular activities and a broad approach to competence development, improves achievement levels in basic skills. In addition, new ways of learning need to be explored for a society that is becoming increasingly mobile and digital. [4] Digital technologies have an impact on education, training and learning by developing more flexible learning environments adapted to the needs of a highly mobile society [5].

(7) In the knowledge economy, memorisation of facts and procedures is key, but not enough for progress and success. Skills, such as problem solving, critical thinking, ability to cooperate, creativity, computational thinking, self-regulation are more essential than ever before in our quickly changing society. They are the tools to make what has been learned work in real time, in order to generate new ideas, new theories, new products, and new knowledge.

(8) The New Skills Agenda for Europe [6] announced the review of the 2006 Recommendation on key competences for lifelong learning acknowledging that investing in skills and competences and in a shared and updated understanding of key competences is a first step for fostering education, training and non-formal learning in Europe.

(9) Responding to the changes in society and economy, reflecting discussions on the future of work, and following the public consultation on the review of the 2006 Recommendation on key competences, both the Recommendation and the European Reference Framework of key competences for lifelong learning need to be revised and updated.

(10) The development of key competences, their validation and the provision of competence-oriented education, training and learning should be supported by establishing good practices for better support of educational staff in their tasks and improving their education, for updating assessment and validation methods and tools, and for introducing new and innovative forms of teaching and learning [7]. Therefore, basing itself on the experiences of the last decade, this Recommendation should address the challenges in implementing competence-oriented education, training and learning.

(11) Supporting the validation of competences acquired in different contexts will enable individuals to have their competences recognised and obtain full or, where applicable, partial qualifications [8]. It can build on the existing arrangements for the validation of non-formal and informal learning as well as the European Qualification Framework [9], which provides a common reference framework to compare levels of qualifications, indicating the competences required to achieve them. In addition, assessment may help in structuring learning processes and in guidance, helping people to improve their competences also with regard to changing requirements on the labour market [10].

[1] OECD (2016), PISA 2015 results
[2] European Commission (2016), Education and Training Monitor 2016
[3] European Commission's Digital Scoreboard 2017
[4] Reflection Paper on Harnessing Globalisation, COM(2017) 240 final
[5] Rethinking Education: Investing in skills for better socioeconomic outcomes, COM(2012) 669 final
[6] COM(2016) 381 final
[7] Joint Report of the Council and the Commission on the implementation of the strategic framework for European cooperation in education and training (ET 2020) (OJ C 417, 15.12.2015, p. 25).
[8] OJ C 398, 22.12.2012, p. 1.
[9] OJ C 189, 15.6.2017, p. 15.
[10] Council Resolution of 21 November 2008 on better integrating lifelong guidance into lifelong learning strategies (OJ C 319, 13.12.2008, p. 4).

(12) The definition of the set of key competences needed for personal fulfilment, health, employability and social inclusion has been shaped not only by societal and economic developments, but also by various initiatives in Europe during the last decade. Special attention has been given to improving basic skills, investing in language learning, improving digital and entrepreneurial competences, the relevance of common values in the functioning of our societies, and motivating more young people to engage in science related careers. These developments should be reflected in the Reference Framework.

(13) Target 4.7 of the Sustainable Development Goals highlights the need to 'ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development' ([1]). Unesco's Global Action Programme on Education for Sustainable Development affirms that education for sustainable development is an integral element of quality education and key enabler of all other Sustainable Development Goals. This aim is reflected in the revision of the Reference Framework.

(14) The provision of language learning, which is increasingly important for modern societies, intercultural understanding and cooperation, profits from the Common European Framework of Reference for Languages (CEFR). This Framework helps to identify the main elements of the competence and supports the learning process. It also lays the foundation of defining language competences, in particular those referring to foreign languages and is reflected in the update of the Reference Framework.

(15) The development of the Digital Competence Framework and the Entrepreneurship Competence Framework support competence development. Likewise, the Council of Europe's Reference Framework of Competences for Democratic Culture presents a comprehensive set of values, skills and attitudes for an appropriate participation in democratic societies. All of these have been taken into due consideration when updating the Reference Framework.

(16) In order to motivate more young people to engage in science, technology, engineering and mathematics (STEM) related careers, initiatives across Europe started to link science education more closely with the arts and other subjects, using inquiry-based pedagogy, and engaging with a wide range of societal actors and industries. While the definition of those competences has not changed much over the years, the support of competence development in STEM becomes increasingly relevant and should be reflected in this Recommendation.

(17) The importance and relevance of non-formal and informal learning is evident from the experiences acquired through culture, youth work, voluntary work as well as grassroots sport. Non-formal and informal learning play an important role in supporting the development of essential interpersonal, communicative and cognitive skills such as: critical thinking, analytical skills, creativity, problem solving and resilience that facilitate young people's transition to adulthood, active citizenship and working life ([2]). Establishing better cooperation between different learning settings helps promoting a variety of learning approaches and contexts ([3]).

(18) In addressing the development of key competences in a lifelong learning perspective, support should be ensured at all levels of education, training and learning pathways: to develop quality early childhood education and care ([4]), to further enhance school education and ensure excellent teaching ([5]), to provide up-skilling pathways to low-skilled adults ([6]) as well as to further develop initial and continuing vocational education and training and modernise higher education ([7]).

([1]) United Nations Resolution adopted by the General Assembly on 25 September 2015, Transforming our world: the 2030 Agenda for Sustainable Development

([2]) Council conclusions on the role of youth work in supporting young people's development of essential life skills that facilitate their successful transition to adulthood, active citizenship and working life (OJ C 189, 15.6.2017, p. 30).

([3]) Council conclusions on enhancing cross-sectorial policy cooperation to effectively address socioeconomic challenges facing young people (OJ C 172, 27.5.2015, p. 3).

([4]) Council conclusions on the role of early childhood education and primary education in fostering creativity, innovation and digital competence (OJ C 172, 27.5.2015, p. 17).

([5]) Council conclusions on school development and excellent teaching (OJ C 421, 8.12.2017, p. 2).

([6]) Council Recommendation of 19 December 2016 on Upskilling Pathways: New Opportunities for Adults (OJ C 484, 24.12.2016, p. 1).

([7]) Council conclusions on a renewed EU agenda for higher education (OJ C 429, 14.12.2017, p. 3).

(19) This Recommendation should cover a wide range of education, training and learning settings, both formal, non-formal and informal in a lifelong learning perspective. It should seek to establish a shared understanding of competences which can support transitions and cooperation between these different learning settings. It sets out good practices that could address the needs of educational staff which includes teachers, trainers, teacher educators, leaders of education and training institutes, employees in charge of training colleagues, researchers and university lecturers, youth workers and adult educators as well as employers and labour market stakeholders. This Recommendation also addresses institutions and organisations, including social partners and civil society organisations, guiding and supporting people in improving their competences from early age on throughout their lives.

(20) This Recommendation fully respects the principles of subsidiarity and proportionality,

HAS ADOPTED THIS RECOMMENDATION

Member States should:

1. support the right to quality and inclusive education, training and lifelong learning and ensure opportunities for all to develop key competences by making full use of the 'Key Competences for Lifelong Learning — A European Reference Framework' as set out in the Annex, and

1.1. support and reinforce the development of key competences from an early age and throughout life, for all individuals, as part of national lifelong learning strategies;

1.2. support all learners, including those facing disadvantages, or having special needs, to fulfil their potential;

2. support the development of key competences paying special attention to:

2.1. raising the level of achievement of basic skills (literacy, numeracy and basic digital skills) and supporting the development of learning to learn competence as a constantly improved basis for learning and participation in society in a lifelong perspective;

2.2. raising the level of personal, social and learning to learn competence to improve health conscious, future-oriented life management;

2.3. fostering the acquisition of competences in sciences, technology, engineering and mathematics (STEM), taking into account their link to the arts, creativity and innovation and motivating more young people, especially girls and young women, to engage in STEM careers;

2.4. increasing and improving the level of digital competences at all stages of education and training, across all segments of the population;

2.5. nurturing entrepreneurship competence, creativity and the sense of initiative especially among young people, for example by promoting opportunities for young learners to undertake at least one practical entrepreneurial experience during their school education;

2.6. increasing the level of language competences in both official and other languages and supporting learners to learn different languages relevant to their working and living situation and that may contribute to cross-border communication and mobility;

2.7. fostering the development of citizenship competences with the aim of strengthening the awareness of common values, as referred to in Article 2 of the Treaty on European Union and the Charter of Fundamental Rights of the European Union;

2.8. increasing the awareness of all learners and educational staff of the importance of the acquisition of key competences and their relation to society;

3. facilitate the acquisition of key competences by making use of good practices to support the development of the key competences as set out in the Annex, in particular by:

   3.1. promoting a variety of learning approaches and environments, including the adequate use of digital technologies, in education, training and learning settings;

   3.2. providing support to educational staff as well as other stakeholders supporting learning processes, including families, to enhance key competences of learners as part of the approach for lifelong learning in education, training and learning settings;

   3.3. supporting and further developing the assessment and validation of key competences acquired in different settings in line with the Member States' rules and procedures;

   3.4. reinforcing collaboration between education, training and learning settings at all levels, and in different fields, to improve the continuity of learner competence development and the development of innovative learning approaches;

   3.5. reinforcing tools, resources and guidance in education, training, employment and other learning settings to support people in managing their lifelong learning pathways;

4. mainstream the ambitions of the UN Sustainable Development Goals (SDG), in particular within the SDG4.7, into education, training and learning, including by fostering the acquisition of knowledge about limiting the multifaceted nature of climate change and using natural resources in a sustainable way;

5. report through existing frameworks and tools of the Strategic Framework for European Cooperation in Education and Training (ET2020) and any successor framework on experiences and progress in promoting key competences in all education and training sectors, including non-formal and, as far as possible, informal learning;

HEREBY WELCOMES THAT THE COMMISSION WITH DUE REGARD TO MEMBER STATES' COMPETENCES:

6. supports the implementation of the Recommendation and the use of the European Reference Framework by facilitating mutual learning among Member States and developing in cooperation with Member States reference material and tools such as:

   6.1. where appropriate, frameworks for specific competences which facilitate development and assessment of competences ([1]);

   6.2. evidence-based guidance material on new forms of learning and supportive approaches;

   6.3. support tools for educational staff, and other stakeholders, such as on-line training courses, self-assessment tools ([2]), networks, including eTwinning and the Electronic Platform for Adult Learning in Europe (EPALE);

   6.4. approaches to the assessment and support of validation of key competences acquired following up on previous work in the context of ET2020 ([3]) and any successor framework;

7. supports initiatives to further develop and promote education for sustainable development with regard to the UN Sustainable Development Goal 4 on inclusive and equitable quality education and lifelong learning opportunities for all;

8. reports on experiences and good practices to enhance key competences of learners as part of the approach for lifelong learning in education, training and learning settings in the Union through existing frameworks and tools.

([1]) Based on the experiences and expertise developed in creating the Common European Framework of References for Languages, the Digital Competence Framework and the Entrepreneurship Competence Framework
([2]) Such as the Digital Competence Framework
([3]) Assessment of Key Competences in initial education and training: Policy Guidance, SWD (2012) 371

This Recommendation replaces the Recommendation of the European Parliament and of the Council of 18 December 2006 on key competences for lifelong learning.

Done at Brussels, 22 May 2018.

For the Council

The President

K. VALCHEV

ANNEX

KEY COMPETENCES FOR LIFELONG LEARNING

A EUROPEAN REFERENCE FRAMEWORK

Background and aims

Everyone has the right to quality and inclusive education, training and life-long learning in order to maintain and acquire skills that enable them to participate fully in society and manage successfully transitions in the labour market.

Everyone has the right to timely and tailor-made assistance to improve employment or self-employment prospects. This includes the right to receive support for job search, training and re-qualification.

These principles are defined in the European 'Pillar of Social Rights'.

In a rapidly changing and highly interconnected world, each person will need a wide range of skills and competences and to develop them continually throughout life. The key competences as defined in this Reference Framework aim to lay the foundation for achieving more equal and more democratic societies. They respond to the need for inclusive and sustainable growth, social cohesion and further development of the democratic culture.

The main aims of the Reference Framework are to:

a. identify and define the key competences necessary for employability, personal fulfilment and health, active and responsible citizenship and social inclusion;

b. provide a European reference tool for policy makers, education and training providers, educational staff, guidance practitioners, employers, public employment services and learners themselves;

c. support efforts at European, national, regional and local level to foster competence development in a lifelong learning perspective.

Key competences

For the purposes of this Recommendation, competences are defined as a combination of knowledge, skills and attitudes, where:

d. knowledge is composed of the facts and figures, concepts, ideas and theories which are already established and support the understanding of a certain area or subject;

e. skills are defined as the ability and capacity to carry out processes and use the existing knowledge to achieve results;

f. attitudes describe the disposition and mind-sets to act or react to ideas, persons or situations.

Key competences are those which all individuals need for personal fulfilment and development, employability, social inclusion, sustainable lifestyle, successful life in peaceful societies, health-conscious life management and active citizenship. They are developed in a lifelong learning perspective, from early childhood throughout adult life, and through formal, non-formal and informal learning in all contexts, including family, school, workplace, neighbourhood and other communities.

The key competences are all considered equally important; each of them contributes to a successful life in society. Competences can be applied in many different contexts and in a variety of combinations. They overlap and interlock; aspects essential to one domain will support competence in another. Skills such as critical thinking, problem solving, team work, communication and negotiation skills, analytical skills, creativity, and intercultural skills are embedded throughout the key competences.

The Reference Framework sets out eight key competences:

— Literacy competence,

— Multilingual competence,

— Mathematical competence and competence in science, technology and engineering,

— Digital competence,

— Personal, social and learning to learn competence,

— Citizenship competence,

— Entrepreneurship competence,

— Cultural awareness and expression competence.

1. **Literacy competence**

Literacy is the ability to identify, understand, express, create, and interpret concepts, feelings, facts and opinions in both oral and written forms, using visual, sound/audio and digital materials across disciplines and contexts. It implies the ability to communicate and connect effectively with others, in an appropriate and creative way.

Development of literacy forms the basis for further learning and further linguistic interaction. Depending on the context, literacy competence can be developed in the mother tongue, the language of schooling and/or the official language in a country or region.

Essential knowledge, skills and attitudes related to this competence

This competence involves the knowledge of reading and writing and a sound understanding of written information and thus requires an individual to have knowledge of vocabulary, functional grammar and the functions of language. It includes an awareness of the main types of verbal interaction, a range of literary and non-literary texts, and the main features of different styles and registers of language.

Individuals should have the skills to communicate both orally and in writing in a variety of situations and to monitor and adapt their own communication to the requirements of the situation. This competence also includes the abilities to distinguish and use different types of sources, to search for, collect and process information, to use aids, and to formulate and express one's oral and written arguments in a convincing way appropriate to the context. It encompasses critical thinking and ability to assess and work with information.

A positive attitude towards literacy involves a disposition to critical and constructive dialogue, an appreciation of aesthetic qualities and an interest in interaction with others. This implies an awareness of the impact of language on others and a need to understand and use language in a positive and socially responsible manner.

2. **Multilingual competence** ([1])

This competence defines the ability to use different languages appropriately and effectively for communication. It broadly shares the main skill dimensions of literacy: it is based on the ability to understand, express and interpret concepts, thoughts, feelings, facts and opinions in both oral and written form (listening, speaking, reading and writing) in an appropriate range of societal and cultural contexts according to one's wants or needs. Languages competences integrate a historical dimension and intercultural competences. It relies on the ability to mediate between different languages and media, as outlined in the Common European Framework of Reference. As appropriate, it can include maintaining and further developing mother tongue competences, as well as the acquisition of a country's official language(s) ([2]).

Essential knowledge, skills and attitudes related to this competence

This competence requires knowledge of vocabulary and functional grammar of different languages and an awareness of the main types of verbal interaction and registers of languages. Knowledge of societal conventions, and the cultural aspect and variability of languages is important.

Essential skills for this competence consist of the ability to understand spoken messages, to initiate, sustain and conclude conversations and to read, understand and draft texts, with different levels of proficiency in different languages, according to the individual's needs. Individuals should be able to use tools appropriately and learn languages formally, non-formally and informally throughout life.

A positive attitude involves the appreciation of cultural diversity, an interest and curiosity about different languages and intercultural communication. It also involves respect for each person's individual linguistic profile, including both respect for the mother tongue of persons belonging to minorities and/or with a migrant background and appreciation for a country's official language(s) as a common framework for interaction.

([1]) While the Council of Europe uses the term '*plurilingualism*' for referring to multiple language competences of individuals, European Union's official documents use '*multilingualism*' to describe both individual competences and societal situations. This is partly due to difficulties making a distinction between *plurilingual* and *multilingual* in other languages than English and French.

([2]) The acquisition of classical languages such as Ancient Greek and Latin is also included. Classical languages are the source of many modern languages and therefore can facilitate language learning in general.

3. **Mathematical competence and competence in science, technology, engineering**

A. Mathematical competence is the ability to develop and apply mathematical thinking and insight in order to solve a range of problems in everyday situations. Building on a sound mastery of numeracy, the emphasis is on process and activity, as well as knowledge. Mathematical competence involves, to different degrees, the ability and willingness to use mathematical modes of thought and presentation (formulas, models, constructs, graphs, charts).

B. Competence in science refers to the ability and willingness to explain the natural world by making use of the body of knowledge and methodology employed, including observation and experimentation, in order to identify questions and to draw evidence-based conclusions. Competences in technology and engineering are applications of that knowledge and methodology in response to perceived human wants or needs. Competence in science, technology and engineering involves an understanding of the changes caused by human activity and responsibility as an individual citizen.

Essential knowledge, skills and attitudes related to this competence

A. Necessary knowledge in mathematics includes a sound knowledge of numbers, measures and structures, basic operations and basic mathematical presentations, an understanding of mathematical terms and concepts, and an awareness of the questions to which mathematics can offer answers.

An individual should have the skills to apply basic mathematical principles and processes in everyday contexts at home and work (e.g. financial skills), and to follow and assess chains of arguments. An individual should be able to reason mathematically, understand mathematical proof and communicate in mathematical language, and to use appropriate aids including statistical data and graphs and to understand the mathematical aspects of digitalisation.

A positive attitude in mathematics is based on the respect for truth and a willingness to look for reasons and to assess their validity.

B. For science, technology and engineering, essential knowledge comprises the basic principles of the natural world, fundamental scientific concepts, theories, principles and methods, technology and technological products and processes, as well as an understanding of the impact of science, technology, engineering and human activity in general on the natural world. These competences should enable individuals to better understand the advances, limitations and risks of scientific theories, applications and technology in societies at large (in relation to decision-making, values, moral questions, culture, etc.).

Skills include the understanding of science as a process for the investigation through specific methodologies, including observations and controlled experiments, the ability to use logical and rational thought to verify a hypothesis and the readiness to discard one's own convictions when they contradict new experimental findings. It includes the ability to use and handle technological tools and machines as well as scientific data to achieve a goal or to reach an evidence-based decision or conclusion. Individuals should also be able to recognise the essential features of scientific inquiry and have the ability to communicate the conclusions and reasoning that led to them.

Competence includes an attitude of critical appreciation and curiosity, a concern for ethical issues and support for both safety and environmental sustainability, in particular as regards scientific and technological progress in relation to oneself, family, community, and global issues.

4. **Digital competence**

Digital competence involves the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society. It includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), safety (including digital well-being and competences related to cybersecurity), intellectual property related questions, problem solving and critical thinking.

Essential knowledge, skills and attitudes related to this competence

Individuals should understand how digital technologies can support communication, creativity and innovation, and be aware of their opportunities, limitations, effects and risks. They should understand the general principles, mechanisms and logic underlying evolving digital technologies and know the basic function and use of different devices, software, and networks. Individuals should take a critical approach to the validity, reliability and impact of information and data made available by digital means and be aware of the legal and ethical principles involved in engaging with digital technologies.

Individuals should be able to use digital technologies to support their active citizenship and social inclusion, collaboration with others, and creativity towards personal, social or commercial goals. Skills include the ability to use, access, filter, evaluate, create, program and share digital content. Individuals should be able to manage and protect information, content, data, and digital identities, as well as recognise and effectively engage with software, devices, artificial intelligence or robots.

Engagement with digital technologies and content requires a reflective and critical, yet curious, open-minded and forward-looking attitude to their evolution. It also requires an ethical, safe and responsible approach to the use of these tools.

5. **Personal, social and learning to learn competence**

Personal, social and learning to learn competence is the ability to reflect upon oneself, effectively manage time and information, work with others in a constructive way, remain resilient and manage one's own learning and career. It includes the ability to cope with uncertainty and complexity, learn to learn, support one's physical and emotional well-being, to maintain physical and mental health, and to be able to lead a health-conscious, future-oriented life, empathize and manage conflict in an inclusive and supportive context.

Essential knowledge, skills and attitudes related to this competence

For successful interpersonal relations and social participation it is essential to understand the codes of conduct and rules of communication generally accepted in different societies and environments. Personal, social and learning to learn competence requires also knowledge of the components of a healthy mind, body and lifestyle. It involves knowing one's preferred learning strategies, knowing one's competence development needs and various ways to develop competences and search for the education, training and career opportunities and guidance or support available.

Skills include the ability to identify one's capacities, focus, deal with complexity, critically reflect and make decisions. This includes the ability to learn and work both collaboratively and autonomously and to organise and persevere with one's learning, evaluate and share it, seek support when appropriate and effectively manage one's career and social interactions. Individuals should be resilient and able to cope with uncertainty and stress. They should be able to communicate constructively in different environments, collaborate in teams and negotiate. This includes showing tolerance, expressing and understanding different viewpoints, as well as the ability to create confidence and feel empathy.

The competence is based on a positive attitude toward one's personal, social and physical well-being and learning throughout one's life. It is based on an attitude of collaboration, assertiveness and integrity. This includes respecting diversity of others and their needs and being prepared both to overcome prejudices and to compromise. Individuals should be able to identify and set goals, motivate themselves, and develop resilience and confidence to pursue and succeed at learning throughout their lives. A problem-solving attitude supports both the learning process and the individual's ability to handle obstacles and change. It includes the desire to apply prior learning and life experiences and the curiosity to look for opportunities to learn and develop in a variety of life contexts.

6. **Citizenship competence**

Citizenship competence is the ability to act as responsible citizens and to fully participate in civic and social life, based on understanding of social, economic, legal and political concepts and structures, as well as global developments and sustainability.

Essential knowledge, skills and attitudes related to this competence

Citizenship competence is based on knowledge of basic concepts and phenomena relating to individuals, groups, work organisations, society, economy and culture. This involves an understanding of the European common values, as expressed in Article 2 of the Treaty on European Union and the Charter of Fundamental Rights of the European Union. It includes knowledge of contemporary events, as well as a critical understanding of the main developments in national, European and world history. In addition, it includes an awareness of the aims, values and policies of social and political movements, as well as of sustainable systems, in particular climate and demographic change at the global level and their underlying causes. Knowledge of European integration as well as an awareness of diversity and cultural identities in Europe and the world is essential. This includes an understanding of the multi-cultural and socioeconomic dimensions of European societies, and how national cultural identity contributes to the European identity.

Skills for citizenship competence relate to the ability to engage effectively with others in common or public interest, including the sustainable development of society. This involves critical thinking and integrated problem solving skills, as well as skills to develop arguments and constructive participation in community activities, as well as in decision-making at all levels, from local and national to the European and international level. This also involves the ability to access, have a critical understanding of, and interact with both traditional and new forms of media and understand the role and functions of media in democratic societies.

Respect for human rights as a basis for democracy lays the foundations for a responsible and constructive attitude. Constructive participation involves willingness to participate in democratic decision-making at all levels and civic activities. It includes support for social and cultural diversity, gender equality and social cohesion, sustainable lifestyles, promotion of culture of peace and non-violence, a readiness to respect the privacy of others, and to take responsibility for the environment. Interest in political and socioeconomic developments, humanities and intercultural communication is needed to be prepared both to overcome prejudices and to compromise where necessary and to ensure social justice and fairness.

7. **Entrepreneurship competence**

Entrepreneurship competence refers to the capacity to act upon opportunities and ideas, and to transform them into values for others. It is founded upon creativity, critical thinking and problem solving, taking initiative and perseverance and the ability to work collaboratively in order to plan and manage projects that are of cultural, social or financial value.

Essential knowledge, skills and attitudes related to this competence

Entrepreneurship competence requires knowing that there are different contexts and opportunities for turning ideas into action in personal, social and professional activities, and an understanding of how these arise. Individuals should know and understand approaches to planning and management of projects, which include both processes and resources. They should have an understanding of economics and the social and economic opportunities and challenges facing an employer, organisation or society. They should also be aware of ethical principles and challenges of sustainable development and have self-awareness of their own strengths and weaknesses.

Entrepreneurial skills are founded on creativity which includes imagination, strategic thinking and problem-solving, and critical and constructive reflection within evolving creative processes and innovation. They include the ability to work both as an individual and collaboratively in teams, to mobilize resources (people and things) and to sustain activity. This includes the ability to make financial decisions relating to cost and value. The ability to effectively communicate and negotiate with others, and to cope with uncertainty, ambiguity and risk as part of making informed decisions is essential.

An entrepreneurial attitude is characterised by a sense of initiative and agency, pro-activity, being forward-looking, courage and perseverance in achieving objectives. It includes a desire to motivate others and value their ideas, empathy and taking care of people and the world, and accepting responsibility taking ethical approaches throughout the process.

8. **Cultural awareness and expression competence**

Competence in cultural awareness and expression involves having an understanding of and respect for how ideas and meaning are creatively expressed and communicated in different cultures and through a range of arts and other cultural forms. It involves being engaged in understanding, developing and expressing one's own ideas and sense of place or role in society in a variety of ways and contexts.

Essential knowledge, skills and attitudes related to this competence

This competence requires knowledge of local, national, regional, European and global cultures and expressions, including their languages, heritage and traditions, and cultural products, and an understanding of how these expressions can influence each other as well as the ideas of the individual. It includes understanding the different ways of communicating ideas between creator, participant and audience within written, printed and digital texts, theatre, film, dance, games, art and design, music, rituals, and architecture, as well as hybrid forms. It requires an understanding of one's own developing identity and cultural heritage within a world of cultural diversity and how arts and other cultural forms can be a way to both view and shape the world.

Skills include the ability to express and interpret figurative and abstract ideas, experiences and emotions with empathy, and the ability to do so in a range of arts and other cultural forms. Skills also include the ability to identify and realise opportunities for personal, social or commercial value through the arts and other cultural forms and the ability to engage in creative processes, both as an individual and collectively.

It is important to have an open attitude towards, and respect for, diversity of cultural expression together with an ethical and responsible approach to intellectual and cultural ownership. A positive attitude also includes a curiosity about the world, an openness to imagine new possibilities, and a willingness to participate in cultural experiences.

Supporting the development of key competences

Key competences are a dynamic combination of the knowledge, skills and attitudes a learner needs to develop throughout life, starting from early age onwards. High quality and inclusive education, training and lifelong learning provides opportunities for all to develop key competences, therefore competence-oriented approaches can be used in all education, training and learning settings throughout life.

In support of competence-oriented education, training and learning in lifelong learning context, three challenges have been identified: the use of a variety of learning approaches and contexts; support for teachers and other educational staff; and assessment and validation of competence development. In order to address those challenges, certain examples of good practices have been identified.

a. *A variety of learning approaches and environments*

(a) Cross-discipline learning, partnerships between different education levels, training and learning actors, including from the labour market, as well as concepts such as whole school approaches with its emphasis on collaborative teaching and learning and active participation and decision-making of learners can enrich learning. Cross-discipline learning also allows for strengthening the connectivity between the different subjects in the curriculum, as well as establishing a firm link between what is being taught and societal change and relevance. Cross-sectoral cooperation between education and training institutions and external actors from business, arts, sport and youth community, higher education or research institutions, can be key to effective competence development.

(b) Acquisition of basic skills as well as broader competence development can be fostered by systematically complementing academic learning with social and emotional learning, arts, health-enhancing physical activities supporting health conscious, future-oriented and physically active life styles. Strengthening personal, social and learning competences from early age can provide a foundation for development of basic skills.

(c) Learning methodologies such as inquiry-based, project-based, blended, arts- and games-based learning can increase learning motivation and engagement. Equally, experimental learning, work-based learning and scientific methods in science, technology, engineering and mathematics (STEM) can foster development of a range of competences.

(d) Learners, educational staff and learning providers could be encouraged to use digital technologies to improve learning and to support the development of digital competences. For example, by participating in Union initiatives such as 'The EU Code Week'. The use of self-assessment tools, such as the SELFIE tool, could improve the digital capacity of education, training and learning providers.

(e) Specific opportunities for entrepreneurial experiences, traineeships in companies or entrepreneurs visiting education and training institutions including practical entrepreneurial experiences, such as creativity challenges, start-ups, student-led community initiatives, business simulations or entrepreneurial project-based learning, could be particularly beneficial for young people, but also for adults and for teachers. Young people could be given the opportunity to have at least one entrepreneurial experience during their school education. School, community and business partnerships and platforms at local level, notably in rural areas, can be key players in spreading entrepreneurial education. Appropriate training and support for teachers and principals could be crucial to create sustained progress and leadership.

(f) Multilingual competence can be developed by close cooperation with education, training and learning settings abroad, the mobility of educational staff and learners and the use of eTwinning, EPALE and or similar on-line portals.

(g) All learners, including those facing disadvantages, or having special needs, could be given adequate support in inclusive settings to fulfil their educational potential. Such support could consist of language, academic or socio-emotional support, peer coaching, extra-curricular activity, career guidance or material support.

(h) The collaboration between education, training and learning settings at all levels can be key to improve the continuity of learner competence development throughout life and for developing innovative learning approaches.

(i) Cooperation between education and training and non-educational partners in local communities and employers in combination with formal, non-formal and informal learning can support competence development and ease the transition from education to work as well as from work to education.

b. *Support for educational staff*

(a) Embedding competence-oriented approaches to education, training and learning in initial education and continuing professional development can help educational staff in changing teaching and learning in their settings and to be competent in implementing the approach.

(b) Educational staff could be supported in developing competence-oriented approaches in their specific contexts by staff exchanges and peer learning, and peer counselling allowing for flexibility and autonomy in organising learning, through networks, collaboration and communities of practice.

(c) Educational staff could be provided assistance in creating innovative practices, taking part in research and making appropriate use of new technologies, including digital technologies, for competence-oriented approaches in teaching and learning.

(d) Guidance could be provided for educational staff, access to centres of expertise, appropriate tools and materials can enhance the quality of teaching and learning methods and practice.

c. *Assessment and validation of competence development*

(a) Key competence descriptions could translate into frameworks of learning outcomes that could be complemented with suitable tools for diagnostic, formative and summative assessment and validation at appropriate levels ([1]).

(b) Digital technologies, in particular, could contribute to capturing the multiple dimensions of learner progression, including entrepreneurial learning.

(c) Different approaches to assessment of key competences in non-formal and informal learning settings could be developed, including related activities of employers, guidance practitioners and social partners. These should be available to everyone, and especially to low skilled individuals to support their progression to further learning.

(d) Validation of learning outcomes acquired through non-formal and informal learning could expand and become more robust, in line with the Council Recommendation on the Validation of prior non-formal and informal learning, including different validation processes. Also the use of tools such as Europass and Youthpass, which serve as tools for documentation and self-assessment, may support the validation process.

([1]) E.g. the Common European Framework of References for Languages, the Digital Competence Framework, the Entrepreneurship Competence Framework as well as PISA competence descriptions provide supporting material for assessment of competences.

LINEE GUIDA PER LE DISCIPLINE STEM

Sommario

Linee guida per le discipline STEM

Le presenti Linee guida, emanate ai sensi dell'articolo 1, comma 552, lett. *a)* della legge 197 del 29 dicembre 2022, sono finalizzate ad introdurre *"nel piano triennale dell'offerta formativa delle istituzioni scolastiche dell'infanzia, del primo e del secondo ciclo di istruzione e nella programmazione educativa dei servizi educativi per l'infanzia, azioni dedicate a rafforzare nei curricoli lo sviluppo delle competenze matematico-scientifico-tecnologiche e digitali legate agli specifici campi di esperienza e l'apprendimento delle discipline STEM, anche attraverso metodologie didattiche innovative"*. Le Linee guida attuano la riforma inserita nel Piano nazionale di ripresa e resilienza e contribuiscono al raggiungimento degli obiettivi dell'investimento "Nuove competenze e nuovi linguaggi", con la finalità di "*sviluppare e rafforzare le competenze STEM, digitali e di innovazione in tutti i cicli scolastici, dall'asilo nido*[1] *alla scuola secondaria di secondo grado, con l'obiettivo di incentivare le iscrizioni ai curricula STEM terziari, in particolare per le donne*".

Perché rinforzare le discipline STEM

Come è noto, STEM è l'acronimo inglese riferito a diverse discipline: Science, Technology, Engineering e Mathematics, e indica, pertanto, l'insieme delle materie scientifiche-tecnologiche-ingegneristiche.

L'acronimo è nato negli Stati Uniti a partire dagli anni 2000[2] per indicare un gruppo di discipline ritenute necessarie allo sviluppo di conoscenze e competenze scientifico-tecnologiche richieste prevalentemente dal mondo economico e lavorativo. Nell'ambito del dibattito sulle interconnessioni tra istruzione, in primo luogo universitaria, e lavoro, risultò evidente, anche sulla base degli esiti di ricerche internazionali sul livello di preparazione degli studenti, quali le indagini PISA[3] e TIMSS[4], la presenza di alte percentuali di studenti con

[1] La dizione "asilo nido" utilizzata nel PNRR corrisponde ai servizi educativi previsti dal decreto legislativo 65/2017
[2] National Foundation 2001
[3] Programme International Student Assessment
[4] Trends in International Mathematics and Science Study

scarse competenze nelle discipline scientifiche, con conseguenti ripercussioni sul mercato del lavoro e sullo sviluppo economico.

Gli esiti di questi studi spinsero i governi di diversi Paesi a ricercare soluzioni per migliorare il processo di insegnamento-apprendimento delle discipline scientifiche e tecnologiche, sia incentivando l'iscrizione degli studenti, e soprattutto delle studentesse, a percorsi post-secondari attinenti alle STEM, sia individuando le modalità più efficaci e stimolanti per l'insegnamento di queste discipline, anche secondo approcci interdisciplinari.

L'approccio STEM parte dal presupposto che le sfide di una modernità sempre più complessa e in costante mutamento non possono essere affrontate che con una prospettiva interdisciplinare, che consente di integrare e contaminare abilità provenienti da discipline diverse (scienza e matematica con tecnologia e ingegneria) intrecciando teoria e pratica per lo sviluppo di nuove competenze, anche trasversali.

Per questa ragione vengono indicate con "4C" le competenze potenziate nell'approccio integrato STEM:

- Critical thinking (pensiero critico)
- Communication (comunicazione)
- Collaboration (collaborazione)
- Creativity (creatività)

Più recentemente, e nella stessa prospettiva volta a ricercare soluzioni per i problemi mondiali, l'Agenda ONU 2030, tra le finalità elencate nell'Obiettivo 4 - Traguardi per una istruzione di qualità - prevede di incrementare le competenze scientifiche e tecnico-professionali della popolazione, di eliminare le disparità di genere e favorire l'accesso all'istruzione e alla formazione anche alle persone più vulnerabili, garantendo che la popolazione giovane acquisisca sufficienti e consolidate competenze di base linguistiche e logico-matematiche.[5]

L'importanza della matematica nell'ambito delle discipline STEM

Perché la matematica è così importante per la società attuale? La risposta più naturale, ma anche più banale, è che è utile. Questa risposta, però, è ingenerosa oltre che parziale. D'altra parte, sorprendentemente, la matematica è *il linguaggio in cui è scritto il gran libro della natura*[6].

Da sempre la matematica si è sviluppata in relazione alle esigenze della vita quotidiana: il calcolo per fornire una risposta a problemi quali lo studio di un moto, il calcolo di aree e volumi, le equazioni dell'aerodinamica, ecc..

Grazie alla matematica, alla fisica e alle scienze sperimentali, l'uomo è stato capace di intervenire sull'ambiente che lo circonda. Tutta la tecnologia prodotta è figlia di questo azzardo, della scommessa che gli uomini non sono fatti *a viver come bruti, ma per seguir virtute e canoscenza*[7].

Tutte le scienze fisiche e sperimentali seguono l'approccio matematico. Spinoza descriveva il metodo scientifico come un processo induttivo-deduttivo: dall'osservazione, tramite l'induzione, si arriva alla formulazione di leggi universali che, tramite un processo deduttivo, si applicano in altre situazioni.

La matematica si basa proprio su questo equilibrio fra astrazione ed applicazione. Solo mera astrazione rende la matematica sterile e noiosa; d'altra parte, una matematica solo diretta alle applicazioni fa perdere in creatività ed innovazione. Bisogna saper coniugare questi due aspetti anche nell'insegnamento.

L'universo sembra essere scritto non solo in un linguaggio matematico, perché sembra anche prediligere equazioni semplici ed eleganti. In "Dynamica de potentia" W. G. Leibniz utilizza il latino, inteso come lingua universale, per approcciare fenomeni scientifici. La storia della scienza, le civiltà classiche, la

[5] Trasformare il nostro mondo: l'Agenda 2030 per lo Sviluppo Sostenibile. ONU, 2015
[6] Cfr. Galileo Galilei, "Il saggiatore"
[7] Dante Alighieri, Divina Commedia, Inferno, Canto XXVI

grammatica latina, possono pertanto contribuire allo sviluppo delle conoscenze matematiche, scientifiche, tecnologiche nonché delle competenze attese dalle discipline STEM, in una visione armonica della formazione dei giovani e in un orizzonte di unitarietà della cultura. Per questo si è passati dal paradigma STEM a quello olistico di STEAM.

Lo studio delle materie STEM permette di non "subire" la tecnologia che ci circonda: da Internet alla musica elettronica, dallo sport al cinema con i suoi effetti speciali. Tramite la cosiddetta "*matematica del cittadino*" si possono formare studenti capaci di interpretare i tempi moderni proiettandosi verso il futuro tecnologico.

La società attuale ci sommerge di informazioni non sempre veritiere. Compito della scuola è anche quello di far diventare tutti, nessuno escluso, cittadini consapevoli con un bagaglio di adeguate conoscenze scientifiche e capacità logiche-deduttive che li rendano in grado di distinguere il vero dal falso. Si vuole raggiungere questo obiettivo, insegnando la matematica in un modo non solo procedurale ma anche laboratoriale.

Come diceva Maria Montessori, *per insegnare bisogna emozionare*. Solo così si genererà passione verso le discipline STEM. Non solo noiose verifiche procedurali, ma anche applicazioni, esperimenti laboratoriali, giochi e sfide a cui tutti gli studenti possono partecipare. Come non esistono bambini stonati, ma solo bambini che non hanno avuto una giusta educazione musicale, così non esistono bambini che non comprendono la matematica, ma solo bambini che non hanno avuto la giusta educazione. Occorre trovare il modo di interessarli e renderli partecipi. Le linee guida propongono di raggiungere questo risultato in molteplici modi, anche per superare le differenze sia di genere che socioeconomiche: utilizzando le nuove tecnologie didattiche a disposizione, favorendo la formazione degli insegnanti sia in itinere che all'inizio del loro percorso, promuovendo la diffusione di nuovi saperi come l'informatica.

Le discipline STEM nel contesto europeo

A livello europeo, il sostegno allo sviluppo delle competenze negli ambiti STEM ha trovato espressione nella Raccomandazione sulle competenze chiave per l'apprendimento permanente del 2018. Rispetto alla precedente formulazione del 2006, la nuova Raccomandazione ha previsto tra le otto competenze, la **competenza matematica e competenza in scienze, tecnologie e ingegneria**. Con specifico riguardo ai contesti di apprendimento, viene ribadito che *"metodi di apprendimento sperimentali, l'apprendimento basato sul lavoro e su metodi scientifici in scienza, tecnologia, ingegneria e matematica (STEM) possono promuovere lo sviluppo di varie competenze"*[8].

Più in generale, la Commissione europea promuove, a partire dall'istruzione terziaria, l'evoluzione dell'idea STEM in STEAM (dove A identifica l'Arte e, di conseguenza, le discipline umanistiche) come "*un insieme multidisciplinare di approcci all'istruzione che rimuove le barriere tradizionali tra materie e discipline per collegare l'educazione STEM e ICT (tecnologie dell'informazione e della comunicazione) con le arti, le scienze umane e sociali*"[9]. Il Parlamento europeo con la Risoluzione del 10 giugno 2021 ha introdotto specifiche proposte per la promozione della parità tra donne e uomini in materia di istruzione e occupazione nel campo della scienza, della tecnologia, dell'ingegneria e della matematica (STEM)[10].

In questa prospettiva si pone anche il Piano d'azione per l'istruzione digitale 2021-2027 - Ripensare l'istruzione e la formazione per l'era digitale[11], secondo il quale "*l'approccio STEAM per l'apprendimento e l'insegnamento collega le discipline STEM e altri settori di studio. Promuove competenze trasversali quali le competenze digitali, il pensiero critico, la capacità di risolvere problemi, la gestione e lo spirito imprenditoriale. Promuove inoltre la cooperazione con partner non accademici e risponde alle sfide economiche, ambientali, politiche e sociali. L'approccio STEAM incoraggia la combinazione di conoscenze necessarie nel mondo reale e della curiosità naturale*".

[8] https://eur-lex.europa.eu/legal-content/IT/TXT/PDF/?uri=CELEX:32018H0604(01)
[9] https://education.ec.europa.eu/it/education-levels/higher-education/relevant-and-high-quality-higher-education
[10] https://eur-lex.europa.eu/legal-content/IT/TXT/PDF/?uri=CELEX:52021IP0296&from=EN
[11] https://education.ec.europa.eu/it/focus-topics/digital-education/action-plan, Commissione europea, 2020

Le discipline STEM negli ordinamenti e nei curricoli italiani

Il curricolo italiano riferito ai vari gradi di istruzione non presenta specifici riferimenti alle STEM nel loro complesso, essendo matematica, scienze, tecnologia e, ove prevista, ingegneria, affidate spesso a docenti appartenenti a diverse classi di concorso. Con particolare riferimento al secondo ciclo, i curricoli sono differenziati a seconda degli indirizzi di studio e possono prevedere, anche tra le discipline fondanti, diversi livelli di approfondimento delle discipline scientifiche.

Ferma restando la valutazione delle competenze logico-matematiche con prova scritta nell'esame di Stato conclusivo del primo ciclo di istruzione e delle competenze di matematica, informatica o tecnologia con seconda prova scritta nazionale in taluni indirizzi di scuola secondaria di secondo grado, le uniche competenze riferite alle discipline STEM rilevate con prove standardizzate a livello nazionale riguardano la matematica.

Dagli esiti delle prove Invalsi svolte nell'anno scolastico 2021/2022[12] dopo il lungo periodo pandemico emerge che le difficoltà nell'apprendimento in matematica, già evidenziate negli anni precedenti, divengono ancora più preoccupanti se si considerano le differenze territoriali, di origine sociale e anche di genere. Inoltre, tali differenze si acuiscono al crescere del grado scolastico, venendo meno l'effetto perequativo della scuola.

Tuttavia, è evidente lo sforzo che, attraverso il Piano Nazionale Scuola Digitale (PNSD), i progetti PON finanziati con i fondi strutturali europei e, più recentemente il Piano Nazionale di Ripresa e Resilienza (PNRR), nell'ambito del quale è stato anche adottato il Piano "Scuola 4.0", è stato compiuto e si sta compiendo per incentivare la diffusione di metodologie didattiche innovative basate sul problem solving, sulla risoluzione di problemi reali, sulla interconnessione dei contenuti per lo sviluppo di competenze matematico-scientifico-tecnologiche.

Le discipline STEM nel Piano nazionale di ripresa e resilienza

La Raccomandazione del Consiglio dell'Unione europea sul programma nazionale di riforma 2020 dell'Italia (COM(2020) 512 final) ha richiesto al nostro Paese di investire nell'apprendimento a distanza, nonché nell'infrastruttura e nelle competenze digitali di educatori e discenti, anche **rafforzando i percorsi didattici relativi alle discipline STEM**. In risposta a tale Raccomandazione, il PNRR ha previsto una specifica linea di investimento, denominata "Nuove competenze e nuovi linguaggi" (Missione 4, Componente 1, Investimento 3.1), cui è correlata l'adozione di specifiche norme di legislazione primaria, introdotte dall'articolo 1, commi 552-553, della legge n. 197 del 2022. La misura promuove l'integrazione, all'interno dei curricula di tutti i cicli scolastici, di attività, metodologie e contenuti volti a sviluppare le competenze STEM, digitali e di innovazione, secondo un approccio di piena interdisciplinarità e garantendo pari opportunità nell'accesso alle carriere STEM, in tutte le scuole. Per il PNRR "*l'intervento sulle discipline STEM - comprensive anche dell'introduzione alle neuroscienze - agisce su un nuovo paradigma educativo trasversale di carattere metodologico*".

Per sostenere lo sviluppo delle competenze STEM, il PNRR investe importanti risorse sia per rafforzare l'educazione e la formazione degli alunni e degli studenti[13] sia per la formazione dei docenti[14], a favore di tutte le istituzioni scolastiche. La linea di investimento "Scuola 4.0" e il relativo "Piano Scuola 4.0" hanno

[12] https://invalsi-areaprove.cineca.it/docs/2022/rilevazioni_nazionali/rapporto/Sintesi_Prove_INVALSI_2022.pdf

[13] Con decreto del Ministro dell'istruzione e del merito 12 aprile 2023, n. 65, sono stati destinati a tutte le scuole 600 milioni di euro per realizzazione di percorsi didattici, formativi e di orientamento per alunni e studenti finalizzati a promuovere l'integrazione, all'interno dei curricula di tutti i cicli scolastici, di attività, metodologie e contenuti volti a sviluppare le competenze STEM, digitali e di innovazione,

[14] Con decreto del Ministro dell'istruzione e del merito 12 aprile 2023, n. 66, sono stati ripartiti 450 milioni di euro a tutte le scuole quali nodi formativi locali del sistema di formazione continua per la transizione digitale finalizzato alla realizzazione di percorsi formativi per il personale scolastico sulla transizione digitale nella didattica e nell'organizzazione scolastica, nell'ambito della linea di investimento 2.1 "*Didattica digitale integrata e formazione alla transizione digitale per il personale scolastico*" della Missione 4, Componente 1, del Piano Nazionale di Ripresa e Resilienza.

definito specifiche misure per la creazione di ambienti innovativi per la didattica delle STEM, in linea con le ricerche e le raccomandazioni dell'OCSE, e di laboratori per le professioni digitali del futuro.

Le azioni didattiche e formative, finanziate con le risorse dell'investimento "Nuove competenze e nuovi linguaggi", sono finalizzate al rafforzamento delle competenze STEM, digitali e di innovazione da parte degli studenti in tutti i cicli scolastici, con particolare attenzione al superamento dei divari di genere nell'accesso alle carriere STEM e possono ricomprendere, a titolo esemplificativo e non esaustivo, lo svolgimento di percorsi formativi di tipo laboratoriale e attività di orientamento sulle STEM, la creazione di reti di scuole e di alleanze educative per la promozione dello studio delle discipline STEM e delle competenze digitali. Inoltre, i finanziamenti contribuiscono allo sviluppo di una didattica innovativa, alla condivisione di buone pratiche, alla realizzazione di iniziative, anche extrascolastiche, per gli alunni della scuola primaria e della scuola secondaria di primo grado volte a stimolare l'apprendimento delle discipline STEM e digitali. Infine, possono essere promosse azioni di informazione, sensibilizzazione e formazione rivolte alle famiglie, in particolare in occasione della celebrazione nelle istituzioni scolastiche della Giornata internazionale delle donne e delle ragazze nella scienza, per incoraggiare la partecipazione ai percorsi di studio nelle discipline STEM, principalmente delle alunne e delle studentesse, superando gli stereotipi di genere[15]. Con le risorse PNRR per la formazione dei docenti, le istituzioni scolastiche hanno la possibilità di organizzare percorsi formativi sull'utilizzo delle metodologie didattiche innovative per l'apprendimento delle STEM, in linea con le scelte operate all'interno del piano triennale per l'offerta formativa e del proprio curricolo, anche basate su percorsi "immersivi", centrati su simulazioni in spazi laboratoriali innovativi.

La piattaforma "Scuola Futura"[16] realizzata dal PNRR contiene il catalogo - in continuo e costante aggiornamento - dell'offerta formativa dei poli nazionali e territoriali e dei nodi formativi per la formazione del personale scolastico, individuati nelle singole scuole, con la possibilità di iscriversi e frequentare numerosi percorsi specificamente dedicati anche alle STEM e alle STEAM.

Indicazioni metodologiche per un insegnamento efficace delle discipline STEM

I vigenti documenti programmatici relativi alla scuola dell'infanzia, al primo e al secondo ciclo di istruzione offrono molti spunti di riflessione per un approccio integrato all'insegnamento delle discipline STEM, pur non trattandole unitariamente. Non mancano, infatti, rimandi e collegamenti interdisciplinari tra l'una e l'altra disciplina, comprese anche quelle non rientranti formalmente nell'acronimo STEM.

La consapevolezza della necessità della collaborazione tra i diversi saperi, la contaminazione tra la formazione scientifica e quella umanistica è ben chiara nelle Indicazioni nazionali per il curricolo del 2012: "*il bisogno di conoscenze degli studenti non si soddisfa con il semplice accumulo di tante informazioni in vari campi, ma solo con il pieno dominio dei singoli ambiti disciplinari e, contemporaneamente, con l'elaborazione delle loro molteplici connessioni. È quindi decisiva una nuova alleanza fra scienza, storia, discipline umanistiche, arti e tecnologia*", dal momento che "*le discipline non vanno presentate come territori da proteggere definendo confini rigidi, ma come chiavi interpretative disponibili ad ogni possibile utilizzazione*"[17].

Analogamente, il profilo culturale, educativo e professionale dei Licei prevede che gli studenti, al termine del percorso, siano "*consapevoli della diversità dei metodi utilizzati dai vari ambiti disciplinari*" e che siano in grado di "*valutare i criteri di affidabilità dei risultati in essi raggiunti per compiere le necessarie interconnessioni tra i metodi e i contenuti delle singole discipline*"[18].

Anche le Linee guida per gli istituti tecnici intendono il sapere come "*un laboratorio di costruzione del futuro, capace di trasmettere ai giovani la curiosità, il fascino dell'immaginazione e il gusto della ricerca, del costruire insieme dei prodotti, di proiettare nel futuro il proprio impegno professionale per una piena*

[15] Cfr. articolo 1, comma 552, della legge n. 197 del 2022
[16] https://scuolafutura.pubblica.istruzione.it/
[17] Indicazioni nazionali per il curricolo della scuola dell'infanzia e del primo ciclo di istruzione – pagg. 7 e 25.
[18] Profilo culturale, educativo e professionale dei licei – Allegato A al DPR 89/2010.

realizzazione sul piano culturale, umano e sociale", con una forte connotazione per il *"lavoro per progetti"*[19].

Gli istituti professionali si propongono, infine, di "*includere nella didattica ordinaria attività in grado di suscitare l'intelligenza pratica, (….) intuitiva, riflessiva ed argomentativa, ricorrendo ad esempio a tecniche quali il lavoro di gruppo, l'educazione tra pari, il problem solving, il laboratorio su compiti reali, il project work…*"[20]

L'approccio inter e multi disciplinare, unitamente alla contaminazione tra teoria e pratica, costituisce pertanto il fulcro dell'insegnamento delle discipline STEM, che risultano particolarmente indicate per favorire negli alunni e negli studenti lo sviluppo di competenze tecniche e creative, necessarie in un mondo sempre più tecnologico e innovativo. A tal fine, gli insegnanti, qualunque sia il grado scolastico, possono fare riferimento, a titolo esemplificativo e non esaustivo, alle seguenti metodologie:

Laboratorialità e learning by doing
L'apprendimento esperienziale, attraverso attività pratiche e laboratoriali, è un modo efficace per favorire l'apprendimento delle discipline STEM. Il coinvolgimento in attività pratiche e progetti consente di porre gli studenti al centro del processo di apprendimento, favorendo un approccio collaborativo alla risoluzione di problemi concreti. Questo approccio, inoltre, aiuta gli studenti a riflettere sul proprio processo di apprendimento, stimolandoli a identificare le proprie strategie di apprendimento, a individuare eventuali difficoltà, ad applicare strategie volte a sviluppare la consapevolezza delle proprie abilità e del proprio progresso.

Problem solving e metodo induttivo
Lo sviluppo delle competenze di *problem solving* è essenziale per le discipline STEM se promosso attraverso attività che mettano gli studenti di fronte a problemi reali e li sfidino a trovare soluzioni innovative. Il metodo induttivo, che parte dall'osservazione dei fatti e conduce alla formulazione di ipotesi e teorie, è un approccio efficace per lo sviluppo del pensiero critico e creativo. L'apprendimento basato sul *problem solving* e su sfide progettuali consente agli studenti di sviluppare competenze pratiche e cognitive attraverso l'elaborazione di un progetto concreto. Gli studenti possono identificare un problema, pianificare, implementare e valutare soluzioni, sviluppando così una comprensione approfondita dei concetti e delle abilità coinvolte. Inoltre, stabilire collegamenti con il mondo reale può rendere l'apprendimento più significativo e coinvolgente. E proprio la matematica, come disciplina che consente di comprendere e costruire la realtà, sostiene lo sviluppo del pensiero logico fornendo gli strumenti necessari per la descrizione e la comprensione del mondo e per la risoluzione dei problemi.

Attivazione dell'intelligenza sintetica e creativa
L'osservazione dei fenomeni, la proposta di ipotesi e la verifica sperimentale della loro attendibilità possono consentire agli studenti di apprezzare le proprie capacità operative e di verificare sul campo quelle di sintesi. In questo modo si incoraggiano gli studenti a diventare autonomi nell'apprendimento favorendo lo sviluppo di competenze trasversali come la gestione del tempo e la ricerca indipendente. Ciò può essere facilitato fornendo opportunità per l'autovalutazione, la pianificazione individuale e la scelta di attività di apprendimento in base agli interessi e alle preferenze degli studenti. La ricerca di soluzioni innovative a problemi reali stimola il ragionamento attraverso la scomposizione e ricomposizione dei dati e delle informazioni e, specialmente quando la situazione può essere inquadrata sotto una molteplicità di punti di vista e non presenta soluzioni univoche, attiva il pensiero divergente, favorendo lo sviluppo della creatività.

Organizzazione di gruppi di lavoro per l'apprendimento cooperativo
Il lavoro di gruppo, dove ciascuno studente assume specifici ruoli, compiti e responsabilità, personali e collettive, consente di valorizzare la capacità di comunicare e prendere decisioni, di individuare scenari, di ipotizzare soluzioni univoche o alternative. Promuovere l'apprendimento tra pari, in cui gli studenti si

[19] Linee guida per il passaggio al nuovo ordinamento, ai sensi del d.P.R. 15 marzo 2010, articolo 8, comma 3).
[20] Decreto interministeriale 24 maggio 2018, n. 92: Linee guida per favorire e sostenere l'adozione del nuovo assetto didattico e organizzativo dei percorsi di istruzione professionale

insegnano reciprocamente, è un'efficace strategia didattica. Gli studenti possono così lavorare in coppie o gruppi per spiegare concetti, risolvere problemi insieme e offrire supporto reciproco, favorendo così l'apprendimento collaborativo e la condivisione delle conoscenze.

Promozione del pensiero critico nella società digitale

L'utilizzo di risorse digitali interattive, come simulazioni, giochi didattici o piattaforme di apprendimento online, può arricchire l'esperienza di apprendimento degli studenti. Queste risorse offrono spazi di esplorazione, sperimentazione e applicazione delle conoscenze, rendendo l'apprendimento più coinvolgente e accessibile. L'utilizzo delle nuove tecnologie non deve essere però subìto ma governato dal sistema scolastico. Deve essere mirato ad incentivare gli studenti a sviluppare il pensiero critico al fine di diventare cittadini digitali consapevoli. La creazione di un pensiero critico può essere incoraggiata attraverso attività che richiedono la raccolta, l'interpretazione e la valutazione dei dati, nonché la capacità di formulare argomentazioni basate su prove scientifiche.

Adozione di metodologie didattiche innovative

Per sviluppare la curiosità e la partecipazione attiva degli studenti, la scuola dovrebbe superare i modelli trasmissivi, ricorrendo anche alle tecnologie, adottando una didattica attiva che pone gli studenti in situazioni reali che consentono di apprendere, operare, cogliere i cambiamenti, correggere i propri errori, supportare le proprie argomentazioni. La diffusione delle migliori esperienze attuate negli ultimi anni incentiva il processo di trasformazione della didattica, soprattutto per l'approccio integrato alle discipline STEM.[21]

In particolare, si segnalano l'apprendimento basato su problemi (Problem Based Learning, approccio basato sulla risoluzione di problemi) e il Design thinking (approccio che si fonda sulla valorizzazione della creatività degli studenti), metodologie che prevedono sempre il coinvolgimento attivo degli alunni e la generazione di idee per la ricerca di soluzioni innovative a problemi reali. Con il Tinkering si promuove l'indagine creativa attraverso la sperimentazione di strumenti e materiali; l'Hackathon si configura come approccio didattico collaborativo basato su sfide di co-progettazione che stimolano l'innovazione; il Debate (confronto tra squadre che argomentano tesi contrapposte su specifiche tematiche) può essere applicato anche a temi etici in ambito STEM. Si segnala, infine, l'apprendimento basato sull'esplorazione o ricerca (Inquiry Based Learning, IBL), approccio educativo che favorisce lo sviluppo del pensiero critico, la risoluzione di problemi e lo sviluppo di competenze pratiche. Questa metodologia consente agli studenti di essere i veri protagonisti delle attività didattiche durante le quali sono invitati a porre domande, proporre ipotesi di risoluzione di problemi, realizzare esprimenti e verifiche sotto la guida dei propri docenti. La possibilità di raccogliere dati e di discutere la fattibilità delle ipotesi proposte può contribuire anche allo sviluppo delle "soft skills", competenze fondamentali per affrontare sfide complesse e preparare gli studenti a diventare cittadini attivi.

Integrare queste e altre metodologie può consentire agli studenti di affrontare sfide in modo innovativo e sviluppare una comprensione più approfondita dei concetti.

A tal fine, le istituzioni scolastiche potranno utilizzare tutte le possibilità offerte dalla flessibilità loro riconosciuta dall'autonomia nell'organizzazione degli spazi, dei tempi e dei gruppi, nella predisposizione e nell'utilizzo di efficaci ambienti di apprendimento, nella gestione dell'organico dell'autonomia.

Indicazioni metodologico-educative specifiche per il Sistema integrato di educazione e di istruzione "zerosei"

Nel sistema integrato di educazione e di istruzione per bambini dalla nascita sino ai sei anni, definito dal decreto legislativo n. 65/2017, l'avvio alle STEM – o meglio alle STEAM – si realizza attraverso attività educative che incoraggiano il bambino ad un approccio matematico-scientifico-tecnologico al mondo naturale e artificiale che lo circonda. Considerata l'età dei bambini, si fa riferimento più propriamente ai sistemi simbolico-culturali citati nelle "Linee pedagogiche per il sistema integrato zerosei", negli

[21] Cfr. https://innovazione.indire.it/avanguardieeducative/

"Orientamenti nazionali per i servizi educativi per l'infanzia" e nelle "Indicazioni nazionali per il curricolo della scuola dell'infanzia e del primo ciclo di istruzione", cui si rimanda per i necessari approfondimenti.

Tenuto conto che l'apprendimento, in questa specifica fascia di età, *"avviene attraverso l'azione, l'esplorazione, il contatto con gli oggetti, la natura, l'arte, il territorio, in una dimensione ludica da intendersi come forma tipica di relazione e di conoscenza"*[22] possono essere indicazioni metodologiche comuni per tutti i bambini che frequentano il sistema integrato:

- la predisposizione di un ambiente stimolante e incoraggiante, che consenta ai bambini di effettuare attività di esplorazione via via più articolate, procedendo anche per tentativi ed errori
- la valorizzazione dell'innato interesse per il mondo circostante che si sviluppa a partire dal desiderio e dalla curiosità dei bambini di conoscere oggetti e situazioni
- l'organizzazione di attività di manipolazione, con le quali i bambini esplorano il funzionamento delle cose, ricercano i nessi causa-effetto e sperimentano le reazioni degli oggetti alle loro azioni
- l'esplorazione vissuta in modo olistico, con un coinvolgimento intrecciato dei diversi canali sensoriali e con un interesse aperto e multidimensionale per i fenomeni incontrati nell'interazione con il mondo
- la creazione di occasioni per scoprire, toccando, smontando, costruendo, ricostruendo e affinando i propri gesti, funzioni e possibili usi di macchine, meccanismi e strumenti tecnologici

Nei servizi educativi per l'infanzia per bambini fino ai tre anni (nidi[23] e micronidi, sezioni primavera, servizi integrativi, di cui all'articolo 2, comma 3, del D.lgs. n. 65/2017) occorre dare spazio alla molteplicità dei linguaggi - grafico-pittorico, plastico, musicale, coreutico, motorio, ma anche matematico, scientifico e tecnologico - che troveranno negli anni successivi ulteriori possibilità di arricchimento ed espansione. L'importanza dei molteplici linguaggi è connessa alla pluralità delle forme dell'intelligenza e alla necessità che, già a partire dai primi mille giorni di vita, esse trovino possibilità di promozione e arricchimento.

Nella scuola dell'infanzia è campo di esperienza privilegiato, ma non unico, "La conoscenza del mondo" che, nella sua doppia articolazione "Oggetti, fenomeni, viventi" e "Numeri e spazio", consente ai bambini di elaborare la prima "organizzazione fisica" del mondo esterno e di familiarizzare con le prime fondamentali competenze aritmetiche e geometriche. Si pongono così le basi per la successiva elaborazione di concetti scientifici e matematici che verranno proposti e sistematizzati nella scuola primaria[24].

Un ruolo importante nello sviluppo dei concetti logico-matematici nei servizi educativi e nelle scuole dell'infanzia è svolto dalle cosiddette *routine*, che *"vanno progettate in modo da costituirsi come occasioni di arricchimento conoscitivo, di maturazione dell'autonomia, di acquisizione di padronanza di sé e di scambio con gli altri"* [25]. L'annotazione delle presenze, con la conta dei bambini e la stima degli assenti, l'assegnazione, attraverso turnazione, di ruoli e compiti specifici, la costruzione di tabelle per la registrazione del tempo atmosferico, la quantificazione del tempo mancante a un evento particolare, l'apparecchiatura del tavolo, la distribuzione di oggetti e materiali, ecc. sono azioni che stimolano i bambini a osservare la realtà, raccogliere dati, confrontare quantità e situazioni, seriare, raggruppare, ordinare, stabilire corrispondenze biunivoche, quantificare e misurare, aggiungere e togliere, numerare, formulare ipotesi, elaborare idee personali da confrontare con i compagni e con le figure educative e pianificare azioni per verificarne la correttezza, simbolizzare, collocare eventi e situazioni nel tempo e nello spazio.

Indicazioni metodologiche specifiche per il primo ciclo di istruzione

I Traguardi delle Indicazioni Nazionali per il curricolo del 2012 relativi alla matematica, soprattutto quelli riguardanti "Funzioni e relazioni" e "Dati e previsioni", suggeriscono significativi contesti di lavoro riferiti alla scienza, alla tecnologia, alla società, contribuendo a sviluppare negli alunni la capacità di comunicare e discutere, di argomentare in modo corretto, di comprendere i punti di vista propri e degli altri. Proprio tenendo a riferimento quanto previsto dalle Indicazioni Nazionali, e nella considerazione che le discipline

[22] Indicazioni nazionali per il curricolo della scuola dell'infanzia e del primo ciclo di istruzione
[23] Asili nido è la dizione utilizzata per il PNRR e che non ricomprende i servizi integrativi
[24] Indicazioni nazionali per il curricolo della scuola dell'infanzia e del primo ciclo di istruzione
[25] Linee pedagogiche per il sistema integrato zerosei

STEM sono strettamente interconnesse, si possono individuare specifici suggerimenti, anche se non esaustivi, per un efficace insegnamento di tali discipline attraverso il quale gli alunni possano acquisire conoscenze e competenze in modo progressivo ed integrato.

Insegnare attraverso l'esperienza

L'apprendimento per esperienza è uno dei metodi didattici più efficaci nel primo ciclo di istruzione. Gli ambienti di vita naturali, artificiali e sociali in cui sono immersi gli alunni, infatti, sono permeati di concetti matematici, scientifici, tecnologici che possono essere esplorati attraverso esperienze dirette e concrete, che consentano l'esame dei diversi aspetti della realtà o dei problemi, l'emergere di domande e ipotesi, la ricerca attiva di una pluralità di risposte e soluzioni possibili, il confronto, la verifica, l'emergere di nuovi interrogativi o nuovi sviluppi. Organizzare attività che coinvolgano gli alunni in modo attivo favorisce altresì lo sviluppo di abilità pratiche.

Utilizzare la tecnologia in modo critico e creativo

La tecnologia è uno strumento potente per supportare l'apprendimento, grazie alla sua attrattività, all'innovazione continua, alle innumerevoli applicazioni a tanti settori di ricerca e di vita quotidiana, ma va utilizzata in modo critico e creativo, tenendo conto sia delle potenzialità, sia dei rischi legati a un utilizzo non corretto. Le attività che coinvolgono la tecnologia, se ben progettate e finalizzate a sviluppare specifiche competenze, rendono l'alunno attivo, ideatore di contenuti e soluzioni originali; pertanto, va evitato un uso passivo e ripetitivo degli strumenti tecnologici.

Favorire la didattica inclusiva

Nella progettazione delle attività connesse alle discipline STEM occorre prendere in considerazione le diverse potenzialità, capacità, talenti e le diverse modalità di apprendimento degli alunni. È importante valorizzare le differenze e promuovere un clima di accoglienza e rispetto reciproco. La ricerca, infatti, procede per prove ed errori e l'apporto di ciascuno diventa il punto di partenza per successive elaborazioni. L'errore diventa, quindi, una risorsa preziosa e la discussione, con il confronto tra una pluralità di punti di vista, favorisce l'emergere di soluzioni innovative. Per gli alunni con disabilità o con disturbi specifici di apprendimento (DSA) le modalità di approccio alle discipline STEM sono individuate, rispettivamente, nel Piano educativo Individualizzato e nel Piano Didattico Personalizzato.

Promuovere la creatività e la curiosità

Nella scuola del primo ciclo gli alunni esprimono creatività e curiosità: nelle discipline STEM, così come in quelle umanistiche, il pensiero divergente rappresenta un valore, in quanto apre a soluzioni inedite. Viceversa, la proposta di situazioni stereotipate, che richiedano soluzioni univoche o la semplice applicazione di formule o meccanismi automatici, non favorisce l'attivazione degli alunni, l'emergere di nuove curiosità e del desiderio di ricerca. Promuovere attività che incoraggino fantasia e creatività consente di trasformare la didattica frontale in didattica attiva.

Sviluppare l'autonomia degli alunni

Gli alunni imparano fin dalla scuola primaria ad essere autonomi, a gestire il proprio tempo e a organizzare il proprio lavoro. Promuovere attività che permettano agli alunni di ricercare in autonomia le soluzioni ai problemi proposti, avendo a disposizione una pluralità di strumenti e materiali, anche tecnologici e digitali, consente di sviluppare le loro abilità organizzative.

Utilizzare attività laboratoriali

In matematica, come in tutte le altre discipline scientifiche, il laboratorio, inteso sia come luogo fisico sia come momento in cui l'alunno è attivo, diventa elemento fondamentale, perché gli consente di formulare ipotesi, sperimentarle e controllarne le conseguenze, anche mediante la raccolta di dati ed evidenze, di argomentare le proprie scelte, di negoziare conclusioni ed essere aperto alla costruzione di nuove conoscenze. Il laboratorio consente di selezionare e realizzare esperimenti che permettono di esplorare i fenomeni con approccio scientifico. Sperimentazione, indagine, riflessione, contestualizzazione dell'esperienza, utilizzo della discussione e dell'argomentazione, effettuati a livello sia individuale sia di gruppo, rafforzano negli alunni la fiducia nelle proprie capacità di pensiero, l'imparare dai propri errori e da quelli altrui, l'aprirsi ad opinioni diverse dalle proprie.[26]

Indicazioni metodologiche specifiche per il secondo ciclo di istruzione

Per quanto riguarda la scuola secondaria di secondo grado, ferma restando la specificità dei vari indirizzi di studio, i documenti pedagogici di riferimento prevedono una didattica centrata sul protagonismo degli studenti, con l'obiettivo di sviluppare in loro la capacità critica, lo spirito d'osservazione e la creatività. La metodologia deve quindi prevedere il superamento di una didattica trasmissiva a favore di attività e momenti di lavoro in gruppo, di ricerca e di sperimentazione.

In particolare, si forniscono alcune possibili indicazioni metodologiche, anche se non esaustive:

Promuovere la realizzazione di attività pratiche e di laboratorio. L'acquisizione di competenze tecniche specifiche attraverso l'utilizzo di strumenti e attrezzature, considerata la dimensione costitutiva delle discipline STEM, si realizza individuando attività sperimentali particolarmente significative che possono essere svolte in laboratorio, in classe o "sul campo". Tali attività sono da privilegiare rispetto ad altre puramente teoriche o mnemoniche.

Utilizzare metodologie attive e collaborative. Con il lavoro di gruppo, il problem solving, la ricerca guidata, il dibattito, la cooperazione con gli altri studenti, si favorisce l'acquisizione del metodo sperimentale, dove *"l'esperimento è inteso come interrogazione ragionata dei fenomeni naturali, analisi critica dei dati e dell'affidabilità di un processo di misura, costruzione e/o validazione di modelli"*[27].

Favorire la costruzione di conoscenze attraverso l'utilizzo di strumenti tecnologici e informatici. Un uso appropriato, critico e ragionato degli strumenti tecnologici ed informatici favorisce l'apprendimento significativo laddove tali strumenti sostengono processi cognitivi quali investigare, esplorare, progettare, costruire modelli e richiedono agli studenti di riflettere e rielaborare le informazioni per costruire, in gruppo, nuove conoscenze, abilità e competenze.

Promuovere attività che affrontino questioni e problemi di natura applicativa. In questo modo è possibile far emergere, anche con riferimento alla futura vita sociale e lavorativa degli studenti, i collegamenti tra le competenze di natura prevalentemente tecnica e tecnologica, propria dei vari indirizzi e percorsi, e le conoscenze e abilità connesse agli assi matematico e scientifico-tecnologico.

Utilizzare metodologie didattiche per un apprendimento di tipo induttivo. Attraverso esperienze di laboratorio o in contesti operativi, si consente agli studenti di analizzare problemi, trovare soluzioni, realizzare e gestire progetti. Si può, così, intercettare l'evoluzione del fabbisogno di competenze che emerge dalle richieste del mondo del lavoro offrendo possibili risposte alle nuove necessità occupazionali.

Realizzare attività di PCTO nell'ambito STEM. La realizzazione di percorsi per le competenze trasversali e l'orientamento in contesti scientifici e tecnologici rende significativo il raccordo tra competenze trasversali e competenze tecnico-professionali. Si possono offrire agli studenti reali possibilità di sperimentare interessi, valorizzare stili di apprendimento e facilitare la partecipazione autonoma e responsabile ad attività formative nell'incontro con realtà innovative del mondo professionale.

Anche per il secondo ciclo di istruzione, la progettazione delle attività connesse alle discipline STEM tiene conto delle diverse potenzialità, capacità, talenti e delle diverse modalità di apprendimento degli studenti in una prospettiva inclusiva. Per gli studenti con disabilità o con disturbi specifici di apprendimento (DSA) le modalità di approccio alle discipline STEM sono individuate, rispettivamente, nel Piano educativo Individualizzato e nel Piano Didattico Personalizzato.

[26] Indicazioni nazionali e nuovi scenari, MIUR 2018
[27] Indicazioni nazionali per i licei, MIUR 2011

Indicazioni metodologiche specifiche per l'istruzione degli adulti

Premesso che i percorsi di istruzione per gli adulti sono organizzati in modo da consentire la personalizzazione del percorso attraverso la sottoscrizione di un Patto formativo individuale che discende dal riconoscimento dei saperi e delle competenze posseduti, alcune indicazioni metodologiche per un apprendimento integrato delle discipline STEM possono essere così sintetizzate:

Adattare la didattica alle esigenze e all'esperienza pregressa degli studenti adulti

Gli adulti che frequentano i CPIA – Centri Provinciali per l'Istruzione degli Adulti – nei vari percorsi offerti manifestano esigenze e bisogni di apprendimento diversi rispetto agli alunni dei corsi ordinari di primo e secondo ciclo. Gli adulti, infatti, hanno esperienze di vita e di lavoro che possono essere messe in luce, utilizzate e potenziate nella didattica delle discipline STEM, inserite nell'asse matematico e nell'asse scientifico-tecnologico. Risulta fondamentale, proprio per la specificità dell'utenza adulta, tenere nella dovuta considerazione il ruolo centrale delle attività laboratoriali, utilizzando metodologie didattiche flessibili che tengano conto di esperienze e competenze pregresse, acquisite in contesti formali, non formali e informali.[28] È necessario, quindi, coinvolgere gli adulti nella costruzione del loro percorso di apprendimento attraverso la formulazione personalizzata del Patto formativo individuale.

Utilizzare la tecnologia in modo efficace

La tecnologia riveste un ruolo fondamentale per l'apprendimento delle discipline STEM anche nell'istruzione degli adulti. La realizzazione delle aule a distanza denominate Agorà (Ambiente interattivo per la Gestione dell'Offerta formativa Rivolta agli Adulti) costituisce elemento di qualità per consentire agli studenti adulti di integrare modalità di apprendimento in presenza e a distanza. Con tali strumenti l'adulto è portato a promuovere un apprendimento attivo e collaborativo.

Sviluppare le competenze trasversali

Anche per gli studenti adulti, l'acquisizione di competenze nel campo delle discipline STEM può agevolare lo sviluppo delle competenze trasversali, come la capacità di lavorare in gruppo, la creatività e l'innovazione, la capacità di risolvere problemi e di prendere decisioni. In questa prospettiva, potrà essere ulteriormente promossa la cultura dell'apprendimento permanente, incentivando gli adulti ad una formazione e ad un aggiornamento continuo delle proprie competenze, anche in prospettiva di una riqualificazione in campo professionale.

Valutazione delle competenze STEM

La valutazione formativa, che fornisce un riscontro continuo e mirato agli studenti, è essenziale per guidare e migliorare il processo di apprendimento. Il feedback specifico, costruttivo e basato sugli obiettivi di apprendimento, può consentire agli studenti di identificare i propri punti di forza e le eventuali aree di miglioramento.

L'acquisizione di competenze, in particolare in ambito STEM, può essere accertata ricorrendo soprattutto a compiti di realtà (prove autentiche, prove esperte, ecc.) e a osservazioni sistematiche.

Con un compito di realtà lo studente è chiamato a risolvere una situazione problematica, per lo più complessa e nuova, possibilmente aderente al mondo reale, applicando un patrimonio di conoscenze e abilità già acquisite a contesti e ambiti di riferimento diversi da quelli noti. Pur non escludendo prove che chiamino in causa una sola disciplina, proprio per il carattere interdisciplinare e integrato delle STEM, occorre privilegiare prove per la cui risoluzione debbano essere utilizzati più apprendimenti tra quelli già acquisiti.[29] La soluzione del compito di realtà costituisce così l'elemento su cui si può basare la valutazione dell'insegnante e l'autovalutazione dello studente.

Per verificare il possesso di una competenza è utile fare ricorso anche ad osservazioni sistematiche che consentono di rilevare il processo seguito per interpretare correttamente il compito assegnato, per richiamare

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[28] Decreto legislativo 16 gennaio 2013, n. 13

[29] Linee guida per la certificazione delle competenze nel primo ciclo di istruzione di istruzione, MIUR, 2018

conoscenze e abilità già possedute ed eventualmente integrarle con altre, anche in collaborazione con insegnanti e altri studenti.

Orientamento e discipline STEM

"I talenti e le eccellenze di ogni studente, quali che siano, se non costantemente riconosciute ed esercitate, non si sviluppano, compromettendo in questo modo anche il ruolo del merito personale nel successo formativo e professionale"[30]. Se il riconoscimento e l'esercizio dei talenti di cui ogni alunno e ogni studente sono portatori rivestono un ruolo fondamentale per l'apprendimento e per la vita, ancora più significativo è il ruolo che possono rivestire le discipline STEM per il potenziamento delle competenze e delle capacità di ciascuno. In questo senso, assume una fondamentale importanza il consiglio di orientamento che, valorizzando le esperienze e le inclinazioni dello studente anche verso le discipline matematiche, scientifiche e tecnologiche, può supportare la famiglia nella scelta del percorso scolastico successivo alla scuola del primo ciclo. Proprio in questa prospettiva si collocano alcune delle linee di investimento che il Ministero sta realizzando nell'ambito delle azioni promosse con il PNRR. L'azione "Nuove competenze e nuovi linguaggi"[31], ad esempio, consente alle scuole di realizzare attività di orientamento, ad alto contenuto innovativo, verso gli studi e le carriere professionali nelle discipline STEM. È attraverso azioni di orientamento verso tali discipline che si può promuovere la parità di genere nel campo dell'istruzione, per la prosecuzione degli studi o per l'inserimento nel mondo del lavoro.

Coding, pensiero computazionale e informatica: quale evoluzione possibile?

L'articolo 24 bis del decreto legge n. 152/2021, convertito, con modificazioni, nella legge n. 233/2021, ha disposto che nel Piano nazionale di formazione triennale destinato al personale docente, a partire dal 2022/2023, al fine di consentire l'attuazione della linea progettuale M4-C1 - Investimento 3.1 «Nuove competenze e nuovi linguaggi» del Piano nazionale di ripresa e resilienza, sia individuata tra le priorità nazionali, l'approccio agli apprendimenti della programmazione informatica (coding) e della didattica digitale. Successivamente, a decorrere dall'anno scolastico 2025/2026, *"nelle scuole di ogni ordine e grado si dovrà perseguire lo sviluppo delle competenze digitali, anche favorendo gli apprendimenti della programmazione informatica (coding), nell'ambito degli insegnamenti esistenti"*[32].

Già la legge 107/2015, all'articolo 1, comma 7, lettera h) aveva previsto tra gli obiettivi formativi prioritari per le istituzioni scolastiche lo *"sviluppo delle competenze digitali degli studenti, con particolare riguardo al pensiero computazionale, all'utilizzo critico e consapevole dei social network e dei media nonché alla produzione e ai legami con il mondo del lavoro"*. In questa prospettiva si collocano, ad esempio, i riferimenti al pensiero computazionale previsti dal decreto legislativo 62/2017, che può essere oggetto di eventuale accertamento durante la prova scritta sulle competenze logico-matematiche dell'esame di Stato conclusivo del primo ciclo. Il documento ministeriale "Indicazioni nazionali e nuovi scenari" del 2018, ha precisato che *"per pensiero computazionale si intende un processo mentale che consente di risolvere problemi di varia natura seguendo metodi e strumenti specifici pianificando una strategia. È un processo logico creativo che, più o meno consapevolmente, viene messo in atto nella vita quotidiana per affrontare e risolvere problemi."*

Attività legate al pensiero computazionale con macchine (robot, computer, ecc.) o senza (cosiddetto coding unplugged), soprattutto nella scuola dell'infanzia e del primo ciclo, consentono di affrontare le situazioni *"scomponendole nei vari aspetti che le caratterizzano e pianificando per ognuno le soluzioni più idonee"*[33]. È fondamentale che le procedure e gli algoritmi, quali essi siano, vengano costantemente accompagnate da una riflessione metacognitiva che consenta all'alunno di chiarire e di motivare le scelte che ha effettuato. Queste strategie operative possono contribuire all'acquisizione delle competenze matematiche, scientifiche e tecnologiche, in un mondo in cui la tecnologia è in costante evoluzione.

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[30] Decreto ministeriale 328/2022 - Linee guida per l'orientamento
[31] https://pnrr.istruzione.it/competenze/nuove-competenze-e-nuovi-linguaggi/
[32] Legge 233/2021, art. 24 bis
[33] Indicazioni Nazionali e nuovi scenari, MIUR 2018

Come indicato dal CINI (Consorzio Interuniversitario Nazionale per l'Informatica), sembrerebbe però riduttivo non fare riferimento anche all'informatica che è *"sia la disciplina scientifica di base che fornisce i concetti ed i linguaggi indispensabili per comprendere e per partecipare a pieno titolo alla società digitale, sia una disciplina di interesse trasversale che mette a disposizione un punto di vista addizionale, complementare a quello di altre discipline, per analizzare e affrontare situazioni e fenomeni."*[34]

Pertanto, a partire dall'introduzione ad alcuni linguaggi di programmazione nel primo ciclo di istruzione, sarà possibile nella scuola secondaria di secondo grado utilizzare l'informatica per aiutare a comprendere e risolvere processi complessi suddividendoli in problemi semplici.

L'informatica va intesa come disciplina trasversale che può integrarsi nel curricolo. L'uso del coding unplugged, ad esempio, può permettere agli studenti di applicare il pensiero computazionale anche senza l'ausilio di strumenti digitali, stimolando la loro capacità di analisi, astrazione e sequenzialità.

In questa prospettiva si pone anche la recente proposta per una raccomandazione al Consiglio della Commissione europea[35] sul miglioramento dell'offerta relativa alle competenze digitali nel settore dell'istruzione e della formazione. Con questa proposta gli Stati membri sono invitati a sostenere un insegnamento dell'informatica di alta qualità nelle scuole, ad integrare lo sviluppo delle competenze digitali per gli adulti e ad affrontare le carenze nelle professioni del settore delle tecnologie dell'informazione adottando strategie inclusive.

Difatti, nel contesto attuale, le competenze digitali, così come definite nel *Quadro delle competenze digitali per i cittadini (DigComp 2.2)*[36], elaborato dal Joint Research Centre (JRC) della Commissione europea, sono diventate fondamentali per la partecipazione attiva nella società digitale. Il coding, il pensiero computazionale e l'informatica offrono strumenti e conoscenze necessarie per comprendere, utilizzare e contribuire al progresso tecnologico. L'inclusione delle competenze connesse al coding, al pensiero computazionale e all'informatica nel percorso educativo può preparare gli studenti alle sfide e alle opportunità offerte dal mercato del lavoro digitale. L'acquisizione di tali competenze può favorire l'occupabilità degli individui e contribuire alla crescita economica e all'innovazione del paese.

È indubbio che oltre alle competenze tecniche, è importante includere nel curricolo anche obiettivi di apprendimento riferiti alla cittadinanza digitale, già previsti dalla legge 92/2019 sull'insegnamento dell'educazione civica[37]. Ciò implica promuovere la consapevolezza dell'etica digitale, dei diritti e delle responsabilità nell'uso delle tecnologie, nonché la capacità di valutare criticamente le informazioni online, partecipando in modo attivo e responsabile nella società digitale.

In questo specifico contesto, nell'ambito del coding, del pensiero computazionale e dell'informatica può trovare spazio anche un corretto e consapevole utilizzo dell'intelligenza artificiale (IA) che, in ambito scolastico, può fornire varie opportunità formative, quali la personalizzazione dell'apprendimento e l'ampliamento dell'accesso all'istruzione, soprattutto in contesti in cui le risorse sono limitate. Le risorse digitali, gli strumenti e gli approcci didattici basati sull'IA possono migliorare l'efficacia dell'insegnamento e dell'apprendimento consentendo agli studenti di accedere a contenuti educativi di qualità. L'uso dell'IA in ambito scolastico può favorire negli studenti lo sviluppo di competenze tecniche rilevanti per il mercato del lavoro digitale, preparandoli per le sfide future e le opportunità di carriera legate alla tecnologia.

È importante, comunque, affrontare anche i rischi associati all'uso dell'IA che potrebbe portare a una dipendenza eccessiva dalla tecnologia, rischiando di trascurare altre competenze e abilità fondamentali per gli studenti, quali la creatività, il pensiero critico e la risoluzione dei problemi in modo autonomo. Inoltre,

[34] Proposta di Indicazioni Nazionali per l'insegnamento dell'Informatica nella Scuola, CINI, 2017
[35] Proposal for a COUNCIL RECOMMENDATION on improving the provision of digital skills in education and training, Strasburgo, 18 aprile 2023
[36] https://repubblicadigitale.innovazione.gov.it/assets/docs/DigComp-2_2-Italiano-marzo.pdf
[37] Legge 20 agosto 2019, n. 92 recante "Introduzione dell'insegnamento scolastico dell'educazione civica" e, in particolare, articolo 5, concernente "Educazione e cittadinanza digitale"

l'IA potrebbe richiedere la raccolta e l'elaborazione di grandi quantità di dati personali degli studenti, con ricadute sulla sicurezza delle informazioni sensibili. È necessario, pertanto, adottare misure rigorose per proteggere i dati degli studenti e garantire la conformità alle norme sul trattamento dei dati personali[38].

[38] Cfr. "La scuola a prova di privacy", Vademecum del Garante per la protezione dei dati personali. https://www.gpdp.it/web/guest/temi/scuola

Attachment 3.

<u>The Role of a Good Mentor</u>

Developed by the Coordinators and Mentors of HoPE Roiti in the academic year 2020-2021

One role of a mentor is to inspire their students to become passionate about their project, so they genuinely care about it and enjoy every small step achieved as they strive to reach their goal.

A good mentor doesn't have to know the answer to every question but should be able to respond with, "I don't know! Let's find out together!" and guide their students in the search for an answer. Often, they should respond this way even if they know the answer, allowing students to learn on their own through research and experimentation.

A good mentor ensures that all team members have the opportunity to speak and express their opinions. Sometimes, this means stopping someone who has already spoken a lot, even if they are sharing good ideas, and inviting someone more introverted to speak.

A good mentor should intervene in the project as little as possible: this is a project for the students, let them build it!

Even in the most challenging situations, a good mentor should be able to remain calm. Students will always look up to you as a role model; if they see you in despair, they will feel the same way. Your task is to make them believe that there is always hope, even if you don't truly think so. You will see the magic that can come from determined individuals who never give up.

A good mentor should provide suggestions but never impose their own ideas. Remember that overly endorsing an idea will automatically lead the team to pursue it, and this should be avoided.

A mentor will also be considered a behavioral model. Therefore, while with the team, you should be as kind as possible, especially with your fellow mentors. You should avoid being seen as annoyed, angry, or discouraged as much as possible.

Characteristics of a Good Mentor:

1. **Empathy:** Understanding the emotions of others, any difficulties and/or fears, demonstrating attentiveness, positivity, and encouragement.
2. **Good Character:** Patience, availability, positivity, humility are essential characteristics for a mentor. Their main goal is not to create the "best" project but to support the mentee in their growth and improvement journey.
3. **Sense of Awareness and Consistent Behavior:** Aligned with the project's principles and objectives.
4. **Self-reflection:** Ability to reconsider choices made, if necessary.
5. **Communication Skills:** Listening without passing judgment, asking questions to guide the mentee to find their solution.

6. **Organizational and Group Management Skills:**
7. **Collaborative Skills:** Within their team and with all other stakeholders (students, mentors, teachers, external experts, etc.).
8. **Focus Oriented:** Skillful in helping the mentee identify and pursue their goals, supporting them in unexpected or occasional challenges, helping them stay focused on the true objective and reformulating if necessary.
9. **Flexibility:** The mentor is a helmsman, adapting their behaviors to the situation at hand and helping the mentee face change.

La DAD: è un muro che chiude o una finestra che possiamo aprire? (Aprile 2021_4M)

19 risposte

Pubblica i dati di analisi

Quali sono stati a tuo avviso gli aspetti positivi di lavorare per progetti? Quali quelli negativi?

19 risposte

È stato positivo il fatto di fare qualcosa con altre persone e divertirsi nel farlo, oltre che capire in modo pratico le nozioni teoriche.
È stato negativo forse il fatto che, anche se c'è stata l'esposizione, mi sento meno pronto negli argomenti trattati dagli altri gruppi.

L'aspetto positivo, oltre a quello di aver lavorato con un gruppo di amici, è stato quello di comprendere meglio la parte teorica, permettendomi di applicarla nel progetto presentato. Non ho riscontrato nessuno aspetto negativo.

innanzitutto penso che non ci siano stati lati negativi ma solo positivi, in particolare: il lavoro di gruppo (sia quello da casa, che quello a scuola) e il fatto di provare nella realtà ciò che studiamo sui libri, attraverso oggetti non comuni e molto interessanti.

Lavorare a distanza ti impedisce di avere un contatto umano con i tuoi compagni di gruppo e rende le comunicazioni a volte un po' meno chiare rispetto ad una situazione in cui ci si può incontrare (fonte di errore). D'altra parte lavorare a distanza mi ha spinto a cercare qualcosa di diverso e di nuovo che potesse rendere un lavoro più coinvolgente possibile e più divertente da realizzare

Lavorare per progetti per me è molto utile per suddividere gli argomenti in maniera chiara e semplice quando iniziamo a trattare di nuovi capitoli. Penso che sezionare in parti un capitolo o comunque un argomento sia comodo per tutti, a me aiuta molto e mi permette di mettere in ordine le idee Costruendo il mio sapere un gradino alla volta.

Sicuramente un aspetto positivo è lavorare in gruppo ed è anche più divertente. Un aspetto più negativo sono le limitazioni presenti in questo periodo che non hanno facilitato

Un aspetto positivo è sicuramente quello di aver costruito il progetto, quindi aver fatto una cosa nuova, e provare soddisfazione nel vederlo funzionare. A mio avviso di aspetti negativi non c'è ne sono

Positivi: lavorare in gruppo , apprendere in maniera totale e pratica l'argomento teorico in modo più agevole rispetto allo studio tradizionale

Ritengo che lavorare per progetti possa aiutare la comprensione di un determinato problema o di una determinata tematica , la condivisione di idee e più di una persona che pensa ad una soluzione per un determinato problema è sicuramente meglio di un lavoro singolo . Non credo ci siano aspetti negativi

È stato sicuramente un modo divertente per apprendere più facilmente le parte teorica dei principi elettrostatici. Sono anche dell'opinione che i lavori di gruppo servano per preparare un alunno ad un eventuale "team-work" futuro nel mondo lavorativo. L'unico lato negativo di questa esperienza è che personalmente mi sento sempre rallentato nei lavori di gruppo.

Dover aspettare e doversi concordare fa perdere tantissimo tempo prezioso. Se fosse stato un lavoro individuale, avrei ottimizzato i tempi in un miglior modo.

Gli aspetti positivi sono sicuramente il fatto che lavorare a progetti del genere in gruppo sono molto più divertenti, interattivi e manuali di qualsiasi altro lavoro. Anche se non si è appassionati alla fisica lavori di questo tipo vengono fatti molto più volentieri e con molta più passione. Soprattutto l'esperienza in laboratorio è una cosa che non si può svolgere molto spesso perciò farla è stato molto divertente.
L'unico aspetto negativo che mi viene in mente è che comunque lavori del genere portano via molto tempo ed energie ma personalmente li preferisco a molte altre cose.

Sicuramente , la realizzazione di un progetto collabora positivamente nella media scolastica o almeno , la maggior parte delle volte ; questo accade , probabilmente perché si riesce ad applicare la teoria , che di solito si esporrebbe quasi a "memoria " , tramite ragionamenti ristrettì o esercizi , alla realtà , alla quotidianità che viviamo ogni giorno e questo ci porta ad interessarci e stupirci molto di più dei fenomeni , i quali, visti nel "nostro mondo" ci sembrano più semplici , quasi banali , ma che in realtà formalmente sono complessi . È questa la cosa bella : stupirsi di ciò che si studia , che in realtà non dovrebbe essere studiata per essere dimenticata , ma per dare un senso alle cose che vediamo .
Parlando dei lati negativi , sicuramente la spiegazione con un progetto power point , per esempio , richiede un tempo non indifferente di realizzazione , che si somma alle ore di studio normali . Penso però , che nel momento in cui l'esperienza da realizzare sia coinvolgente per noi ragazzi e anche divertente , manuale e creativa , le ore passate davanti al computer diano in realtà tanta soddisfazione , che porta al piacere personale, alla consapevolezza di essere riusciti a realizzare un progetto a partire da concetti teorici e , quindi , di aver appreso davvero le "formalità " .

Positivi: possibilità di scelta in base a ispirazione e possibilità di costruzione; divertimento nell'affrontare una parte pratica oltre a quella teorica.
Negativi: avendo molta libertà di scelta sia sull'esperimento che sulla modalità di esposizione, avevamo pochi punti di riferimento

Non penso ci siano aspetti negativi nel lavorare a gruppi, ma più che altro difficoltà. Per esempio, la prima che mi viene in mente (anche a causa della situazione in cui ci troviamo) è quella del riuscire a comunicare e a svolgere il lavoro senza potersi incontrare. Nonostante ciò ci sono molti aspetti positivi come il lavoro di squadra, la collaborazione, il divertimento ma anche la determinazione nel voler fare un bel lavoro.

Credo che lavorare per progetti ti permetta di comprendere meglio l'argomento trattato, poiché si lavora a team e quindi i vari membri di quest'ultimo riescono a confrontarsi tra loro sia sulle basi teoriche sia sulla realizzazione del progetto.
Per me l'unico aspetto negativo di lavorare per progetti è nelle componenti del gruppo che è possibile che interagiscano poco tra loro.

positivi sono stati sicuramente quelli di lavorare insieme e poter conoscere i punti di vista di ognuno così da arrivare alle radici di ciò che stavamo facendo , di aspetti negativi davvero non ne trovo in questo tipo di esperienza.

Il principale aspetto positivo è stato sicuramente il mettersi in gioco. L'ultimo progetto (nel mio caso il generatore) mi ha coinvolto particolarmente. e ripensandoci avrei scelto di partecipare alle iniziative della scuola a riguardo. I progetti in questa fase delicata della nostra 'carriera scolastica' sono stati dei preziosi jolly che hanno aiutato a portare a termine questo anno scolastico. Non trovo aspetti negativi . Un altro aspetto positivo è stato lo stare insieme, esperienza che ci è mancata fin troppo.

Aspetti positivi:
1) lavorando a diversi progetti abbiamo avuto modo di sperimentare un metodo alternativo di apprendimento (più pratico, meno teorico e spesso più coinvolgente)
2) lavorare a gruppi ci ha permesso di apprendere attraverso un confronto con gli altri compagni (ognuno ha dato un proprio contributo per costruire una conoscenza collettiva)

Aspetti negativi:
1) maggior coinvolgimento emotivo conseguente al maggiore carico di responsabilità individuale per la riuscita del progetto (timore che ciascuno non faccia abbastanza per gli altri componenti del gruppo)

Positivi- Lavoro in gruppo, divertirsi, sentirsi importanti quando si spiega alla classe, confrontarsi con i compagni di gruppo sui dubbi.
Negativi- direi nessuno

Quali sono stati gli aspetti positivi del lavorare in modo collaborativo? Quali quelli negativi?

19 risposte

Nel caso specifico del mio gruppo non ho avuto aspetti negativi di ciò, perché ognuno ha fatto la sua parte esaltando le proprie abilità e facendo ciò che magari un altro componente non si sentiva sicuro di fare.

Abbiamo avuto la possibilità di confrontarci su idee che inizialmente erano leggermente discordanti, sforzandoci al tempo stesso di trovare una mediazione, un punto di accordo. Ci sono stati anche momenti scherzosi, che hanno aiutato ad rinforzare l'amicizia. Nessun aspetto negativo.

positivi: avere varie idee su come condurre il progetto, quindi confrontarsi e scegliere il percorso migliore. poi anche il divertimento che si è venuto a creare nel realizzare il progetto
negativo: l'unico era trovare un giorno nel quale trovarci tutti assieme, perché a causa di allenamenti e impegni non era sempre possibile

Lavorare in gruppo significa suddividersi i compiti in base ai propri campi di interesse e di forza e quindi si riesce a rendere un lavoro anche complesso con meno peso sul singolo individuo. L'altra faccia della medaglia è che molto spesso è difficile riuscir a fare combaciare perfettamente tutti i compiti suddivisi in un unico progetto, per questo è molto importante l'organizzazione.

Sicuramente un aspetto positivo è quello di non chiudersi nella propria idea ma spaziare e confrontarsi con i componenti del gruppo. Questo ci permette di non chiuderci in noi stessi e di vedere come le persone esterne vedono o considerano la nostra idea. Ciò ci permette di migliorare gli aspetti negativi o carenti del nostro pensiero e di unirlo agli altri per crearne una più bello, esaustivo e concreto.

Lavorare in modo collaborativo rende migliore il progetto e offre più punti di vista utili per il progetto stesso

Come aspetto positivo quello di aver appunto lavorato molto in gruppo… anche se solo in chiamata ci siamo divertiti oltre ad aver lavorato. Anche qui di aspetti negativi non ne ho trovati

Positivo: ognuno ha le proprio dire e mettendole insieme si realizza un lavoro migliore
Negativo: cercare di indirizzare tutti i componenti del gruppo sulla stessa linea , rispettando le opinioni altrui

Sicuramente lavorare in team aiuta molto sia sul progetto ma soprattutto in ambito umano , a migliorare noi stessi come persona . A distanza non è facile progredire nella parte costruttiva del progetto , però mi ha aiutato ad organizzare meglio i compiti e le scadenze prefissate

Positivi: divertimento
Negativi: scarsa ottimizzazione del tempo

Lavorare in gruppo è più divertente e inoltre hai la possibilità di condividere idee, compiti e lavori.
L' aspetto negativo forse è dato dal periodo. La situazione attuale del Covid non ti permette di trovarti e lavorare al progetto anche fuori da scuola quindi risulta maggiormente complicato portare a termine il progetto.

Ne parlo nella risposta alla domanda 4

Positivi: rimanere in contatto nonostante la DAD
Negativi: dover trovare una soluzione a opinioni contrastanti

Penso che collaborare dia sempre degli ottimi risultati perché naturalmente in un gruppo ci sono più spunti e idee di quanti ce ne siano in un singolo. Quindi collaborando si imparano sempre cose nuove!

Parlando personalmente nel mio team non ci sono stati aspetti negativi, tutti abbiamo fatto la nostra parte e il nostro dovere, ci siamo sempre confrontati su tutti gli aspetti della realizzazione e se qualcuno aveva un dubbio o incertezza su qualsiasi cosa ci abbiamo ragionato assieme e lo abbiamo risolto.

è stato positivo il poter divertirsi nell'apprendere questa materia perchè si sa che in compagnia si vive meglio ogni cosa, anche qui aspetti negativi per quanto riguarda il mio gruppo non ne ho trovati perchè tutti ci siamo dati da fare.

L'approccio a questi progetti, a mio parere, è stato del tutto collaborativo da entrambe le parti. Sia lei che che i professori hanno saputo venirci incontro, ovviamente nei limiti necessari, in caso di imprevisti o piccoli ritardi. Il lavoro, se collaborativo, diventa più facile e aiuta anche a maturare dal punto di vista umano .

Aspetti positivi:
1) la condivisione degli sforzi e dei risultati che ne conseguono

Aspetti negativi:
Già spiegati nella risposta alla domanda precedente

Penso sia stato solo positivo perché dividersi il lavoro in gruppo aiuta ad avere una conoscenza più ampia del tutto ascoltandolo anche dagli amici.

Quali difficoltà hai trovato nel lavorare in modo collaborativo a distanza? Hai suggerimenti per migliorarli?

19 risposte

La cosa difficile è che finché si è a distanza, non sembra di essere parte di un gruppo, ci si sente molto come se si dovesse svolgere una parte individuale.

Il lavoro collaborativo a distanza si è realizzato senza troppe difficoltà, perché ormai siamo abituati a lavorare in questo modo e fortunatamente abbiamo a disposizione buoni strumenti tecnologici e una buona connessione. C'è stato un piccolo contrattempo dovuto ad un errore nella costruzione ma forse anche causato da un incomprensione generale che però si è risolta facilmente, con una chiamata aggiuntiva.

in realtà essendo a distanza, si ha una possibilità molto più immediata nell'incontrarsi e questo è un vantaggio. Di aspetti negativi non c'è ne sono direi

Non ho trovato nessuna difficoltà rilevante, come riportato prima l'unico punto che può risultare più difficoltoso è quello della comunicazione tra il gruppo ma che è tranquillamente risolvibile con una chiamata vocale o una nota vocale in cui è più facile esprimersi.

Sicuramente la connessione, la distanza e il non vedersi non aiutato e non ha facilitato la riuscita del progetto, nonostante ciò si può lavorare discretamente cercando di e sostituire il vedersi dal vivo con una chiamata. Non avrei suggerimenti per migliorare oltreché usare o comunque trovare delle app che ti permettono di colloquiare senza particolari problemi. Ad esempio io mi sono trovato molto bene con zoom a differenza di meet, infatti zoom permetteva di registrare le chiamate e inoltre si poteva avere una connessione migliore e una qualità migliore della chiamata.

La difficoltà principale è che bisognava lavorare attraverso una chiamata meet mentre secondo me è molto più produttivo incontrarsi e discutere insieme su cosa fare

L'unica difficoltà è stata quella di non essere a contatto… è sicuramente più stimolante lavorare in compagnia fisica. Purtroppo non penso ci sia una via di mezzo tra lavorare a distanza o a contatto

Eh si

Ho riscontrato problemi nella costruzione del progetto perché essendo da solo a costruire non ci sono proposte da tutto il team e idee condivise per costruire. Secondo me quando si affrontano progetti con costruzioni difficili e che richiedono molta attenzione nei dettagli può essere utile costruire ,in chiamata con tutto il team ,un prototipo 3D che comprenda la costruzione data dalle idee di tutti .

Il dover aspettare gli audio e i video degli altri componenti del gruppo

Spostarsi fra app e stanze è forse l'unica difficoltà che abbiamo avuto in questo tipo di lavoro. Penso che sia difficile da migliorare ulteriormente. Sono convinto però che lavorare in gruppo anche solo su un singolo esercizio mi ha permesso di capire più cose essendo aiutato da diversi compagni in diverse lezioni.

Non ho riscontrato particolari difficoltà .

Il lavoro rimaneva comunque abbastanza individuale. Per migliorare la cosa, aumentare le applicazioni che permettono un lavoro di più utenti in tempo reale

Non abbiamo riscontrato grosse difficoltà nel lavorare a distanza. L'unica cosa è che chiaramente lavorare tutti assieme in presenza è più bello. Di sicuro c'è qualcosa da migliorare ma penso che ciò si ottenga solo con l'esperienza.

Devo ammettere che all'inizio non è stato semplice ci dovevamo un attimo abituare ma dopo averci preso la mano siamo riusciti ad organizzarci, a realizzare e a perfezionare il progetto anche se eravamo a distanza.

sicuramente il non poter lavorare tutti a contatto nella realizzazione del progetto.

Sinceramente non ho avuto difficoltà nel lavorare collaborativamente a distanza, sono sempre state fissate deadline e termini da rispettare che hanno reso il lavoro fluido e organizzato.

È stato fondamentale per la realizzazione del progetto incontrarsi nel laboratorio scolastico. Senza questo incontro la finalizzazione del progetto non sarebbe riuscita.

Siamo riusciti ad incontrarci grazie alla zona arancione. Comunque lavorare a distanza è stato abbastanza semplice, magari più “”noioso”” che farlo in una casa tutti assieme.

Pensi che lavorare per progetti in fisica possa averti aiutato in qualche modo a vivere meglio questo periodo? Se sì, come?

19 risposte

Nel mio caso specifico era un periodo dove mi sentivo sempre come se non avessi niente da fare e mi stavo impigrendo, lavorare al progetto e sforzarsi di capire gli argomenti mi ha un po 'svegliato.

Sia il progetto di quest'anno che quello dello scorso anno, mi hanno aiutato tanto a trovare momenti di socializzazione con i miei compagni e mi hanno permesso di passare alcune ore pomeridiane e serali, facendo qualcosa di diverso e più coinvolgente, contribuendo a superare la monotonia del periodo del lockdown.

assolutamente si, collaborare con i propri compagni è stato divertente e mi ha anche aiutato a chiarire alcuni dubbi riguardanti la materia.. sicuramente dopo tutto il periodo che abbiamo passato, sembrava quasi anormale vivere dei momenti così

Sicuramente lavorare con dei coetanei ed amici ad uno stesso obiettivo ti spinge a dare di più perché oltre che la responsabilità del tuo risultato hai anche una responsabilità sul lavoro complessivo degli altri, ed è importante dare il massimo. In questo periodo sta diventando sempre più difficile trovare la concentrazione ottimale e sicuramente lavorare in gruppo ti da il giusto stimolo per svolgere un buon lavoro.

Sicuramente questo periodo non è stato piacevole per nessuno. Personalmente io non l’ho mai vissuta bene questa situazione, il lavorare assieme con i miei compagni e con i miei amici mi ha aiutato nell’affrontare diversamente questo periodo. Secondo il mio modo di pensare i lavori di gruppo sono molto utili e molto costruttivi.

Certamente è stata un'esperienza molto utile e divertente quindi da una parte si dall'altra comunque sarebbe stato sicuramente meglio realizzarlo insieme

Sicuramente mi ha fatto occupare in maniera diversa le mie giornate e personalmente un po’ di diversità in un periodo così monotono è sempre bene accetta

Si perché come mi sono tenuta in contatto con i miei compagni e ho “studiato” fisica in maniera diversa è più divertente

Bensì abbiamo affrontata a distanza ,questa esperienza è stata un momento di ritrovo e condivisione di pomeriggi di apprendimento e divertimento con amici , quindi sicuramente ha avuto un impatto positivo .

Mi ha dato un qualcosa in più da fare di molto divertente, essendo appassionato di video editing

Si a mio parere ha reso più spensierate e più divertenti le ore di fisica. Ovviamente non si pu lavorare tutto l’anno evitando le classiche lezione di fisica ma seguendo anche il modello della scuola americana sono convinto che questo tipo di progetti coinvolgano più lo studente dentro la materia.

Sicuramente si , il fatto di poter concepire un progetto , un'idea insieme ad altri AMICI , in un periodo in cui si è prettamente da soli o con la propria famiglia (estranea ovviamente alle applicazioni scolastiche) mi ha stimolata . Per quanto riguarda l'ultimo progetto di fisica , nello specifico , mi sono ritrovata in un gruppo che , in realtà , ci è sempre stato al di fuori , ma mai dal punto di vista collaborativo per la scuola ; forse perché non ci abbiamo mai pensato o forse perché tendevano a scegliere una composizione più scontata dei gruppi in precedenza . Io , Giacomo e Demetra abbiamo personalità a tratti uguali e a tratti opposte , ma ciò che ci accomuna è sicuramente la creatività , il sarcasmo e la VOGLIA DI ECCELLERE , la quale ci porta a voler lavorare al massimo delle nostre capacità . Siè trattato di un continuo dibattito e confronto tra idee , critiche e aggiunte , che ci ha permesso di creare un prodotto che avesse parte di ognuno di noi , senza giudizi o voglia di prevalere l'uno sull'altra . Credo di aver trovato il gruppo perfetto per divertirmi, per essere stimolata e per restare concentrata al tempo stesso e questo mi ha donato un attimo di soddisfazione in un momento di caos e sconforto (ne ho parlato nella risposta all'ultima domanda).

No, fortunatamente sono riuscito a trovare interessi personali che mi stanno aiutando in questo periodo

Di sicuro lavorare in questo modo mi aiuta a capire meglio i concetti e ad avere in mente un modello di ciò che succede nella realtà. Oltre a ciò penso che lavorare in un modo diverso a scuola sia un opportunità per non pensare alla situazione generale attuale e sentirsi un po' di più a proprio agio sperando in un ritorno alla normalità.

Si, credo che sia stato utile per riuscire a riprendere quei rapporti sociali che abbiamo perso in quest'ultimo anno.

Si perchè mi ha permesso di riallacciare il rapporto con i compagni e soprattutto mi ha fatto divertire molto cosa che credo in questo periodo sia fondamentale.

Ci ha dato la possibilità di trovarci, passare ore insieme e all'aperto. Meglio di così...

Si, è un metodo di studio molto più coinvolgente e allo stesso tempo divertente.

Si, hanno alleggerire un periodo già molto difficile causa verifiche (matematica, italiano latino scienze) e varie interrogazioni. Soprattuto contando che la nostra vita va avanti oltre alla scuola, e per una volta questo ci ha aiutato.

Quali si sono rivelate le potenzialità che la DAD è riuscita a fornirci e quali di esse suggeriresti di mantenere anche quando l'emergenza sarà finita?

19 risposte

Penso che sia un modo completamente diverso di fare lezione, e credo sia difficile replicarne gli aspetti positivi in presenza. In ogni caso credo che la possibilità di presentare lavori sia stata importante.

L'emergenza epidemiologica ci ha insegnato ad utilizzare in un modo sicuramente più proficuo la tecnologia. Da un lato mi ha permesso di dedicare maggiore tempo allo studio pomeridiano, visto che il tempo impiegato per tornare da Ferrara mi porta via due ore.
Dall'altro è mancata la possibilità di socializzare con i compagni, scherzare, progettare gite o uscite insieme.

per molte persone, me compreso, ha fatto scoprire anche il mondo del computer, che non ero solito ad utilizzare. poi la dad potrà essere utilizzata in molti casi: per esempio per trasferte sportive, per un semplice virus stagionale (che magari è molto contagioso ma non ha sintomi gravi) in più anche il fatto di poter farsi chiarire un dubbio magari da un professore (magari non utilizzando le email, che possono essere dispersive)

La DAD ci ha sicuramente aiutato ad adattarci a qualsiasi difficoltà, la trovo molto utile in un futuro mondo senza emergenza sanitaria per andare incontro ad esigenze di salute, personali che ti impediscano di seguire le lezioni in presenza.

Sicuramente le conoscenze nei confronti dell'uso del computer e delle varie app e piattaforme sono aumentate dopo tutto questo tempo passato davanti al computer. Detto ciò spero che questo finisca presto e di ritornare alla normalità poiché preferisco stare in presenza. A emergenza finita potrebbe ritornarci utile l'utilizzo delle piattaforme come drive, classRoom e Google meet per eventuali incontri pomeridiani e quindi extra scolastici, per non rendere complicato l'incontro e quindi facilitandoci nel vederci via Internet.

In realtà grandi potenzialità non ne ho notate

Una potenzialità può essere quella di esserci cimentati di più nell'uso della tecnologia e questa è una cosa che vorrei mantenere anche in futuro

Presentare progetti interattivi e fare chiamate tra di noi quando non ci riusciamo a vedere

Personalmente preferirei lavorare ad un intero progetto in presenza , però quando non si hanno possibilità di trovarsi si sa già che da casa si può lavorare comunque è soprattuto conosciamo già il modo in cui farlo

I progetti, sia di gruppo che non, e la possibilità di fare esercizi nelle breakoutrooms

Personalmente l'unico aspetto che ho trovato positivo nella DAD è stato non avere più la sveglia alle 6.00 di mattina.
Anche lavorare di più con la tecnologia, con i computer, usando power point o le varie

applicazioni è stato per certi versi meglio. Soprattutto per la nostra generazione abituata ormai ad essere immersa in questo mondo .
Per il resto è una situazione che non auguro a nessuno nel futuro.

Sicuramente , i lavori di gruppo o , in generale , i progetti al computer sono stati un modo di vivere la scuola con meno “pesantezza” , ma che hanno permesso comunque di apprendere gli argomenti , magari dando anche sfogo alla nostra creatività .
Un altro aspetto che ho apprezzato molto è stato l’utilizzo della jamboard: penso che si potrebbe utilizzare anche in classe in quanto comoda , rapida ed efficace , specialmente per la distinzione tra i colori , che spesso ci aiutano a memorizzare meglio i concetti e ad associare quelli in correlazione , caratteristica che è sicuramente più difficile trovare nei colori dei gessi . Personalmente , mi è molto utile questa qualità , in quanto ho una memoria prettamente fotografica ; e perché no .... magari , un giorno, potremmo utilizzarla anche noi portando i nostri computer a scuola .

La DAD permette un collegamento tra molte persone in ogni momento, si potrebbe tenere per quando una persona non riesce a presentarsi a lezione, per motivi legati ad esempio a trasporti o malattie non gravi

Per me il fatto che le nostre spiegazioni siano state registrate e che i nostri lavori possano essere quindi utili per qualcun altro è fonte di grande soddisfazione. Quindi per quanto mi riguarda questa è una potenzialità della Dad da sfruttare anche in futuro

La DAD ci ha dato la possibilità di continuare ad imparare e apprendere nonostante la pandemia in corso, non solo a livello scolastico ma anche nel campo sociale di tutti i giorni, ci ha fatto capire l'importanza delle cose e dei gesti, anche se a volte sono piccoli.
Personalmente quello che terrei della DAD anche quando l'emergenza sarà finita sono le video lezioni registrate in modo tale da permettere agli alunni di potersi riguardare la spiegazione se magari non gli sarà chiaro qualcosa quando andranno a ripassare gli appunti presi.

Le skill in ambito tecnologico sicuramente perchè ritengo che in un mondo sempre più digitalizzato siano davvero fondamentali.

Trovo nell'alternanza tra didattica in presenza e a distanza un valido strumento per il futuro. Magari un giorno alla settimana dove lavorare a distanza e 'spezzare ' dai canoni delle lezioni tradizionali. Il lavoro a distanza rende le lezioni interattive e forse anche più divertenti e godibili.

Potenzialità:
La possibilità potenziale di coinvolge nel progetto anche persone fisicamente lontane da noi

Un evoluzione da parte dei prof e meno ansia sempre da parte di questi. Tornati in presenza si sono dimostrati sempre “agitati” (mi passi il termine) di fare varie verifiche e interrogazioni. Noi ragazzi siamo più uniti invece, stranamente.

Hai qualche suggerimento per facilitare il tuo apprendimento della matematica e della fisica?

19 risposte

Forse potrebbe essere più semplice iniziare a fare gli esercizi di un nuovo argomento anche se non lo si è completamente svolto dal punto di vista teorico, in modo da suddividere in più tempo quelli che faremmo in ogni caso. Questo perché a volte mi sento, soprattutto in fisica, di aver perso l'abitudine a svolgere esercizi.

Per quanto riguarda la fisica mi piacerebbe continuare a svolgere questi tipi di progetti, sia a distanza che in presenza. Per la matematica sento la necessità di fare più esercizi di gruppo perché nonostante mi sembra sia aumentato il mio impegno nelle esercitazioni a casa, a volte ho difficoltà nella loro risoluzione.

ah studiare e fare esercizi su esercizi, nel caso si fanno in gruppo o con l'aiuto di una persona esterna

Il metodo delle "Breakout Room" sperimentato durante le lezioni di matematica ultimamente la vedo come un ottima soluzione per diversificare un lavoro a distanza che può risultare monotono

Non ho particolari suggerimenti se non esercitarsi continuamente perché ho notato che esercitandomi maggiormente e magari aggiungendo anche degli esercizi da fare a quelli dati mi ritrovo facilitato poi durante la risoluzione del compito in classe.

In questi ultimi anni ho capito che quando sono in difficoltà con un argomento devo cercare sempre di paragonarlo ad un esempio concreto così ho più possibilità di capire ed è anche per questo che secondo me i progetti sono molto utili

Probabilmente con modalità più interattive

Fare progetti ed esperimenti

Per la fisica lavorare su un progetto che comprenda un argomento da affrontare o affrontato facilità sicuramente l'apprendimento e fa apprezzare l'argomento stesso . Per la matematica non saprei

No direi di no

Se si dovesse tornare al 100%, che sia quest' anno o il prossimo, mi è piaciuto molto lavorare in gruppo anche nel risolvere esercizi all'apparenza banali. Personalmente penso sia un ottimo modo per apprendere meglio alcuni concetti.

Ho trovato molto stimolante e personalmente utile il fare degli schemi riassuntivi alla fine di ogni argomento / capitolo ; mi permettono di avere un quadro generale di tutto e di capire meglio i collegamenti tra i vari argomenti. Inoltre , mi sono trovata molto bene a svolgere esercizi insieme ai miei compagni , a gruppi : permette di confrontarsi e di imparare l'uno

dall’altra , a volte permette anche di ragionare in maniera più estesa e rapida rispetto a quando lo si fa da soli . Mi piacerebbe riuscire ad applicare questo metodo anche in classe , quando sarà possibile e non solo in DAD.
Ho apprezzato particolarmente l’utilizzo di GEOGEBRA e vorrei farlo anche a scuola , poiché più volte mi ha permesso di osservare meglio i concetti e di confrontare le idee che avevo in mente con la realtà , specialmente per la geometria solida .
Infine , vorrei svolgere più esperienze di laboratorio , perché riesco ad imparare in maniera molto più rapida , osservando i fenomeni , anche se ne abbiamo fatto sicuramente di più rispetto agli altri anni.

Chiedersi spesso il perchè delle cose

Sicuramente fare progetti pratici aiutano tutta la classe a comprendere meglio gli argomenti

Personalmente apprendo molto più velocemente la matematica rispetto alla fisica, però credo che fare degli esercizi in piccoli gruppi con i tuoi compagni di classe sia molto efficace in quanto ti da la possibilità di confrontare la tua idea con quella degli altri.
Inoltre per la fisica credo che possa essere utile risolvere esercizi e cercare di riportarli nella realtà.

Partire dal pratico per arrivare al teorico

Personalmente parlando, ammetto in totale sincerità che ci sono stati momenti dove ho trovato le verifiche un pò troppo affrettate rispetto al lavoro che siamo sempre stati abituati a fare. Nell'ultimo periodo, sia in matematica che in fisica, mi sto trovando veramente bene, e anche se sono le due materie dove ho la situazione più incerta, mi sento sicuro e motivato nello svolgimento delle lezioni.

Avere più opportunità di apprendimento pratico (attraverso laboratorio o tramite l’osservazione) e meno teorico

No, al massimo mi organizzo da solo con ripetizioni ma penso che le spiegazioni in generale siano buone ma non sono per giudicare.

Hai incontrato qualche difficoltà particolare in questo periodo di cui vorresti parlarmi perchè pensi potrebbe facilitare la reciproca conoscenza ed il tuo apprendimento? (La risposta resterà ovviamente riservata tra me e te)

18 risposte

Direi di no, ho qualche dubbio su un tipo di esercizi di geometria solida, ma anche se nelle ultime lezioni sono mancato mi sento più esercitato avendone fatti.

Come detto prima sento la necessità di dover fare più esercizi in classe per potermi migliorarmi nella velocità di risoluzione delle consegne, visto che spesso ho difficoltà a portare a termine la verifica.

forse in alcuni casi mi è mancata la voglia di stare attento (a causa delle molteplici ore attaccato al computer) e di conseguenza anche nello studio pomeridiano (causa stanchezza o mancanza di voglia)

Oltreché per l'organizzazione non ho trovato particolari difficoltà nell'apprendere la materia se non un argomento che ho poi dovuto recuperare poiché non mi era totalmente chiaro. Sicuramente un maggior dialogo tra insegnante e studente, a mio modo di vedere, facilita molto il lavoro di ambo le parti.

No non ho incontrato grandi difficoltà

Nessuna nuova difficoltà al momento

No

Ho incontrato difficoltà nel prestare attenzione e nell'apprendimento delle lezioni di matematica . Sicuramente la dad non mi ha aiutato a migliorare le prestazioni in questa materia...

Scolasticamente è un periodo aureo. La verifica di matematica di oggi è andata molto male e mi dispiace tantissimo se devo essere sincero. Penso di aver ripetuto lo stesso errore (stupido) concettuale in tutta la verifica. Purtroppo è andata. Adesso devo impegnarmi a recuperare

Le difficoltà maggiori che ho avuto quest' anno penso sia stato il periodo in cui ho avuto il virus. Anche se stavo molto bene fisicamente una situazione del genere ti tira giù molto di più dal punto di vista psicologico. Adesso le difficoltà staranno nel riprendere la vita di sempre, il ritmo giornaliero, che comprende studio e sport.

È stato un periodo confusionario per tutti. Io , in particolare , ne ho risentito in ambito scolastico in quanto cosa a cui mi dedico per la maggior parte del tempo e a cui tengo molto
.
In alcune settimane , mi sono ritrovata ad affrontare più interrogazioni o verifiche , a volte anche nello stesso giorno , il che non mi ha permesso di rendere al massimo delle mie potenzialità . Ammetto di non essere una persona molto organizzata nello studio , ma

nonostante ciò , cerco sempre di impiegare tutto l'impegno possibile in ciò che faccio . Non ripiego là colpa di alcuni miei fallimenti o delusioni scolastiche sui professori e sulla scuola in generale , anzi, sono una persona che si colpevolizza molto e si rende conto dei propri sbagli nel momento in cui li commette ; ma se mi viene chiesto di esporre le mie difficoltà dell'ultimo periodo , sicuramente devo dire di non sentirmi più capace come gli anni precedenti . Sento che la mancanza di equilibrio , tra DAD e presenza , mi ha portata al caos totale . Sento di non riuscire più a memorizzare le cose come facevo prima , sento di non riuscire più a dare il 100% .... motivi per i quali forse , specialmente nelle ultime settimane , mi sto arrendendo . Ripeto , sono una ragazza che , in generale , ama la cultura , ama imparare e sapere le cose (anche solo per curiosità personale) , ama capire quali sono i propri punti deboli , ma anche quelli forti . Ecco , adesso non sto più riuscendo a vedere i miei punti forti , il che mi demoralizza e mi porta quasi a "cedere " .
Da sempre , non sono abituata a fare paragoni con gli altri , ma ad essere in una perpetua competizione con me stessa : tendo sempre a volermi superare e migliorare . Non ho mai disdegnato l'impegno , in particolare nel mondo scolastico : sono sempre stata disposta a rinunciare ad uscite con amici (per fare un esempio banale) per studiare qualche ora in più , se era necessario per ottenere i risultati che mi ero prefissata , ma nonostante la mia forza di volontà , ultimamente non riesco a raggiungere i MIEI obiettivi e questo è ciò che mi fa sentire peggio.
So di non essere l'unica ad avere delle difficoltà , che ovviamente non riguardano solo L ambito scolastico , ma la salute mentale di ognuno di noi , sicuramente compromessa dal periodo difficile , ma prendo questo spazio come una piccola pagina di diario , di momento di sfogo personale , sperando di riuscire a superare tutto ciò che ora non mi fa stare al meglio , ma soprattutto , sperando di capire cosa c'è davvero di sbagliato in ciò che sto facendo , con lo scopo di riuscire a rimediare ...

In realtà per me è un periodo felice, sotto molti punti di vista, quindi non ho, per ora, qualcosa di cui dover parlare

Direi di no grazie comunque prof.

Durante questo anno scolastico fortunatamente sono riuscita, bene o male, sempre stare al passo in tutte le discipline. Queste ultime settimane però sono state abbastanza piene e stressanti, durante la settimana rimango a studiare fino alla sera tardi e trascorro quasi tutto il weekend sui libri per cercare di portarmi avanti con i compiti della settimana che verrà, e questo mi porta a non avere più tempo per me stessa per uscire a farmi un giro, poiché l'unico momento in cui esco di casa è per andare a fare allenamento, questo tutti i giorni durante la settimanae e a volte nel weekend, nel caso in cui non abbia gare.
Questa situazione mi porta a un grande accumulo di stress e ansie che faccio fatica a smaltire.

A dire il vero no prof. a scuola va tutto bene gli allenamenti non li ho mai smessi in quanto agonista e adesso che siamo in zona gialla posso vedere più spesso i miei amici.

Come ho più o meno indicato nella risposta sopra, la situazione è molto diversificata in base ai momenti dell'anno scolastico. Il trimestre è volato e sostanzialmente è filato liscio. I primi mesi (gennaio/marzo) del pentamestre sono quelli che ho trovato più difficili e dove forse ho avvertito una frenesia eccessiva da parte dei professori. Sono stati mesi molto intensi e a ritmi serrati, con molte valutazioni. Ora posso dire che, essendo le situazioni personali pressoché delineate, riscontro nei professori di tutte le materie un atteggiamento del tutto collaborativo, che mi permette di chiudere l'anno in serenità. Per fisica e matematica nessun problema, sono io che in verifica faccio errori da pollo!

Come già si dice da mesi la situazione covid non ha giovato a nessuno.
In generale per me questo è stato un periodo davvero difficile e frenetico.

Nella prima parte dell'anno abbiamo avuto qualche difficoltà ad affrontare la modalità della dad (nonostante l'avessimo sperimentata già l'anno scorso) e per questo ci ritroviamo ora a dover comunque raggiungere gli obbiettivi in tappe forzate e incalzanti.

Ho avuto qualche problema in matematica per l'alternarsi dei prof e della presenza. In fisica stranamente sto capendo. Penso comunque che questo modulo sia molto utile!

ESG 8.01/8.012 Physics, Friday "Windmill" Exploration
Pushing on Objects with Air from Hair Dryers

Context
Renewable energy is a 21st century concern, and wind energy offers potential advantages including the absence of carbon emissions and opportunities for local energy production and micro-grids. The conversion of the kinetic energy of moving air to blade rotation and the forces exerted by moving air on windmill blades and structures are fundamental to realizing the potential of wind energy. This Friday's hands-on session encourages you to explore the force, energy, and momentum transfer of air as it moves past balloons and ping-pong balls.

You should experience:
- Further practice playing
- An investigation of what you find interesting
- The connection of 8.01 models of kinematics, force, momentum, and/or energy to phenomena you observe
- If time allows, testing of the relationship between your "model" and the phenomenon you think is interesting.

The learning objective:
- Awareness of the progression from play to model & perhaps to model testing

Resources:
- String/thread
- Ping pong balls
- Balloons
- Assorted scales
- Hair dryers
- Glue and tape
- Many other things that can be found in 24-611B

Exploration Procedure
Either in groups or individually (recognize that you'll have to share hairdryers),
1) Play with the balloons, ping pong balls, and hair dryers. (10 minutes)
2) Identify something you find "interesting" from playing with the balloons, ping-pong balls, and hairdryers. (5 minutes)
3) Identify an 8.01 physics model that might explain the interesting phenomenon.
4) If time permits, test the physics model, perhaps by: a) testing a hypothesis, b) measuring some aspect(s) of the balloon/ping-pong ball/hairdryer interactions, c) optimize the balloons/ping-pong balls/hairdryers system for some characteristic (impart the most energy into a balloon, make a balloon go as fast as possible…) and/or d) pursue the investigation that you are compelled to pursue. (30 minutes)
5) Briefly share your work and discoveries with all present (5 minutes)

Deliverables
In a paragraph or two, identify:

- What you played with
- What you found interesting
- How you modeled what you found interesting
- Perhaps the testing and results of testing
- What you discovered and/or what new questions you have uncovered

Specifications to get an R:

1. Actively participate in the exploration.
2. Describe in a paragraph:
    - What do you play with
    - What you found interesting

Specifications to get an M:

1. Actively participate in the exploration during class.
2. Describe in a paragraph:
    - What do you play with
    - What you found interesting
    - How you modeled the interesting phenomenon

Specifications to get an E:

1. Actively participate in the exploration during class.
2. Describe in a paragraph:
    - What do you play with
    - What you found interesting
    - How you modeled the interesting phenomenon
    - How you investigated (or propose to investigate) the connection between the model and the phenomenon
    - What you discovered and/or what new questions you uncovered

Acknowledgements

This thesis describes a journey wherein the example, synergy, and dedication of many individuals demonstrate the possibility of implementing within the Italian educational system a methodology and educational approach that truly places students at the center. It offers them the opportunity to experiment, express their creativity, challenge themselves, explore and measure their talents and inclinations, thus gaining self-awareness and learning to improve themselves through interaction with their peers.

I would like to express my gratitude to my supervisor, Professor Roberto Calabrese, who immediately recognized the importance of a different learning model for young people. With vision and unwavering support, he provided me with all the opportunities to delve into innovative methodologies and disseminate them during my research.

I am grateful to the one who first inspired me with the idea of a different learning model during my experience at MIT, the instructor of MIT-Edgerton Center Mr. Ed Moriarty. With tireless dedication and valuable advice, he consistently supported me in my field research and in establishing the invaluable HoPE (Hands-on Physics Experience) program at my school.

I extend my gratitude to those at the Massachusetts Institute of Technology who expanded my horizons as an educator, including the entire Experimental Study Group at MIT, Dr. Carmelo Presicce of MIT-MEDIA LAB, and Dr. Elisabeth Cavicchi of the Edgerton Center. They patiently answered my questions and served as a source of inspiration and example for discovering new learning and teaching methodologies.

My thanks also go to those who sparked the initial idea and encouraged me to embark on this journey, including the management of "A. Roiti" High School, who invited me to participate in the first project with MIT in October 2017, and Dr. Serenella Sferza of MISTI-MIT, who, by selecting me, gave me the opportunity to get to know MIT.

I am grateful to those whose support is making it possible to continue the HoPE project, which inspired this research: the current management of "A. Roiti" High School, the Ferrara section of the National Institute of Nuclear Physics, the Department of Physics and Earth Sciences at Unife, and the Edgerton Center at MIT, led by its Director Prof. Kim Vandiver and all its staff.

Special thanks to Prof. Patrizio Bianchi and INDIRE, who provided valuable insights and advice throughout my research.

I want to thank my friends and colleagues Serena Parma, who has been by my side through thick and thin for my whole life, Francesca De Scisciolo, Daniela Rizzieri, and Valentina Rolando, because without their strength, expertise, patience, and commitment, it would not be possible to advance the HoPE project.

I express my gratitude to my Catalan friend and colleague, Alicia Lopez Jornet, with whom, despite being in different countries, I am united in the endeavor to integrate MIT's "Mens et manus" methodology into high school educational systems. Continuous dialogue is a source of constant growth.

I thank all the friends whom I cannot list but who, in different ways, supported me, bringing joy even in the most challenging moments, especially Anna Elisa Camisasca, whose meeting as a doctoral colleague was a happy gift of this journey.

Lastly, and most importantly, I thank the students of HoPE and the staff of Edventure, who are the true beating heart of the HoPE project and, truthfully, the beginning and end of our work as educators.

But special thanks go above all to my family, especially my husband, who stood by my side, believed in what I was doing, and advised me, helping me overcome difficulties and hardships. Without the courage he gave me, this incredible adventure would not have even begun.