Alma Mater Studiorum · University of Bologna

School of Science
Department of Physics and Astronomy
Master Degree in Physics

Analysis of an Interdisciplinary Approach for Teaching Artificial Intelligence in Secondary Schools through Co-planning and Co-teaching Methodologies:

A Proposal for the Open Schooling Model of the FEDORA Project

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Academic Year 2022/2023

“Abbiamo bisogno di uno sguardo e di un coraggio che ci permettano di rimanere intelligenti in un mondo intelligente”

G. Gigerenzer, Perché l’intelligenza umana batte ancora gli algoritmi (2023)

Table of Contents

Abstract

This thesis is part of the FEDORA project (Future-oriented Science EDucation to enhance Responsibility and engagement in the society of Acceleration and uncertainty), a three-year project funded by the EU that started in September 2020. The project involves 6 partner institutions from five European countries coordinated by the University of Bologna. The main objective of FEDORA is to develop a "model for science education for the society of acceleration and uncertainty" (https://www.fedora-project.eu/). To achieve this, the project partners established networks of schools at the European level, called "open schooling networks", to implement interdisciplinary STEM learning-teaching modules on emerging themes such as artificial intelligence, climate change, and quantum computers, and study the implementation of teaching practices. The actions and results of the project provide recommendations for anticipatory policies to promote visionary attitudes towards open schooling and guiding concrete institutional transformations[1]. The work of this thesis focused on following the implementation of the FEDORA module on artificial intelligence at the "Liceo Einstein" in Rimini and the subsequent laboratory between art, creativity, and artificial intelligence (AI Atelier), conceived by the school's teachers themselves. The research work consists of the investigation of co-planning and co-teaching methodologies implemented in the two projects. This is accomplished by directly observing the courses and later interviewing the teachers, with the goal of highlighting the benefits of this type of teaching as well as the difficulties faced in implementing it within a real school context. The overarching objective is to suggest potential solutions for improving future courses and potentially raising awareness among policymakers about the necessary reforms to align education with the demands of a society characterized by acceleration.

[1]https://dfc.unibo.it/it/ricerca/progetti-di-ricerca/h2020-swafs-20-2018-2019-fedora-future-oriented-science-education-to-enhance-responsibility-and-engagement-in-the-society-of-acceleration-and-uncertainty

Introduction

We live in a society strongly influenced by artificial intelligence (AI), which has permeated multiple aspects of our daily lives. From searching for information online to interacting on social media, from smart devices in our homes to personalized content recommendations in streaming, AI has become a constant presence. Moreover, it has a significant impact on the personal and social sphere, introducing a range of implications and challenges that extend beyond the technological realm, such as privacy and data security, automation of work, bias, and discrimination, modification of social behaviors, ethics, and human relationships.
Due to these implications, AI represents an inherently interdisciplinary field that lies at the interface of technical, human, and social sciences.

Incorporating AI into school curricula is a crucial worldwide effort to educate the future generation. However, at the present time, teaching AI in high schools is a new phenomenon and there is a lack of studies that inform schools' teachers about AI curriculum design and teaching methods (Chiu et al., 2020; Yau et al., 2022).
One of the main goals of the European project FEDORA (Future-oriented Science Education to enhance Responsibility and Engagement in the society of acceleration and uncertainty), coordinated by the University of Bologna and started in 2020, is to develop a "model for science education for the society of acceleration and uncertainty"[2]. In order to do so, the project partners have established networks of schools at the European level where they can implement learning-teaching modules on emerging and interdisciplinary STEM topics, such as AI, and study the implementation of teaching practices, the so-called "open schooling networks".

The present thesis is part of this project and aims to explore possible valid educational methodologies to teach interdisciplinary topics, such as AI, in upper secondary schools: co-planning and co-teaching.
Interdisciplinary co-planning and co-teaching can represent an opportunity to promote change within the school institution and to introduce the teaching of AI. However, they can represent a challenge for both teachers, who must redefine their role within collaboration among peer experts from different disciplines, and for the school institution itself, which has to question its historical core structure. We explored how co-planning and co-teaching have been managed during the implementation of the FEDORA teaching module on AI and the subsequent AI Atelier, both delivered as two PCTO ("Percorsi per le Competenze Trasversali e l'Orientamento")[3] laboratories at the Liceo Einstein in Rimini, which is part of the Bologna open schooling network.

[2] https://www.fedora-project.eu/open-schooling/
[3] The "Percorsi per le Competenze Trasversali e l'Orientamento"(PCTO) are curricular projects that allow students to integrate traditional classroom education with training periods at companies or private/public affiliated organizations, as well as in school laboratories or simulated environments.
Introduced in 2019 as an evolution of school-work alternation, implemented in Italy in the upper secondary schools of all fields of study, these pathways are carried out by students in the third, fourth, and fifth years, aiming particularly at the development of key skills for lifelong learning with a guiding significance. According to the current regulations, the minimum hour requirement is 90 hours for the final three years for licei, 150 hours for istituti tecnici, and 210 hours for istituti professionali; the educational institution, within its autonomy, can also implement PCTO for a longer period. (D.M. n. 774 del 4 settembre 2019:
https://www.miur.gov.it/documents/20182/1306025/DM+774+del+4+settembre+2019.pdf/10b2cd6a-6f41-2504-0475-69fc9abd730b?version=1.0&t=1570548387944;
Linee guida per i PCTO:
https://www.miur.gov.it/documents/20182/1306025/Linee+guida+PCTO+con+allegati.pdf/3e6b5514-c5e4-71de-8103-30250f17134a?version=1.0&t=1570548388496)

Specifically, our purpose is to point out the elements, the benefits, and the challenges that characterized the co-planning and co-teaching phases from the perspective of teachers and propose possible solutions to include these methodologies in the regular educational structure. Finally, the results of this thesis will contribute to formulating a co-teaching model that will converge into the "model for science education" developed by FEDORA.

The thesis is articulated in five chapters.

The first chapter is specifically focused on the FEDORA project. After a general description of its goals and structure, the concept of "open schooling" is introduced, and the open schooling networks established by the project partners and the teaching modules implemented within them are illustrated.

The second chapter is a literature review on co-planning and co-teaching to make the state of the art in these methodologies and the contexts in which they have been applied so far. Then, the main elements emerging from the review that characterize co-teaching and co-planning are described, and the research questions chosen to investigate these methodologies in our context are illustrated.

The third chapter concerns the description of the teaching module on AI + AI Atelier implemented as PCTO laboratories at the Liceo Einstein. After introducing the teachers who co-designed and co-taught during the course on AI and the AI Atelier, the description of the two PCTO laboratories is presented along with the main contents and learning outcomes presented during the lectures.

The fourth chapter describes the methodologies adopted to investigate the research questions of this study. In particular, it illustrates what kind of data were collected, how the interview protocol was designed, which method of data analysis has been chosen to analyze the data, and how the "triangulation" and "member checking" processes were carried out to validate the results obtained from the analysis.

The fifth chapter concerns the actual analysis of the data in this study. For each research question, after a description of how the collected data were managed during the analysis, the results obtained are, firstly, presented, then, compared with the literature reviewed in chapter 2, and finally discussed. At the end of the chapter, there is also an overview of the FEDORA recommendations on the actions that policymakers should take to align the school with the needs of current society.

Chapter 1 - Research Context: The FEDORA Project

Science and technology are advancing at extremely high speeds, and we are witnessing the emergence or consolidation of new areas of research, such as artificial intelligence, climatology, and quantum technologies. These areas are characterized by their interdisciplinarity, multi-actor approach, and openness to the needs and demands of society (known as "open science")[4]. This society in the field of sociology is known as the "society of acceleration" (Rosa, 2009; 2010; 2013). According to Rosa (2010, 2013), the society is subject to three major dimensions of acceleration: (i) technical acceleration; (ii) social acceleration (i.e. changes in the institutions through which we bring order to our lives); and (iii) acceleration in the pace of life (i.e. the general sense and experience of time and deadlines on a day-to-day basis). The technical acceleration is central to Rosa's argument since it is indicated as the main driver of change.
A central issue emphasized by the sociologist is that social institutions, like political and educational systems, are not able to keep the pace of technological transformation (Levrini et al., 2021a); especially schools are undergoing often superficial changes that do not question their underlying structures (OCSE-OECD, 2018). Because of the misalignment in speeds, a gap in knowledge and skills emerges between what educational institutions produce and what society demands [4]. School science, in particular, instead of preparing the young to navigate our fast-changing and complex society, tends to create "bubbles of rituals" that detach learning from societal concern (Levrini et al., 2021a). According to Levrini (2021a), it is important that schools open up to society and implement processes that not only contribute to shaping students as active and responsible citizens but also transform the institution itself.

This is the main direction of the European project FEDORA (Future-oriented Science EDucation to enhance Responsibility and engagement in the society of Acceleration and uncertainty, https://www.fedora-project.eu) within which the present thesis is framed.
In this chapter, I will present the key points of the FEDORA project, which encompasses the idea of open schooling, and I will describe the European open schooling networks that have been established, especially the Bologna one, and the corresponding modules implemented.

1.1 The FEDORA Project

FEDORA is a 3-year EU-funded project, started in September 2020. The project involves six partner institutions from five European countries: the University of Bologna (coordinator), Kaunas University of Technology, University of Helsinki, University of Oxford, Teach the Future (a global non-profit movement that promotes futures literacy for students and educators), and formicablu (an Italian science communication agency)[5].
FEDORA is the follow-up of other three European projects: the two Erasmus+ projects I SEE (Inclusive STEM Education to Enhance the capacity to aspire and imagine future careers,

[4] https://www.primapagina.sif.it/article/1141/fedora-ripensare-l-educazione-scientifica-nella-societa-dell-accelerazione-e-dell-incertezza
[5] https://www.fedora-project.eu/partners/

https://iseeproject.eu) and IDENTITIES (Integrate Disciplines to Elaborate Novel Teaching approaches to InTerdisciplinarity and Innovate pre-service teacher Education for STEM challenges, https://identitiesproject.eu/), coordinated by the University of Bologna, and the project SEAS (Science Education for Action and Engagement towards Sustainability, https://www.seas.uio.no/), coordinated by the University of Oslo, in which the University of Bologna participated as a partner.

FEDORA, focusing on the time variable of change, individuated the blind spots represented by forms of misalignments that emerge observing how the main institutions, involved in the interface between science and society, react and address the challenges posed by the society of acceleration. More specifically, the FEDORA project aims to contribute to three blind spots recognized in the actual school systems and science education (Tasquier et al., 2021):

1. The ***first blind spot*** refers to the need to revise the institutional, methodological, and conceptual organization in traditional disciplines in order to align school science with the *inter-multi-transdisciplinary*, *multi-actor,* and *open* character of Research and innovation (R&I).
2. The ***second blind spot*** refers to the need to explore *new languages and narratives* to enable the young generation to grapple with the complexity of the current societal challenges and to participate in the current debate valuing the points of view of scientific communities.
3. The ***third blind spot*** refers to the need to "futurize" science education. This implies the need to infuse education with activities able to provide the young with future-scaffolding skills that enable them to construct visions of the future that empower action in the present with an eye on the horizon.

The three misalignments are respectively addressed within work packages (WP)[6].

The first package (WP1) aimed to identify the limits of discipline-based or vertical knowledge organisation and proposed ways to address them through inter-multi-trans-disciplinarity. Therefore, within WP1, the researchers of the consortium analyzed a variety of voices and perspectives on disciplinarity and inter-multi-trans-disciplinarity by experts in research performing and funding organisations, education policymakers and implementers, schools, and industry. Furthermore, WP1 led to the identification of some issues that have to be addressed by policy-makers as well as education managers. From this analysis, a bunch of research evidence-based recommendations was pointed out for multi-teaching and open schooling (Pucetaite and Rauleckas, 2022).

More specifically, WP1 led to:

- the creation of interdisciplinary and multi-actor communities and collaborations;
- the exploration of the inner dynamics of an interdisciplinary study group so as to flesh out models of multi-actor dynamics;
- the elaboration of criteria for designing examples of teaching materials to be implemented in co-teaching and open-schooling contexts and to develop inter-multi-transdisciplinary thinking skills needed to navigate and play an active role in the society of acceleration.

WP2 addressed the exploration and co-design of ideas and strategies to embrace new languages and formats in science education. This work draws inspiration not only from the realm of science but also from the integration of scientific knowledge with literary, artistic, narrative, and visual approaches.

[6] https://www.fedora-project.eu/work-packages/

WP2 led to:

- equipping teachers and their students with linguistic, argumentative, and imaginative thinking skills needed to face contemporary challenges
- experimenting with innovative communication approaches to futurize science education giving the youth a chance to perceive, imagine and envisage and thus shape the future.

WP3 consolidated the future-oriented approach to science education developed within the I SEE project. The idea on which the approach is based is that it possible to extend the scientific competencies with additional skills related to futures thinking, like time perspective, agency beliefs, openness to alternatives, systems perception, and concern for others**,** in order to enrich science education and prepare students for tomorrow.

WP3 led to:

- the exploration of the current status of the role of future in science education as manifested in curricula, textbooks, and other educational materials;
- the development of an analytical framework and methodology to study the young generations' futures thinking in this complex and uncertain society;
- the investigation and understanding of how 11-19 years old students perceive the future;
- the analysis of the "time misalignment" and the need to futurize science education;
- the elaboration of design criteria of examples of future-oriented activities aimed to develop future-scaffolding skills.

The researches carried out in WP1, WP2 and WP3 are turned into orientations and executive suggestions for fundamental actions in WP4: establishing local open schooling networks, designing innovative teaching materials and activities and planning the implementations. The WP4 main outcome is to elaborate a **"research-based model for science education"** to equip, through the implementation of teaching materials and activities in open schooling networks, young generations with thinking (inter-multi-transdisciplinary, and linguistic-argumentative-imaginative) and future-scaffolding skills needed to navigate and participate in science within the society of acceleration (Tasquier et al., 2021). According to Tasquier et al. (2021), the research-based model for science education is progressively elaborated throughout the project and the experiences gathered during the 3 years will converge into the final version of the model that will have the form of guidelines and will be articulated in three main sections:

1. The first section will include the theoretical and pedagogical framework of the approach to science education
2. The second section will include a list of design and implementation principles that operationalize the theoretical and pedagogical approaches into practical recommendations. Principles and recommendations will concern the design and implementation of teaching materials, the creation of interdisciplinary and multi-actor contexts and the examples of co-teaching and open-schooling model implementations.
3. In the third section, the principles will be illustrated through case studies or examples taken from the implementations of learning and teaching activities developed by the partners and the open schooling networks.

1.2 Open Schooling

The idea of open schooling was officially introduced within the EU context in 2015 by the report entitled *Science Education for A Responsible Citizenship*, which asserts the need to create and explore ways to expand science education beyond traditional school models (Tasquier et al., 2022a). According to Tasquier et al. (2022a), open schooling is related to the **ri-definition of the role of the school** in its mutual relationship with society. In particular, "openness" refers to the idea that schools have to become flexible structures, open to society, and should be able to make a difference in the world. The 2015 report defined open schooling as "Institutions that promote partnerships with families and the local community with a view to engaging them in the teaching and learning processes but also to promote education as part of local community development" (European Union, 2015, p.69).

Within FEDORA the open schooling model is developed in strict collaboration with the Horizon2020 project SEAS (Science Education for Action and engagement towards Sustainability), from which FEDORA borrows **the heuristic model of the *three spheres of transformation*** (O'Brien and Sygna, 2013) to understand the changing relationship between individual, collective, and political agency.
As depicted in Figure 1.1, this model identifies three interconnected spheres of change: the practical sphere, the political sphere, and the personal sphere. The practical sphere includes technical and behavioral changes. The political sphere focuses on the systems and structures that either facilitate or hinder transformations in the practical sphere, including social norms, rules, regulations, institutions, and infrastructure that shape the organization of society. Both the political and practical spheres are influenced by the (inter-)personal sphere, which highlights the importance of individual and collective worldviews, values, beliefs, and paradigms that are at stake and which drive people's motives for practical and political action (Tasquier et al., 2021).

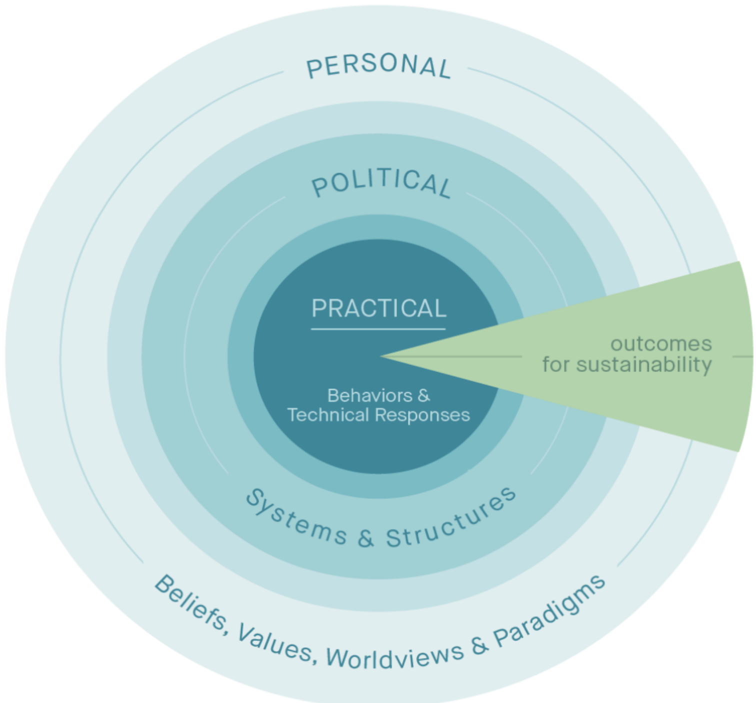


Figure 1.1: The three spheres of transformation (O'Brien and Sygna, 2013, p.5)

According to Tasquier et al. (2021), SEAS defines the concept of "openness" as an effort to open up traditional schooling to:

1. **include and reinterpret education content** that is not commonly included in education, as well as scientific, and disciplinary perspectives;
2. **include non-traditional stakeholders** in schooling and actors associated with traditional schooling to engage with actors outside of schooling;
3. **connect school learning with** that which is traditionally considered **outside** the issue of schooling .

FEDORA elaborates on the SEAS's characterization of openness focusing on the idea of action (Tasquier et al., 2021), starting from:

1. Action at a level of content
2. Action at a level of interaction among the various stakeholders in interdisciplinary and multi-actor contexts and open schooling networks
3. Action at a level of (institutional) transformation

In order to accomplish the executive suggestions for fundamental actions in WP4, three open schooling network were established by the FEDORA partners: the **Helsinki** Open Schooling Network (HOSN), the **Oxford** Open Schooling Network (OON), and the **Bologna** Open Schooling Network (BOSN). Within each network, researchers, teachers, communicators, and other professionals worked together on the design of innovative teaching activities and materials based on FEDORA's principles and results[7]. In the next paragraph I will describe more in detail the Bologna Open Schooling Network, that is the context in which my study is situated.

1.2.1 The Bologna Open Schooling Network (BOSN)

The Bologna Open Schooling Network (BOSN) was initiated based on the experience gained from designing innovative approaches and teaching modules to encourage students' future imagination and STEM career aspirations during the I SEE project (September 2016 to August 2019). This experience fed the *open schooling network* established in September 2019, within the SEAS and then the FEDORA project[8].

According to Tasquier et al. (2021), in terms of network composition, two schools with a strong history of collaboration and deep engagement with two FEDORA pillars (interdisciplinarity and the future) were initially involved. These schools are the "Liceo scientifico Einstein" in Rimini and the "Istituto tecnico ITAER Baracca" in Forlì. During teacher training and dissemination activities conducted as part of the FEDORA project, other schools manifested an interest in collaborating with the project. Three additional schools joined the project: an International School (International School of Como), a private International STEM-oriented Lyceum (IESS, Reggio Emilia), and an Art-oriented Lyceum (Liceo Germana Erba e Fondazione Teatro Nuovo in Turin).

[7] https://www.fedora-project.eu/open-schooling/

[8] https://www.seas.uio.no/about/local-networks/italian-local-network/index.html

1.3 Implementations of teaching modules

The “**research-based model for science education”** is developed gradually throughout the project, during two rounds of implementations of some materials and activities in the different countries involved.
FEDORA's first round of implementations took place during the second year of the project within the three open schooling networks. In particular, six implementations were carried out, which are summarized in Table 1.1 (Tasquier et al., 2022b).

Table 1.1. Codes, names, and the number of repetitions for each implementation (From Tasquier et al., 2022b, p.6).

ID of the implementation (OSN-YEAR-ID)	Extended name of the implementation	No. of repetitions
HOSN-2022-CITY	My city of the future	1
OOSN-2022-MUS	Climate change at the museum	3
BOSN-2021-MOCK	Mocku for change	1
BOSN-2021-PHCL	Physics of clouds	1
BOSN-2022-SIM	Simulations of complex systems	2
BOSN-2021-QUAT	Quantum atelier and The second quantum revolution	2

FEDORA's second round of implementations took place during the third year of the project and seven implementations were carried out. Among them, there is the AI Atelier, an interdisciplinary laboratory on artificial intelligence, in its first implementation carried out within the Liceo Einstein in Rimini, that I will describe in detail in chapter 3.
The implementations are outlined in Table 1.2.

Table 1.2. Codes, names, and the number of repetitions for each implementation.

ID of the implementation (OSN-YEAR-ID)	Re-edition of totally new implementation	Extended name of the implementation	No. of repetitions
HOSN-2023-CITY	Re-edition of HOSN-2022-CITY	My city of the future	1
OOSN-2023-MUS	Re-edition of OOSN-2022-MUS	Climate Change and the Future of Learning	3
BOSN-2022-AERO	New implementation	Aerocene	1
BOSN-2023-AI	New implementation	Artificial Intelligence (AI) Atelier	1
BOSN-2023-KAIR	New implementation	Kairos - To correct the subtle drift of days	1

As I said, the liceo Einstein in Rimini is one of the partners of the FEDORA project. In the philosophy of the project, the liceo Einstein has developed and is developing, in collaboration with DIFA (Department of Physics), interdisciplinary educational pathways that have taken shape as PLS (Laboratory of Basic Physics) or PCTO (Transversal Skills and Orientation) courses managed internally within the Institute, targeting specific classes or student groups. Examples of these are creative writing projects ("The Physics of Clouds" and "Kairos"), the PLS on uncertainty, the PCTO on artificial intelligence, and the Ateliers ("Quantum" and "AI"). The work of the teachers created authentic interaction between different disciplines such as physics, mathematics, computer science, philosophy, literature, and art. The overarching goal of these activities is to provide "spaces" for experimentation, between researchers, teachers and students, fostering reflection that involves both the exploration of new concepts and their learning as well as stimulates students to imagine new forms of representation of the knowledge they are acquiring [9].

[9] https://www.einsteinrimini.edu.it/progetti-interdisciplinari/

Chapter. 2 - Co-planning and Co-teaching: A Literature Review

Encompassing the idea of open schooling to create and explore ways to expand science education beyond traditional school models, in this thesis we will analyze co-planning and co-teaching as possible methodologies to introduce the interdisciplinary topic of artificial intelligence in high schools and to implement new rituals of science teaching.
Before doing so, in this chapter we will conduct a literature review, specifically regarding the definition of co-teaching and its application in different contexts and how co-planning has been managed, in order to provide a reference point in the relevant literature and explore potential analytical perspectives for our study.

2.1 Methodology

For this review, five electronic databases were included in the search:

1. Google Scholar (https://scholar.google.com/);
2. ERIC (Institution of Education Sciences, https://eric.ed.gov/);
3. International Journal of Science Education (https://www.tandfonline.com/toc/tsed20/current)
4. Science & Education (https://www.springer.com/journal/11191)
5. PER-Central (the Physics Education Research section of the sites ComPADRE, https://www.compadre.org/per/)

The search terms were “co-teaching”, “team teaching”, “interdisciplinary co-teaching”, “co-teaching in high school”, “interdisciplinary co-teaching in secondary schools”, “co-teaching in STEM education” and “co-planning”. The literature found on co-teaching seems to be divided between **the special education domain**, where co-teaching refers to working relationships between general and special educators in secondary schools; **the higher education domain** where co-teaching describes collegiate teachers’ collaboration, particularly mentoring relationships and interdisciplinary collaborations and **the student teacher education domain** where co-teaching indicates collaboration among peer student teachers. Very few articles were found about this educational methodology for **teaching an interdisciplinary topic in primary or secondary schools**.
By reading the abstracts of the retrieved articles, 15 relevant articles for our study were identified and included in this review. They were selected for their significant value to the literature on co-teaching (Cook and Friend, 1995, 2010) and for the information they provide about the features of co-teaching and co-planning in the context of the application. To these articles, I have added the master's thesis in Physics by Maranzano, carried out during the academic year 2021/2022 at the School of Science, Department of Physics and Astronomy of the University of Bologna. This thesis is not yet traceable in search engines, but it presents a very specific study of co-teaching within an interdisciplinary project at the higher education level.
The reviewed articles and the thesis are presented in Table 2.1, next to their respective domain of application of co-teaching and co-planning (special education, higher education and student-teacher education, and teaching an interdisciplinary topic in primary and secondary schools).

Table 2.1: list of the articles reviewed from the literature on co-teaching and co-planning alongside the context of application

DOMAIN OF APPLICATION	ARTICLES
Special education	1. Co-teaching: Guidelines for Creating Effective Practices (Cook and Friend, 1995) 2. Co-teaching: An Illustration of the Complexity of Collaboration in Special Education (Cook and Friend, 2010) 3. Co-planning in Co-teaching: A Practical Solution (Pratt et al., 2017) 4. A process, Framework, and Set of Tools for Facilitating Co-Planning Among Co-Teachers (Alsarawi et al., 2019) 5. 10 Tips for Using Co-Planning Time More Efficiently (Murawski et al., 2012) 6. Conditions for Co-teaching: Lessons from a Case Study (Weiss et al., 2003)
Higher education and student-teacher education	1. Team teaching implementation in engineering education: teacher perceptions and experiences (Vesikivi et al., 2019) 2. Power, Perceptions, and Relationships: A Model of Co-teaching in Higher Education (Morelock et al., 2017) 3. Promoting instructional change via co-teaching (Hendersen et al., 2009) 4. Teaching in teams: A planning guide for successful collaborations (Meizlish et al., 2018) 5. Discourse forms in a classroom transitioning to student-centred scientific inquiry through co-teaching (Rees et al., 2019) 6. Student teachers' team teaching: Models, effects and conditions for implementation (Beaten and Simons, 2014) 7. Co-teaching: Enhancing student learning through mentor-intern partnerships (Badiali et al., 2010) 8. Interdisciplinary analysis of the course "Paradoxes of Space and Time" between Physics, Mathematics and Philosophy (Maranzano, 2022)
Teaching an interdisciplinary topic in primary and secondary schools	1. Teachers' perceptions of social support in the co-planning of multidisciplinary technology education (Aarnio et al., 2021) 2. Co-teaching in non-linear projects: A contextualised model of co-teaching to support educational change (Harkki et al., 2021)

The main results of this review are presented in the next paragraphs divided in the themes of **co-teaching** and **co-planning**.

2.2 Co-teaching

Although it has been studied and applied since the late 1950s and early 1960s (Cook and Friend, 1995; Harkki et al., 2021; Baeten and Simons, 2014), there is no universally agreed definition of co-teaching in literature (Harkki et al., 2021; Morelock et al., 2017; Baeten and Simons, 2014; Vesikivi et al., 2019). What is common in the definitions is that co-teaching refers to teacher collaboration when **planning, teaching, and assessing** students' work (Pratt et al., 2014; Harkki et al., 2021; Baeten and Simons, 2014, Meizlish et al., 2018). Meizlish et al. (2018) identified also a fourth dimension of teacher collaboration, **content integration**, that is particularly applicable in multidisciplinary and interdisciplinary situations and relates to what extent the multiple disciplinary perspectives have been represented. In the domain of teacher education, Rees et al. (2019), echoing Murphy (2016), identified three elements of great importance in co-teaching: **co-planning, co-practice and co-reflection**. In co-planning, teachers share expertise to plan learning opportunities for students; in co-practice, teachers share responsibilities for students' learning opportunities; and in co-reflection, teachers reflect on what went well and what needs to change for next time. Synonyms of co-teaching are cooperative teaching, collaborative teaching, and team teaching (Harkki et al., 2021; Baeten and Simons, 2014). For clarity reasons, I use the term co-teaching in this thesis.

2.2.1 Models of Co-teaching

In the field of special education, Cook and Friend (1995), have defined co-teaching as "two or more professionals delivering substantive instruction to a diverse, or blended group of students in a single physical space" (p.2).

This definition includes four key components. Firstly, it involves two or more educators, with one being a general education teacher and the other being a special educator. The focus is on harnessing the unique possibilities that arise from the different yet complementary perspectives of these professionals. General educators specialize in understanding, structuring, and pacing curriculum for groups of students, while special educators specialize in identifying the unique learning needs of individual students and enhancing curriculum and instruction accordingly. Secondly, this definition specifies that co-teachers deliver substantive instruction. Their role is not limited to supervising a study hall, supporting a single student, monitoring students during a guest speaker session, or providing instructional add-ons that are only marginally related to the general education curriculum, they both rather actively participate in instructing students. Thirdly, in co-teaching, the educators teach a diverse group of students, which includes students with disabilities. Finally, co-teaching primarily takes place in a single classroom or physical space. This does not exclude the possibility of occasionally separating groups of students for instruction that involves active engagement and potentially high levels of noise and distractions. However, it does exclude situations where teachers coordinate instruction (such as planning an integrated unit together) but deliver it to separate groups of students in different locations.

Cook and Friend (1995) identified five models of co-teaching, as depicted in Figure 2.1. These approaches may vary depending on the subject matter, student age and maturity, and the teachers' creativity. There is no definitive "best" or "worst" approach; each approach has its place in a co-taught classroom. In fact, it is common for different approaches, either individually or in combination, to be used during various sessions of a co-taught class. The approaches are presented in a developmental order, indicating the level of planning, trust, and comfort required between the teachers.

1) **One Teaching, One Assisting**: In this co-teaching approach, both educators are present, but one takes the lead in the classroom while the other assists and observes students as needed. This method is straightforward, requiring minimal teacher planning, and provides basic support to meet the diverse learning needs of students. However, it has some drawbacks. The assisting teacher may feel like a glorified teaching assistant, and students might question the authority of the observing teacher. These issues can be addressed by alternating the lead and supporting roles between the teachers.

2) **Station Teaching**: In station teaching, the instructional content is divided into multiple segments, and each teacher presents the content at separate locations within the classroom. With two teachers and two stations, they teach different segments of the material, then trade student groups and repeat the instruction. This approach requires shared planning responsibilities to divide the content, but each teacher has separate responsibilities for delivering instruction. Both teachers have active teaching roles, alleviating concerns about equal status in the classroom. One challenge is pacing the lessons effectively to ensure smooth transitions between stations at scheduled times.

3) **Parallel Teaching**: In parallel teaching, the teachers plan the instruction together but deliver it to separate heterogeneous groups, each consisting of half the class. Successful implementation requires coordination to ensure that students receive essentially the same instruction within a similar timeframe. This approach is suitable for drill-and-practice activities, closely supervised projects, and discussion-based activities. Teachers can create various adaptations, such as using parallel teaching to present different perspectives on a topic and facilitating student sharing.

4) **Alternative Teaching**: In alternative teaching, the class is divided into subgroups, with one large group receiving the main instruction and a small group receiving adapted instruction based on their learning needs. The small group instruction can involve reviewing or re-teaching previously taught material, or it can provide enrichment opportunities for a specific interest group.

5) **Team Teaching**: In team teaching, teachers collaborate to instruct students. They may take turns leading discussions, or one may speak while the other demonstrates a concept, or one might speak while the other models note-taking on a projection system. Team teaching involves a high level of mutual trust and commitment. While some co-teachers may find it challenging, many experienced co-teachers find it rewarding as it brings renewed energy to their teaching and encourages them to explore new approaches to engage their students.

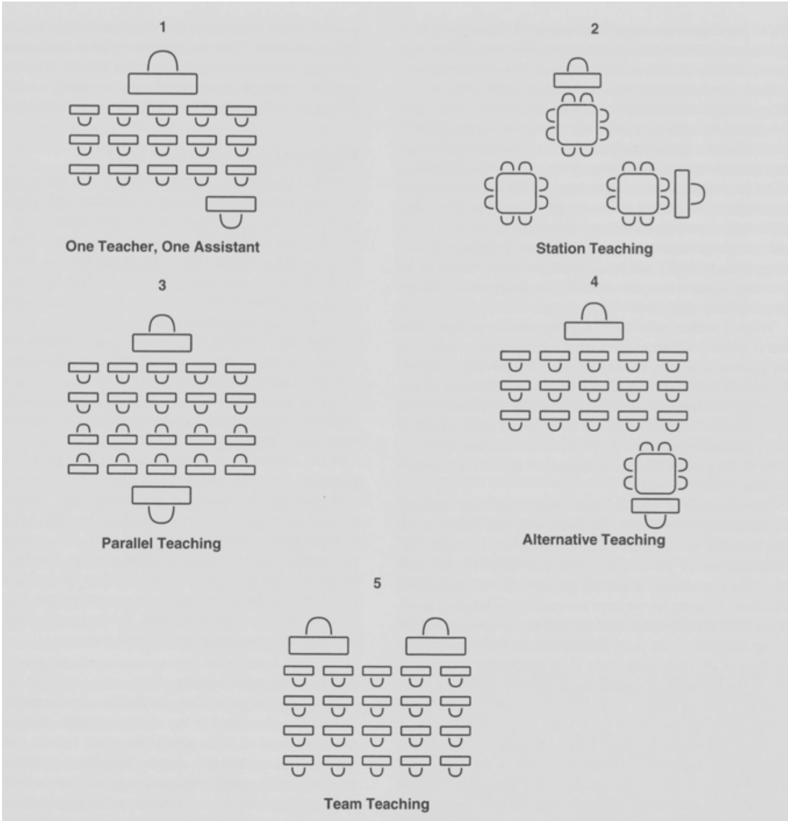


Figure 2.1: Approaches to Co-teaching (from Cook and Friend, 1995, p.6)

In the next papers, Cook and Friend (2010) added **the One teach, one observe approach,** in which one teacher leads large-group instruction while the other gathers academic, behavioral, or social data on specific students or the class group.
The six models identified by Cook and Friend (2010) are taken up with some differences by other authors both in the field of special education (Weiss et al., 2003) to describe the roles assumed by the special educator in the co-taught classroom, and in the field of teacher education (Badiali et al., 2010; Morelock et al., 2017; Bates and Simons, 2014) to coordinate with a mentor/intern relationship. Weiss et al. (2003), in particular, included the model of **teaching the same content in a separate classroom**. This model involved the special and general educators splitting the class into two, each instructing in a different room. The special educator, in this case, focused on being the sole instructor in their classroom. Badiali et al. (2010) and Morelock et al. (2017) included the **mentor modeling**, similar to the one teach, one observe model. Mentor modeling can work in two ways. First, when a novice intentionally watches a master teacher work, he can begin to understand how to interact with children while delivering the curriculum. Second, when the veteran teacher watches the novice work, he can get a sense for which teaching behaviors are effective and which strategies need further development. Simultaneously, the novice teacher can benefit in receiving feedback on his teaching. Bates and Simons (2014) added the **coaching model** in which the teacher with the function of coach, is expected to provide suggestions, assistance, and support to the other teacher. Teachers can coach or mentor one another or the coach can be a teacher with a particular expertise (e.g., content knowledge, pedagogical knowledge), who serves as a consultant to the other teacher.

2.2.2 Co-teaching as a Change Driver and a Contextualized Model of Co-teaching

Many authors of this review, including Harkki et al. (2021), Vesikivi et al. (2019) and Henderson et al. (2009), have promoted co-teaching as a level for fostering pedagogical and educational change.
According to Harkki et al. (2021), in recent times, education systems across the globe have been implementing school reforms to incorporate new curriculum content and teaching methods focused on developing 21st-century skills. These skills encompass critical thinking, problem-solving, collaboration, creativity, and innovation. Teachers need to not only acquire these skills themselves but also develop effective teaching models to impart them to students. Furthermore, schools must transform into learning organizations that foster continuous growth and development for both students and teachers. Harkki et al. (2021) have identified co-teaching as one of the change drivers required to achieve educational changes and reforms. Indeed, co-teaching provides a unique context for professional development and allows teachers to continuously enhance their collaboration skills, which are essential in the 21st century. Additionally, it brings together the diverse perspectives and strengths of teachers, enabling the creation of innovative teaching approaches that may not be possible in other contexts.
Vesikivi et al. (2019) have seen co-teaching as a change driver too, especially concerning engineering education. According to them, working life is changing due to globalisation, networking, and technological development and several publications have analysed the needs of the future workplace and compiled lists of required skills. These include the ability to understand complex systems, tackle interdisciplinary problems, utilize new media for communication, and work effectively in multicultural virtual teams. Indeed to cultivate these newly required skills, educational methods and curricula need to be reevaluated. Multidisciplinary courses that focus on real-world problems offer students an opportunity to enhance their communication and teamwork skills in an environment resembling the actual work-life situations. These kinds of courses are by definition being designed, conducted, and evaluated by a teacher team as opposed to a single subject matter teacher.

According to Harkki et al. (2021) and Henderson et al. (2009), educational changes and reforms come in different shapes and sizes. **First-order change** (Harkki et al., 2021) or **incremental change** (Henderson et al., 2009) refers to incremental and subtle adjustments that fine-tune the existing system while leaving underlying beliefs unchallenged. On the other hand, **second-order change** (Harkki et al., 2021) or **fundamental change** (Henderson et al., 2009) involves a paradigm shift that challenges fundamental beliefs and leads to new goals, roles, structures, and ways of thinking and working.
According to Harkki et al. (2021), implementing change can encounter obstacles both externally (first-order barriers) and internally (second-order barriers). First-order barriers are often seen as beyond teachers' control, such as limited planning time or lack of resources. Second-order barriers involve teachers' underlying beliefs about teaching and learning and their resistance to change. While first-order barriers can pose significant challenges, some teachers find creative ways to navigate through them, while others feel overwhelmed. The presence of numerous complaints about first-order barriers suggests the existence of second-order barriers that may not be readily apparent, even to the teachers themselves.

As co-teaching is seen as a change driver, the aim of the Harkki et al. (2021) research is to develop a contextualized model of co-teaching during a second-order educational change.
The authors investigate co-teaching barriers seen through the analytical lens of second-order educational changes. The results are arranged according to the actors within the educational system (Harkki et al., 2021):

1. In terms of **teachers**, they play a crucial role in any educational change, and various factors can act as second-order barriers. These include teacher competence, beliefs, attitudes, identity, values, teaching philosophy, styles, practices, and resistance. Teachers' attitudes and co-teaching relationships are influenced by the availability of support, required resources, confidence levels, fear of failure, and coping mechanisms.

2. **Schools** play a significant role in the sustainability of educational reforms, which can vary based on the school community and teachers' experiences. The success of a reform relies on the buy-in from the entire school community.

3. **School administration**'s role is crucial but providing basic co-teaching support may not be sufficient. Teachers who have access to shared planning time, adequate supplies, administrative support, and training often find these resources less valuable in practice than in theory. This may be due to the support not meeting their expectations or other missing elements, such as effective leadership. It is crucial for key stakeholders to be prepared for co-teaching implementations. Reform leaders at the local, regional, or national level have the responsibility of defining clear roles and expectations, managing resources and schedules, providing training, coaching, and other forms of professional development, and fostering a professional environment where teachers can partner and collaborate in teaching.

4. **School extramural authorities**, such as national or regional bodies, play a role in initiating second-order educational changes. However, the leadership and support provided by these external bodies may differ. Thorough planning of the reform should involve active participation and support from these external entities.

5. **Potential barriers** to co-teaching and educational transformation arise from contextual issues. Some second-order barriers can be reduced through external activities, and the same issues can be perceived as both barriers and enablers of change, depending on how they are approached and addressed.

Harkki et al. (2021) explored how co-teaching emerged and what barriers teachers experienced as meaningful for their co-teaching. From their study, three mutually exclusive themes were found: 1) pedagogical issues, 2) co-teaching issues, and 3) teacher professional development. In Figure 2.2, themes and sub-themes are presented.

Pedagogical issues	Co-teaching issues	Teacher professional development
Planning	Values and priorities	Reflection on teacher identity
Teaching	Shared regulation of teacher collaboration	Change in teacher identity
Assessment	Support from school administration	Learning
Shared regulation of pedagogical work	School community-level support	
Physical learning environment	Regional-/national-level support	

Figure 2.2: themes and subthemes discussed by the teachers in Harkki et al (2021) study, p.6

During the interviews, some potential barriers were spontaneously brought up by the teachers, who saw them as challenges. These included a divided learning environment, lack of national-level support, differences in teachers' values and dysfunctional partnerships, as well as issues with school schedules. The physical environment, competence, and the lack of shared planning time were rated the most negatively. None of the teams had a regular official planning time agreed upon with the principal, although some had initial planning time for a day or so. Some teachers had their teaching breaks coinciding accidentally, while others were committed to "finding the time" for planning.
Finally, Harkki et al. (2021) propose a model of contextualized co-teaching that supports the implementation and research of co-teaching as part of second-order educational changes. This model recognizes the involvement of various actors at different levels, including teachers, school administration, school community, and educational authorities at the national/regional level who determine educational policies and the core curriculum. A key aspect of co-teaching is shared regulation, which encompasses planning, teaching, assessment, and teacher professional development. Effective co-teaching practices are seen as a co-construction process involving all actors, not limited to just teachers. The model is reported in Figure 2.3.

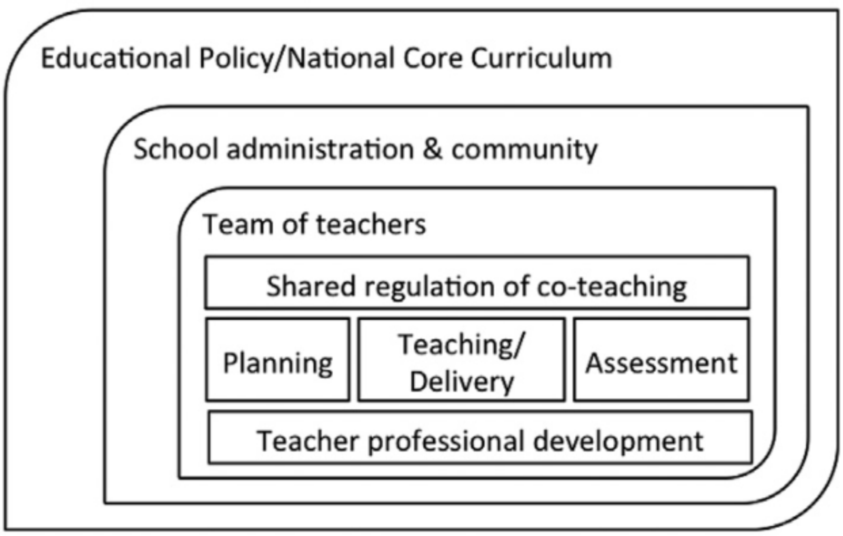


Figure 2.3. Harkki et al. (2021), model of contextualized co-teaching, p.11

2.2.3 A specific case of Interdisciplinary Co-teaching in Higher Education

The thesis by Maranzano (2022) stands out from the other reviewed articles above as it primarily focuses on find the specifics and interdisciplinarity characteristics that emerged during an interdisciplinary course involving mathematics, physics, and philosophy ("Paradoxes of Space and Time), offered by the University of Bologna. The main goal was to derive design principles useful for the formulation of an interdisciplinary course based on co-teaching. In particular, three design principles were recovered:

1) **individuate clearly the role to give to each individual discipline within the interdisciplinary course and the specific contribution to the whole narrative.**

   From the analysis of the teaching course, Maranzano (2022) recovered the fact that it is important to assign a specific purpose for each discipline. In their particular case, they found that philosophy had an introductory role aiming at explaining the theoretical foundations on which the whole course would then rest, while the discipline of mathematics was associated with the task of moving from philosophy to science and concluding with the discipline of physics.

2) **carefully choose the topics that each discipline has to address. The topics must be boundary objects, i.e. they must intrinsically contain elements proper to the discipline that allow for an in-depth disciplinary analysis, but at the same time, they must have elements that allow for a connection with the other disciplines chosen for composing the course.**

   in the specific course analyzed by Maranzano (2022), the following topic were chosen: The philosophy professor chose the Zeno's paradoxes, because of their inherently interdisciplinary nature: these paradoxes have not only influenced the development of philosophy over the centuries but have also generated different directions of thinking about them in the scientific field as well. The math teacher chose the Banach-Tarski's paradox as a topic for the discussion, which introduces the thread of reasoning on the paradox seen as the inconsistency between what the mathematical theory may conclude in comparison with our personal experience. The physics professor chose the Einstein's train paradox.

3) **include both moments of disciplinary focus, necessary to give the basis of knowledge and method, and moments of interdisciplinarity, in which disciplinary tools are used on boundary objects, to allow for a review of the content and a comparison of the roles that different boundary objects may have in the disciplines.**

   Maranzano (2022) retrieved a sinusoidal trend throughout the course: right after a strict disciplinary approach, comes an interdisciplinary block, which has a twofold task: it concludes the previous disciplinary block and at the same time facilitates the strictly disciplinary analysis that follows it.

2.3 Co-planning

Many researches have indicated that co-planning represents the common challenge that co-teachers face (Cook and Friend, 1995; Bates and Simons, 2014; Vesikivi et al., 2019; Alsarawi et al., 2019, Pratt et al., 2017, Murawski et al., 2012). According to Murawski et al. (2012), teachers never have enough time to do everything they need to do, and this includes planning for instruction, so these authors provided 10 tips for how teachers can efficiently plan together, even with limited time. These tips are:

1) ***Establish a Regular Time to Plan Collaboratively.*** If the planning time is scheduled as a regular occurrence and viewed as important, teachers can respond to requests accounting for the time in their schedule.
2) ***Select an Appropriate Environment Without Distractions*****,** such as an empty classroom and the school library or, during the weekend, coffee shops, restaurants, local libraries, parks, or the teachers' houses.
3) ***Save Rapport Building for Another Time.*** Planning sessions should be focused on planning and teachers must keep rapport building and unrelated discussions for other times in order to maximize planning time.
4) ***Have an Agenda and Snacks*****.** Having a checklist related to what needs to be accomplished helps the collaborators feel that there is a plan.
5) ***Determine Regular Roles and Responsibilities,*** according to teachers' strengths and limitations.
6) ***Divide and Conquer*****.** Once tasks are determined, co-teachers should address the work separately.
7) ***Keep a List of Individual Student Concerns*****.** Teachers can save planning time by avoiding discussions about individual student issues during their planning sessions. Instead, they should keep a notepad nearby to jot down any specific student matters they wish to address at the conclusion of their planning period.
8) ***Build in Regular Time for Assessment and Feedback*****.** It is important that co-teachers communicate with one another openly about their own teaching and interactions.
9) ***Document Your Planning and Save It for Future Reference.*** When planning is done, teachers must keep a copy of the plan for future reference and improvement.
10) ***Use the WHAT/HOW/ WHO Approach.*** The WHAT/HOW/WHO approach (Murawski and Spencer, 2011) is a method to efficiently ensure that a lesson aligns with state standards, covers grade-level material according to pacing plans, and optimally utilizes teachers' expertise and strengths. The first question discussed is "**WHAT** needs to be taught in this lesson?" The next item discussed is "**HOW** will we teach this lesson in order to make sure it is universally accessible for all students? The final item discussed is "**WHO** may need additional consideration in order to access this lesson?"

2.3.1 Co-planning Framework

According to Pratt et al. (2017), co-planning takes place every time co-teachers come together to look at the long-term goals and objectives, along with the specific and detailed requirements of students. The outcome of co-teaching and co-planning relies on a focus on both long-term goals and day-to-day adjustments to achieve the final objectives. A successful co-teaching partnership is grounded in the recognition that setting aside time for planning and reflecting is a priority. It is

critical that co-teachers have administrative and district-level support of co-planning time to ensure the success of both the co-teaching relationship and the learners within the co-taught classroom.
Pratt et al. (2017) developed a co-planning framework to focus on long-term and daily goals and allocates time to share reflections on student progress. The framework is structured in:

1) ***Unit Planning:***

   It would be better for the co-teachers to meet in person to set the main expectations of their instruction and the end-of-course goals for the students. After setting the expectations, the approved outlines should be placed in an accessible calendar for the teachers. The developed calendar represents the basis for teachers to plan and teach the lesson and monitor students' progress toward specific goals.

2) ***Biweekly planning:***

   The co-teachers should now start creating a biweekly plan. As they become familiar with the students and their individual needs, it's important to hold regular meetings before and after school, as well as during lunchtime. At this stage of co-planning, the co-teachers can allocate tasks for developing specific lessons. These responsibilities should be distributed based on each teacher's comfort zone, professional expertise, and available resources. This planning phase also allows both teachers to leverage their strengths, whether in general education or special education, to enhance the co-planning process. The concept of dividing and conquering in co-planning goes beyond just splitting tasks; it takes into account the unique pairing of a special education teacher and a content area teacher, ensuring that assigned tasks align with their respective skills and strengths.

3) ***Daily Planning***

   Once the course and unit outlines have been clarified, a simplified co-planning template is employed, following the "who, what, where, and how" approach. This template facilitates clear articulation of learning objectives aligned with the subject area and aids in the development of daily lesson plans. Co-teachers can use tools like Google Docs or similar document sharing systems to collaboratively create learning materials for classroom use. The daily planning process, a key aspect of co-teaching, occurs during pockets of "unplanned" time within the day. These time slots can be found during transitions between classes or subjects. Successful co-teaching necessitates a strong familiarity between teachers that goes beyond mere colleagues. Regular communication is crucial, and both asynchronous (communication without real-time interaction) and synchronous (real-time) technologies play a vital role in facilitating frequent conversations, making co-planning achievable even for busy educators. The advantage of using these technological platforms lies in their flexibility, as they allow co-teachers to work together or independently online. This flexibility is especially valuable when there is no shared plan period, ensuring that co-teachers can effectively collaborate despite potential scheduling challenges.

Alsarawi et al. (2019) drew inspiration from Pratt et al. (2017) in developing a co-planning framework. While these two frameworks share significant similarities, Alsarawi et al. (2019) additionally emphasized the significance of documenting and archiving unit and lesson plans. According to the authors, one of the major problems of co-planning is recognizing the strengths or areas of improvement of the lesson plans because the teachers did not save copies of their lesson plans. Indeed, it is important for co-teachers to continuously save files in order to do not waste time and effort redoing them.

2.3.2 Social Support in the Co-planning phase

Aarnio et al. (2021) conducted a study focusing on collegial support within co-planning for multidisciplinary technology education across different school levels. They applied the social support theory by Cobb (1976) and House (1981) to explore teachers' experiences of emotional, instrumental, and informational support during the co-planning process. This type of support involves assistance that teachers receive from their co-teachers to navigate challenges in specific environments. The study identified three categories of social support—emotional, instrumental, and informational—which were originally outlined by Vaisanen et al. (2017). These categories are described as follows:

- **Emotional support** involves providing mental encouragement and fostering feelings of trust, respect, and value. It also contributes to a sense of belonging within a specific network, such as a community of technology educators.
  Moreover, the teacher community is considered a crucial element in organizing STEAM education, as it allows teachers to share values, collaborate towards common goals, and work together effectively. Emotional support if considered the most important form of social support due to its ability to alleviate stress and provide emotional relief.

- **Instrumental support** involves providing practical assistance to manage specific tasks. It can include support related to time management, labor, or access to materials. In some cases, instrumental support functions can be embedded in other forms of social support if they together serve to solve a particular problem.

- **Informational support** serves two functions: providing information and offering appraisal. It involves receiving information that helps individuals cope with challenges in a specific environment. This type of information is typically expected from experienced individuals with expertise in a particular area. For example, teachers may seek information from their colleagues about technological platforms that assist in planning technology education activities. Informational support also aids in appraisal by offering relevant information for self-evaluation. Feedback from others can be utilized to evaluate an individual, including their actions as a technology educator.

The results of the study of Aarnio et al. (2021) about the social support involved in the teachers' experiences in co-planning of multidisciplinary technology education are presented in Figure 2.4.

Forms of social support	Experiences in co-planning
Instrumental	Support for ideation
	Aid for the planning of teaching
	Flexibility in the guidance of pupils
	Cooperation in teaching
	More opportunities for implementation
	Pedagogical leadership
	Sharing responsibility for teaching
Informational	Technological expertise
	Pedagogical development expertise
	Knowledge of pupils
Emotional	Enthusiasm
	Encouragement
	Sharing interests
	Sense of community

Figure 2.4: Social support in the co-planning of multidisciplinary technology education, from the study of Aarnio et al. (2021), p.16

2.4 The Research Questions

This review has highlighted the gaps in the research literature on co-planning and co-teaching. In particular, it has been observed that these methodologies have poorly been studied for teaching interdisciplinary topics at the secondary school level, which is, in fact, the main focus of this thesis. Hence, arises the first research question (RQ1):

RQ1 *How are co-planning and co-teaching methodologies implemented in the development of a course about an interdisciplinary topic, such as artificial intelligence, in high schools?*

The second research question is mainly formulated based on the aim of this thesis to explore any contextual factor and stakeholders, even external, that might influence the implementation of co-planning and co-teaching methodologies.

The question is as follows:

RQ2 *What are the contextual factors and relationships, including those outside of school, that can promote the implementation of co-planning and co-teaching methodologies?*

Chapter 3 - Context of the Study

For this Master's thesis, my supervisor Professor Levrini asked me to attend a course on artificial intelligence (from now on denoted as "course on AI") and an interdisciplinary laboratory between art and artificial intelligence, the AI Atelier, held at the “Liceo Einstein” in Rimini during the months of January and February 2023 for the course on AI, and March and April 2023 for the AI Atelier.

The course on AI was an implementation of the teaching module on artificial intelligence developed within the European project I SEE (2016-2019), which was independently carried out by the Liceo Einstein for several editions. The AI Atelier was born within the Liceo Einstein as a complement to the course on AI and following the success of the Quantum Atelier held last year in the same high school. The AI atelier is in its first implementation and is part of the second round of implementations of the FEDORA project within the BOSN.

During these months, I visited the high school in Rimini about once a week, sometimes accompanied by my co-supervisor Professor Barelli. In Rimini, I was able to attend the course on AI lectures and the AI Atelier meetings, video record them with the teachers' consent, and also take notes and transcribe the recordings at home.

One of my co-supervisor, Prof. Barelli, actively participated in the course on AI and AI Atelier, not only by responding to clarifications requested by the teachers at the Liceo Einstein but also by giving a lecture on machine learning herself during the course on AI, while the other lectures were conducted by internal teachers at the Liceo Einstein.

During the AI Atelier, apart from the first two more theoretical sessions, the other meetings had a more practical and laboratory approach. Here, I was able to move around among the various student groups, observe what they were doing, and ask them some questions.

The course on AI and the AI Atelier were, then, followed by an hour and half seminar held on April 14, 2023, by physicist Alessandro Vespignani, one of the world's leading experts in epidemiological modeling and forecasting science, about the theme of “predictions and scenarios”. The professor was in an online connection from Northeastern University in Boston and the seminar was broadcast live for all interested parties on the Liceo Einstein’s YouTube channel[10] . The Fermi High School in Padua and the Buonarroti High School in Monfalcone, the lead school of the National Network of High Schools for Data Science and Artificial Intelligence, also joined the meeting through a Meet connection. I attended the seminar online through the Liceo Einstein’s YouTube channel. We will consider this meeting as the last meeting of the course on AI.

3.1 The Teachers

The teachers from the Liceo Einstein who were involved in the organization and implementation of the course on AI and the AI Atelier are listed below. For the purpose of this study, I will refer to them using pseudonyms. The teachers are as follows:

[10] https://www.youtube.com/@liceoeinsteinrimini3123

1. Teacher A: Former teacher of mathematics and physics at the Liceo Einstein, engaged in research activities in physics education.
2. Teacher B: Teacher of mathematics and physics at the Liceo Einstein.
3. Teacher C: Teacher of mathematics and physics at the Liceo Einstein.
4. Teacher D: Teacher of literature at the Liceo Einstein.
5. Teacher E: Teacher of philosophy at the Liceo Einstein.

Teachers A, B, and C have organized and co-taught the course on AI, while Teacher D organized and conducted the AI Atelier with the collaboration of Teachers A, B, and C as scientific consultants. Teacher E delivered a lecture during the AI Atelier.

3.2 The Course on AI

In this paragraph, I will describe the course on AI held at the "Liceo Einstein" in Rimini in 2023. This course is the fourth implementation within Liceo Einstein of the teaching module on artificial intelligence originally developed in 2018 within the EU Erasmus+ project I SEE. The course on AI is recognized as a PCTO ("Percorsi per le Competenze Trasversali e l'Orientamento") activity, takes place over 20 hours between January and February 2023 and involves the participation of 24 fourth and fifth-grade students. Before describing the course I attended, I'll present the general structure of an I SEE module and the original I SEE teaching module on artificial intelligence.

3.2.1 General structure of an I SEE module

The project I SEE (September 2016- August 2019) was an Erasmus + strategic partnership involving three secondary schools, two universities, an environmental NGO, a teachers' association and a private foundation coming from four European countries (Italy, Finland, Iceland and the United Kingdom) (I SEE, 2019a).

The strategic partnership of the project consisted of the following organizations[11]:

- Alma Mater Studiorum - University of Bologna (coordinator)
- University of Helsinki & Normal Lyceum, Helsinki
- Icelandic Environment Association (IEA)
- Liceo A. Einstein, Rimini
- Hamrahlid College, Reykjavik
- Fondazione Golinelli, Bologna
- Association for Science Education (ASE), London

The goal of the I SEE project was to design and implement innovative approaches and teaching modules on future-oriented scientific issues to foster students' capacities to imagine the future and aspire to STEM careers. The I SEE partnership developed a start-up module on climate change, and three more mature modules on Artificial Intelligence, Carbon Sequestration, and Quantum Computing (I SEE, 2019a).

[11] https://iseeproject.eu/partners/

An I SEE module is structured into several four different teaching-learning phases, each with specific features and activities; the activities are carried out to enable students to develop future-scaffolding skills which allow them to engage with the future (social, environmental, economic but also personal) implications of the issue (Branchetti et al., 2018; I SEE, 2019a).

An overview picture of the structure is represented in Figure 3.1.

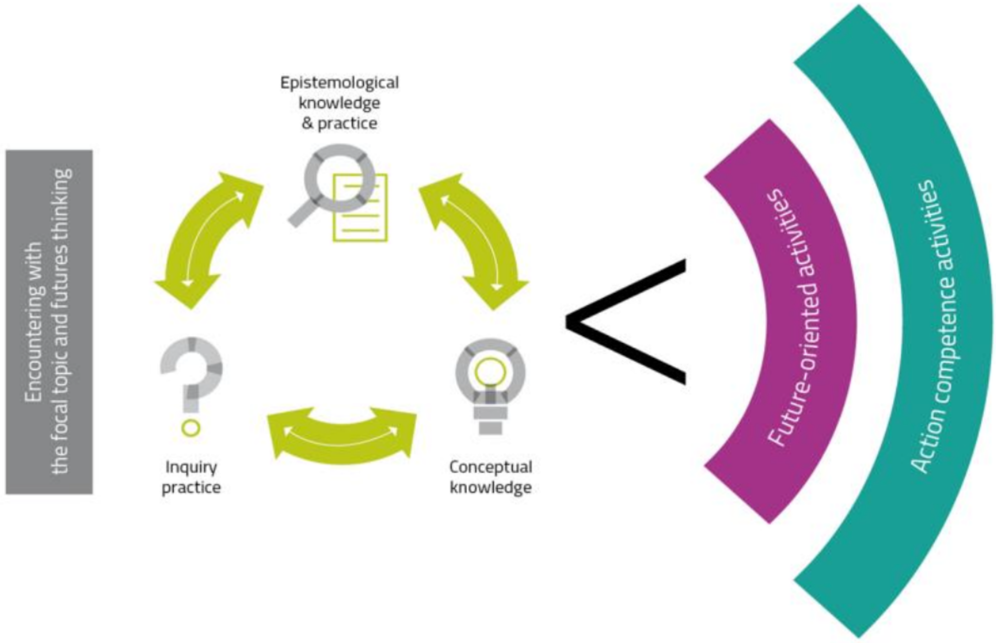


Figure 3.1 structure of the ISEE modules

The different teaching-learning phases are represented in the figure by different colors. They are called: i) *encountering the focal issue*; ii) *engaging with the interaction between science ideas and future; iii) bridge activities; iv) future-oriented activities; iv) action competence activities.*

We provide a short description for each phase, while for a detailed description, we refer to the related intellectual output of the I SEE project (I SEE, 2019a) and to the publications (Branchetti et al., 2018; Levrini et al., 2021b).

The module begins with students' encountering the focal issues (the left section in Figure 3.1). This first experience aims to develop a preliminary level of awareness of the ways in which conceptual and epistemological scientific knowledge, the specific language, the methodological and the pedagogical approaches will interweave in the module

The second phase of the module (central section in Figure 3.1) presents the fundamental elements of the topic that students engage with. In this phase, students deal with different dimensions of knowledge: i. conceptual knowledge, namely the inter-disciplinary content knowledge; ii. epistemological knowledge and practice, which refers to epistemic practices like modelling, arguing, and explaining; and iii. inquiry practice, which refers to inquiry skills like posing questions, formulating hypotheses, designing inquiry, triggering peer-to-peer interaction, recognizing modelling as a process of isolating a particular phenomenon, and moving from models to experiments and vice versa (Branchetti et al., 2018).

The third phase of the module (the "less then symbol" in Figure 3.1) concerns the so-called bridge activities. These activities connect scientific, conceptual, and epistemological knowledge and practice (which characterize the first two phases of the module) with the issue of the future (that is specifically addressed with the following activities). In these kinds of activities, students are guided to recognize the future dimension as embedded in the epistemic structure of science.

The fourth phase of the module (the violet ark in Figure 3.1) concerns future-oriented activities. The I SEE approach foresees at least three types of future-oriented practices that can be developed with the aim of turning knowledge into future-scaffolding skills and competences:

1. activities to flesh out the future-oriented structure of scientific discourse, language, and concepts;
2. activities inspired by future studies or by the working life and societal matters;
3. exposure activities to enlarge the imagination about possible future STEM careers

The fifth phase of the module (the turquoise arc in Figure 3.1) concerns action competence activities. These activities are thought to trigger awareness of the plurality of perspectives at stake in decision-making processes, and so support students in expanding their ethical consideration as they go forward making intentional decisions and taking deliberate actions.

3.2.2 The I SEE Teaching Module on AI

The teaching module on Artificial Intelligence (AI) was originally developed in 2018 within the project I SEE by the research group in physics education of the University of Bologna, in collaboration with academic experts in the field of AI and High School teachers (Ravaioli, 2020). This module aims to develop upper secondary school students' future-thinking skills, imagination, and agency on societal issues in the context of AI. The topic has been chosen for its increasing impact on society, for the epistemological change that AI underwent through its development over the 19th century up to the 'Big Data' sciences, and for its relevance for future-oriented activities (I SEE, 2019b). As a module designed by the I SEE partnership, the module on Artificial Intelligence has a structure divided into five teaching-learning phases and was articulated in nine activities, as we can see in Table 3.1.

Table 3.1: Teaching learning phases and the respective activities of the I SEE module on AI

LEARNING PHASES	ACTIVITIES	TYPES OF ACTIVITIES
Part1: Encountering with the focal topic and futures thinking	1. Overview lectures on AI and the perspective of complex systems	2 Lectures
	1bis. The words of complexity	Group activity

	2. Where can AI be encountered today?	Group activity
Part 2: engaging with the interaction between science ideas and future	3. AI -Imperative paradigmTIC-TAC-TOE & imperative paradigm (Python)	Lecture +Class Activity
	4. AI -Declarative paradigmTIC-TAC-TOE & logical paradigm (Prolog)	Lecture +Class Activity
	5 .AI –Machine Learning paradigmTIC-TAC-TOE & neural networks (Matlab)	Lecture +Class Activity
Part 3: Bridge from STEM to futures studies	6. Predict, hypothesize and imagine the futures: from physics to futures studies	lecture
	7. The town of ADA 1: analysis of a complex citizenship context of urban planning	Group activity
Part 4: Future-oriented activities	8. The town of ADA 2: possible future scenarios	Group activity
Part 5: Action planning activities	9. The town of ADA 3: desirable future, back-casting, and action planning	Group activity

Referring to the Ph.D. thesis of Ravaioli (2020), to the Ph.D thesis of Barelli (2022), and to the intellectual output of the project (I SEE, 2019b) we provide a brief overview of each phase.

1. This first part is constituted of two overview lectures and two group activities. The lectures, held by an expert in Artificial Intelligence and by an expert in the science of complex systems, cover the development of AI in recent years, different approaches to teaching

machines to reason and solve problems, and the significance of studying problems from the point of view of complexity. The first group activity is aimed at reinforcing the concepts of complexity introduced in the lectures, while the second is meant to build an overall picture of where AI can be encountered today, with particular emphasis on the different fields of AI applications (archaeology, art, services, scientific research, ...), the risks and potentialities of AI applications and future changes in the job market and STEM careers that the use of AI is going to induce.

2. In the second part, three main programming paradigms are introduced for how to teach a machine to reason and solve a problem: procedural/imperative, logical/declarative, and machine learning. The problem of coding a Tic-Tac-Toe player is addressed with each paradigm, exploited in three different programming languages (Python, Prolog, Matlab).

3. The bridge part includes two activities that connect the concepts introduced until this moment with the following parts. The first activity introduces the science of complex systems as a new paradigm to think about the future, radically different from that of classical physics. This new non-deterministic way of thinking about the future has also inspired a branch of social sciences, the futures studies. The second activity aims to help students turn typical concepts of complex reasoning (linear or circular causality, feedback...) into skills to analyze a citizenship context, the city of Ada, where complex dynamics are involved.

4. In the fourth part, the activity, based on the town of Ada, is focused on the concept of *future scenarios* and guides the students to reflect on events that may have caused a possible and/or a *desirable scenario* and which values are involved.

5. Through the activity of the last part, the students are encouraged to imagine the town where they wish to live or visit in 2040, and to think about their roles/professions there.
   The activity is focused on the concept of *desirable future* and, through action competence strategies, the students are guided to play with *forecasting* and *back-casting* activities and to plan actions that can contribute to achieving the desirable future. During the activities, the students are encouraged to imagine possible future careers and unleash their creativity.

So far, the module has been implemented in various contexts, summarized in Table 3.2:

Table 3.2: Implementations of the teaching module on AI

CONTEXT OF IMPLEMENTATION	PERIOD	TYPE OF ACTIVITY	NUMBER OF STUDENTS	NUMBER OF HOURS
	January-February 2018	school-work alternation activity on AI	31 students	20 hours

"Liceo Einstein" in Rimini	November-December 2018	school-work alternation activity on AI	20 students	20 hours
	Scheduled for March 2020, postponed to October 2020 due to the Covid emergency	PCTO activity on AI	27 students	20 hours
	Jenuary-february 2023 (PCTO activity) February- April 2023 (AI atelier)	PCTO activity on AI + AI atelier	24 students (PCTO activity) 10 students (AI atelier)	20 hours (PCTO activity) 15 hours (AI atelier)
Department of Physics and Astronomy of the University of Bologna	Jenuary-february 2018	PLS laboratory	19 students	20 hours
	June 2018	Summer school	40 students	36 hours
Helsinki Normal Lyceum, Finland	spring 2019	extra-curricular course	9 students	16 hours

3.2.3 This year Implementation of the Course on AI

This year the PCTO course on AI, following the structure of the ISEE module on AI described in the section above, consists of six meetings of three hours each, organized by Teachers A, B and C and involved two experts, Prof. Federico Chesani from the University of Bologna and Prof. Massimo Bosetti from the University of Trento, and a researcher, Prof. Eleonora Barelli of the University of Bologna. We will consider the seminar held by physicist Vespignani on April 14, 2023, as the seventh meeting of the course. The teachers that carried out the course are three math and physics teachers who have collaborated with the physics education research group of Bologna for many years. In particular, teacher A, now a retired teacher, started to work with the University of Bologna in 2001 collaborating on the development of different teaching and learning paths on themes like thermodynamics and quantum physics. Teachers B and C joined the collaboration for the project I SEE, of which the high school was a partner.

As in the previous implementation, the module consisted of different kinds of activities from lectures, collective discussions, and teamwork. In Table 3.3, I report an overview of this implementation.

Table 3.3: Overview of the present implementation of the AI course

Day	Name of the activity	Kind of activity	Main contents	Lecturers
1	Introduction to AI	Seminar	• Weak and strong AI • Top-down symbolic approach and bottom-up sub-symbolic approach • AI applications and problems.	Prof. Federico Chesani (Department of Computer Science - UNIBO, professor in the Master's degree program in Artificial Intelligence).
2	Complexity and AI challenges	Interactive lecture + "The attacker/defender game"	• Top-down symbolic approach and bottom-up sub-symbolic approach • Neural network • Complex system: characteristics and words of complexity (multiplicity, irreducibility, circular relationship, unpredictability, self-organization)	Teacher A
		Interactive lecture	• Risks of AI, biases, and opportunities • AI as an interdisciplinary and cross-cutting topic	Teacher B

3	Machine learning and neural networks	Interactive lecture + Netlogo simulation of a flock of birds	● Neural network ● Procedural approach and machine learning approach ● Supervised learning: hypothesis function, cost function, parameters, forward propagation and back propagation, efficiency. ● Bias ● Black box	Prof. Eleonora Barelli, researcher in the field of physics education and STEM disciplines at the University of Bologna.
4	AI applications in physics and the different programming paradigms	Seminar	● Big data and deep learning in particle physics	Prof. Massimo Bosetti who is currently pursuing a doctorate in artificial intelligence at the University of Trento in collaboration with CERN
		Interactive lecture + The Tic Tac Toe game	● The 3 programming paradigms (imperative, declarative, machine learning) ● Different programming languages (Python, Prolog, MATLAB)	Teacher C
5	Towards future studies	Interactive lecture + 2 teamwork activities: “the town of Ada 1” and “the town of Ada 2”	● Possible scenarios ● Future studies: forecasting and foresight, futures cone ● Stakeholders ● Relationship between humans and machines	Teacher A and Teacher B

6	Action competence activity	A teamwork activity: "the town of Ada 3"	• Backcast • Action competence	Teacher B
7	Predictions and Scenarios (Networks and Simulations to Investigate the Complexity of Reality): A seminar by Professor Vespignani	Seminar	• Mechanistic and black box algorithms • Data • Networks • Models and predictions • Scenarios	Prof. Alessandro Vespignani, one of the world's leading experts in epidemiological modeling and forecasting science

In the following, I present the main learning objectives of the different activities, and the content.

Day 1 - Overview lecture on AI

This first meeting was held by Prof. Federico Chesani of the Department of Computer Science (UNIBO), a professor in the Master's degree program in Artificial Intelligence.

The main learning objectives were

- Contribute to developing a general understanding of what is meant by intelligence and artificial intelligence.
- Contribute to developing a critical sense and personal opinion on AI (what are their applications? What are the main limits and problems?)

The lecture begins with a question: What is intelligence? After a recollection of ideas, it is explained that there are many types of intelligence that are equally important (logical/rational intelligence, emotional intelligence, etc.), and that artificial intelligence does not represent total intelligence, but only a part of it.

After that, the Turing test is introduced. Alan Turing, considered the father of computer science and artificial intelligence, developed the Turing test in 1950 as a criterion for establishing whether a machine is intelligent. Turing proposed that a human evaluator would judge natural language conversations between humans and machines designed to generate human-like responses. The conversation would be limited to a text-only channel[12]. An example is shown: a few years ago, a research group won a competition on the Turing test by programming a chatbot to respond with swear words to questions it did not know, thus managing to fool most judges into thinking it was a teenager. The question that arises is: is it the machine or the group that programmed it to be intelligent?

[12] https://en.wikipedia.org/wiki/Turing_test

The notions of weak and strong AI are then introduced: the first one concerns systems that act as if they were intelligent, but they are not, while the second one concerns systems capable of thinking intelligently. After a recollection of the diverse definitions of artificial intelligence, the concept of collective intelligence is introduced, and, to clarify the notion, a simulation is shown in which ants must find sources of food and bring them back to the anthill. This model is based on the example of real ants, in which when an ant finds food, it releases pheromones that are perceived by the other ants that reach it and help it bring the food back to the anthill. The anthill exhibits intelligent behavior because it coordinates, but its intelligence is reduced to the release of a chemical element.

Among the approaches used to bring the machines to learn, there are two main strands: the top-down or symbolic approach, which includes logic systems and rule-based systems, and the bottom-up or sub-symbolic approach, which starts from the statistical analysis of examples and simulates neurons and their connections. An example of the first approach is “Mycin”, a rule-based expert system developed in the 1970s for medical diagnosis, particularly of bacterial diseases. The system is based on rules written by questioning doctors about the procedure they follow to make a diagnosis. Although Mycin worked better than an equivalent number of doctors and experts, it was never actually used in practice. Some observers raised ethical and legal issues related to the use of computers in medicine[13]. However, the greatest problem was the extraction of the necessary knowledge from the doctors to use in the rule base: the doctors cannot be replaced in their creativity and competence, and furthermore, knowledge is not static but evolves. For the second approach, an example concerning Volkswagen is shown: a few years ago, Volkswagen created an autonomous driving project in which cars were taught to drive themselves by providing them with examples. During a test on a closed circuit, the car stopped in front of a pedestrian crossing the street, but as soon as a photographer crossed the street to take a photo from the other side of the car, it started again and hit him (the car was not given the example of two pedestrians crossing). In general, the main problem is that our world is too complex, there are too many variables and it is not possible, nowadays, to provide the car with enough examples to cover all the possibilities.

AI has several applications: Games (in 1997 Deep Blue defeated the world champion Kasparov at chess and in 2011 the supercomputer Watson beat the human adversaries at Jeopardy), Chatbots (like ChatGPT), computer vision, deep learning and Deep Neural Networks (DNNs) (an example is shown of an AI that after 240 minutes of training discovers the strategy of digging a tunnel to win the game Breakout) and robotics (Atlas, a robot developed by Boston Dynamics, is capable of doing parkour; Robocup). DNNs present several issues: there may be problems when working on new data that are far from the training data, they have millions of parameters that are difficult to understand, they work on statistics, they do not distinguish causality and correlation, and can make errors that are not understandable by humans. AI also has some ethical problems, such as the case of software used in an American state to give sentences during trials. It was discovered that it has a strong bias towards the racial component and gives higher sentences to people of color, this is because the software has been trained on examples from trials conducted by white judges in the 1950s. The lesson ends with two open questions: Are we sure we want that a software learn from us? Are we always the best example to follow?

Day 2 - Complexity and AI challenges

The second meeting was held by Teacher A and Teacher B and consisted of two different lectures. The first, held by Teacher A, addressed neural networks and established a comparison between

[13] https://en.wikipedia.org/wiki/Mycin

them and complex systems, and the second, held by Teacher B, introduced students to the challenges and opportunities of AI.

The main learning objectives were:

- Getting acquainted with the main terms introduced
- Becoming aware of the similarities between neural networks and complex systems.
- Developing critical thinking on the applications and risks of AI in society.

In the first part of the lecture, the concepts of the top-down symbolic approach and bottom-up sub-symbolic approach, introduced in the overview lecture, are clarified. To do this, an example is proposed: How can we instruct a machine to draw a circle? A top-down approach would either describe its mathematical properties (declarative language) or set a method to draw it with a compass (procedural language). The programmer knows exactly the process to solve the problem and instructs the machine to do it (therefore top-down), the procedure is translated into symbols (therefore symbolic). The bottom-up approach, instead, requires that the concept of circumference is learned implicitly starting from examples (therefore bottom-up).

The concept of "neural networks" is, then, introduced as simulators of the brain, made up of hundreds and thousands of connections of artificial elements that would represent neurons. These neural networks are organized into layers: input (e.g. the figure to be recognized), output (e.g. the machine's response), and intermediate layers. Each neuron receives a more or less strong impulse and transmits or does not transmit the impulse to the other neurons. The approach underlying neural networks is bottom-up and sub-symbolic, as there is no strategy upstream that is being translated into symbols, but the machine learns from examples given to it. The mechanism is as follows: an example is provided as input to the machine, which provides an output. Once an output is obtained, there is a feedback mechanism that provides reinforcement or damping, and the "weights" are adjusted, leading to self-organization in the intermediate layers. Self-organization is a typical characteristic of complex systems.

The students are asked to choose one of the following pairs and discuss them: deterministic/non-deterministic, predictable/unpredictable, certainty/necessity, probability/possibility, and complex/complicated. From the discussions with the students, it emerges that the term deterministic can be associated with predictable, certainty, and necessity (meaning the cause leads to an effect), but not with complex, to which non-deterministic, unpredictable, possibility, and probability can be associated. Classical physics is deterministic because it produces a predictable result with certainty, and symbolic computing also has a deterministic approach because the same input data always produces the same output. The difference between complex and complicated is clarified: complex refers to something like the brain, ant colony, or flock of birds, which is like a "tangle" that loses its characteristics if untangled and cannot be reduced to a sum of simple parts; complicated, on the other hand, refers to something difficult, something that is "folded" and can be opened up.

Now the determinism of Laplace and Laplace's demon are being introduced. The basic idea is that we are limited, but if we had the mind of the demon, we could achieve certainty, predictability, and determinism. This dream of classical physics was shattered with the study of complex systems. Nowadays, we have access to more and more memory and data thanks to the internet, which might make us feel like we're getting closer to Laplace's demon, but we never actually achieve that certainty and necessity because complexity comes into play, based on probability and possibility. A complex system is made up of many elements that interact with each other (a neural network, a human brain, a social system) and cannot be explained based on simple causality. It studies the regular and self-organized behaviors that emerge from complexity, but these are unexpected behaviors that emerge from simple interactions, from below (bottom-up).

At this point, a video is shown of a flock of birds, made up of many elements (the birds) that interact with each other with simple rules. The flock of birds can be analyzed with simulations: three simple rules are given to the agents (separation rule, alignment rule, cohesion rule), the algorithm follows these rules and what is obtained is that from small deterministic rules, collective properties emerge, even if we know these rules, this organization is not predictable, it is indeed self-organization. The students are then shown how uncertainty is inherent in nature and is not due to the fact that we do not have the mind of Laplace's demon.

In summary, a complex system is made up of agents that interact with each other, it is an open system (it exchanges matter, energy, and information with the environment) and presents a self-organization that emerges from the behavior of individual agents and that feeds back on them. It is explained that we too are agents in society and from us a self-organization is formed, which, in turn, conditions the behavior of individuals, with a feedback mechanism. This is why in complex systems we talk about circular causality or feedback effects.

A video is shown of a simulation of an anthill, where these self-organization mechanisms are evident. In conclusion, the words that define complexity are multiplicity, irreducibility, circular relationship (circular causality: the cause cannot be distinguished from the effect), unpredictability, and self-organization.

The brain is therefore a complex system made up of a huge number of elements, neurons, and neural networks are simulators of the brain, in which virtual neurons are organized into interconnected layers.

The activity "The attacker/defender game" is proposed: You randomly choose two classmates A and B, the first attacks you and the second defends you against the first, then you have to move so that B is between you and A. The students go into the corridor to play this game and the properties of self-organization emerge.

The second part of the meeting was dedicated to the challenges and opportunities of AI.

Initially, the students are made aware of how AI has now become pervasive and has infiltrated every aspect of society. Just a few years ago, the situation was quite different, and AI was considered a novelty. In the present, we find ourselves living in a "society of acceleration" (H. Rosa), where the pace of change is so rapid that we do not have time to metabolize it. This raises the question: How much awareness do we possess regarding the relationship between humans and machines? In the past, machines played a purely instrumental role, fulfilling specific tasks for humans. Nowadays, our current relationship with technology has evolved. It is no longer an entity distinct from us, but rather, we both influence and are influenced by it. The students are prompted to reflect on whether they perceive a "misalignment" between the rapid advancements in external aspects such as technology and society, and the relatively slower adaptation times of institutions such as schools. Several students expressed their perception of this misalignment.

The risks associated with AI are discussed with the students. Various words emerge, including privacy, security, transparency, fairness, prejudice, control, and persuasion. These risks involve different domains, including personal, economic, political, and scientific spheres. Concerning transparency, machines can be seen as "black boxes": data are given to the machine, which manages them and provides a result, yet the mechanism that drives the machine to produce that specific outcome remains unknown. The issue surrounding search engines is subsequently raised: is there an ethics of self-regulation that guarantees transparency of the search service regarding sources of information? Do search engines respond to a criterion of fairness? Are the results we obtain from our searches personalized based on our profiles? Concerning privacy, AI algorithms not only process the explicit data we provide but also the implicit data, often referred to as metadata.

The concept of “bias” is further clarified, referring to the inherent prejudices that machines acquire through training on specific data. This leads to the question of how to ensure neutrality and fairness.

The students are asked to reflect on the phrase: “The distance between the two cultures is costing us dearly.” The “two cultures” refer to the humanistic and scientific culture, AI is an interdisciplinary topic that involves not only the scientific sphere but also the humanistic, social, psychological, and various other dimensions. The concept of “digital twins” and the relationship between the physical self and the virtual user are briefly mentioned. Finally, the opportunities of AI are introduced, such as the creation of a three-dimensional structure of millions of proteins by Alfafold, the AI algorithm developed by Deepmind.

Day 3 - Machine learning and neural networks

The third lecture was held by Prof. Eleonora Barelli, a researcher in the field of physics education and STEM disciplines at the University of Bologna, and revolved around the model of neural networks and machine learning.

The main learning objectives were:

- Understanding the mechanism underlying the machine learning approach
- Understanding how a neural network works and its similarity with a complex system
- Grasping some ethical issues concerning the use of AI

The meeting begins with the presentation of DALL-E, an OpenAI platform that can create realistic images and art from natural language descriptions (e.g. an image in the style of Van Gogh). It is explained that, to create DALL-E, a neural network was trained to create images from text strings for a wide range of concepts expressible in natural language. By ”trained”, it is meant that machines need to be trained through examples, by ”create” it is meant to ask what it means for the neural network to ”create” something new, and by ”concepts” it is meant what concepts are needed for the machine to create and how they must be expressed. The machine can take an existing image and create a background for it (”outpainting”) or it can also create new images with variations on the original theme. During the discussion, the students are asked about their feelings toward the topic. Most of them express fascination, but one student raises concerns about how this technology may undermine the essence of art as a human expression of emotions, questions about the nature of artistic creation and the meaning of creativity are raised.

Now machine learning is introduced as the field of study that gives computers the ability to learn without being explicitly programmed (Samuel, 1959), unlike a procedural mechanism in which I provide the procedure. In machine learning, I provide examples to the computer on the basis of which the computer can learn. To clarify the distinction between the two approaches, the example of teaching a robot to go to the bathroom is given: In the procedural approach, precise instructions need to be given to the machine in order for it to perform the task; in the machine learning approach, the machine autonomously learns how to go to the bathroom from a series of examples that are provided.

The concept of **supervised learning** is introduced. The task of the machine is to infer a function from labeled data. For example, if a machine needs to recognize the size of a T-shirt (S or L) based on length and width measurements, a series of correctly classified S-sized T-shirts and a series of correctly classified L-sized T-shirts are provided to the machine for training. Then, using machine learning, we aim to construct a function that can predict the label (S or L) that the machine assigns to a new input, given its length and width. This function, in order to be good, must not only classify the known cases correctly but also be able to generalize to new cases (e.g. when we don't know whether the size is S or L, but only have the length and width measurements). We call this predictive function the **'hypothesis function**.' This function can be, for example, a straight line, and in this case, finding the hypothesis function means finding the slope and the intercept. At this point, if a value of x is known, the corresponding value of y can be found, allowing the determination of the point on the line. Another hypothesis function can be the logistic classification. In general, we call these **parameters** that identify the hypothesis function (which, in the case of a straight line, are m and q) θ_1 and θ_2. The objective of neural network learning is for it to learn these parameters autonomously, without explicit instructions. To achieve this, another function called the **'cost function'** is introduced. This function produces high values when the network makes incorrect predictions and low values when the predictions are accurate. The goal is to minimize the cost function with respect to the initial data, ensuring that accurate predictions can be made for other data as well. The issue of 'overfitting' is then explained: paradoxically, when the machine is trained using excessively detailed and precise examples, it can struggle with generalizing its knowledge to handle future cases. For example, in the context of image recognition, the process of classification involves creating a dataset with accurately labeled pixel values as input for the machine to train on. Once trained, the machine should be capable of classifying new images.

The concept of a 'neuron' model is introduced, which is a computational unit responsible for receiving inputs and generating outputs that are transmitted to other neurons. In the context of creating a neural network, this model represents a computational unit that takes 'features' as inputs and produces the results of the hypothesis function as outputs. When the neural network comprises multiple layers of neurons, the output of the hypothesis function is calculated through a process called **forward propagation**. This involves sequentially calculating the results from neighboring layers and passing them to subsequent layers until reaching the final output.

How are the parameters calculated? Initially, the parameters of the neural network (one parameter for each connection) are assigned random values. The training process starts by providing an initial image as input and observing the final output. If the classification result is incorrect and the difference is significant, the process moves backward from the end to the beginning, and the parameters are updated to improve the accuracy of predictions. This involves adjusting the weights of the connections. Subsequently, another example is presented to the network, and the same procedure is repeated. Through numerous examples, the cost function is minimized, and a well-structured network with optimized weights is obtained. The process of finding the parameters is known as **'back-propagation**,' where adjustments are made to the weights of the network. Once the network is trained, it can be employed to classify new examples during the validation and testing phases. The term 'efficiency' in the context of a neural network refers to the reliability percentage of the network. In the procedural approach, efficiency is not applicable as there is no probability involved. Each individual rule is explicitly provided, leaving no room for uncertainty. However, in machine learning, efficiency is a key factor, as the probability of obtaining the correct result is never 100%.

The students are invited to reflect on these questions: What are we providing to AI? What type of ethics do we wish to instill in the machine?

On the DALL.E page, there is a section dedicated to biases, highlighting the over-representation of white, Western individuals in the images and the presence of a gender bias.

It is emphasized that in the context of machine learning, achieving 100% efficiency has never been possible. This raises the question of whether these machines possess intelligence and what kind of intelligence it is. In machine learning, they are no longer mere machines that follow instructions; they learn from examples, and intelligence, in this context, pertains to the ability to learn.

The problem with a neural network is that the parameters of the constructed network have no inherent meaning. They are a sequence of numbers that convey no specific information. Essentially, neural networks are ’black boxes.’ The numbers are not symbolically associated with any of our ideas, which is why it is referred to as sub-symbolic. The learning process is not interpretable from the outside. Today, the frontier of AI focuses on developing techniques to explore this black box and attempt to make it more transparent. Neural networks acquire implicit knowledge through examples, without being able to explicitly explain the ’why’ behind their results.

A neural network can be viewed as a complex system, where its capacity to classify images is not a predetermined skill that has been explicitly taught. Instead, it emerges as an outcome of individual neurons acting based on simple rules (“emergent property”). Similar to complex systems, neural networks exhibit sensitivity to small variations. Additionally, there is a circular relationship between the overall network and its individual components, as the network’s output influences the weights of the individual neurons.

A simulation of a flock of birds is presented, using NetLogo, to demonstrate emergent behavior. The students are encouraged to conduct experiments by modifying various parameters individually and observing the resulting changes in the simulation. The rules followed by each bird are alignment, separation, and cohesion. The concept of vision is introduced, referring to the visibility radius of the birds. The students are prompted to experiment by setting the vision radius to zero, leading to the absence of flock formation, as the birds cannot perceive each other’s presence and consequently fail to follow the rules. It is seen that increasing the angle extends the time required for convergence since the birds have more directions to move in. Furthermore, it is noted that the movement of individual birds is distinct from the collective movement of the flock, and the precise influence of each rule on the overall evolution remains unclear. The emergence of unpredictable collective behavior, characteristic of complex systems, is emphasized. This type of reasoning differs significantly from the equation-based thinking commonly found in physics, where the exact evolution of a system can be determined based on the equations of motion.

Day 4 - AI applications in physics and the different programming paradigms

The fourth meeting was held by Prof. Bosetti, who is currently pursuing a doctorate in artificial intelligence at the University of Trento in collaboration with CERN, and by Teacher C. Prof. Bosetti delivered a lecture on the applications of AI and machine learning on particle physics and Teacher C introduced students to the different programming paradigms.

The main learning objectives were:

- Gaining an understanding of the possibilities presented by AI to enhance research in physics
- Understanding the different forms of reasoning in the three programming paradigms.

During the first lecture, Prof Bosetti explained that particle physics is currently based on the Standard Model, which includes particles such as quarks and leptons that make up all the matter we know. However, there are still many things we do not understand: why neutrinos have mass, why there is only matter when there should be an equal amount of antimatter, and what dark matter is. It has been discovered that the universe is expanding at an accelerated rate driven by dark energy. The latest discoveries have been made at the CERN particle accelerator, the Large Hadron Collider (LHC). The Higgs boson was discovered in 2012, and it was challenging to separate the signal from background noise, where machine learning was very useful. However, the LHC faces several challenges:

- Managing millions of collisions per second, resulting in the use of two triggering methods to reduce data, with 99.9% of the data being discarded.
- The cost of simulations.
- The desire to upgrade to the High-Luminosity LHC, which will generate an enormous amount of data.

To handle the immense complexity and data volume in particle physics research, the utilization of machine learning and deep learning techniques has become indispensable alongside the Large Hadron Collider (LHC). The concept of generative networks is introduced, which operate by providing random inputs to a mathematical function that generates outputs based on certain parameters. These models generate a probability distribution and their fidelity to reality is assessed using a cost function. The process of training a neural network is revisited in this context.
A practical application of this approach is demonstrated in addressing the challenge of analyzing jets at the LHC. Jets, which consist of collimated sets of particles resulting from the decay of heavy particles, play a critical role in verifying the Standard Model. However, studying jets necessitates simulations. Neural networks are trained to complete the shape of jets through a process called "completion."

During the second part of the meeting, held by Teacher C, the concept of "games" is introduced, referring to consensual competitions among multiple individuals that follow shared rules, all with the goal of winning. An image of the chess match between Kasparov and DeepBlue is presented as an example, illustrating the extensive focus of computer scientists on games as an intellectual challenge. In designing the course, the decision was made to center on the game of tic-tac-toe due to its simplicity.
The students are asked to play some Tic-Tac-Toe games in couples, paying attention to their own strategies. They are encouraged to write their strategies on a virtual board. During the class, the contributions of the students are shared and discussed, revealing the most common strategy mentioned, which is the "fork move." This strategy involves strategically placing one's symbol in three corners to gain an advantage. Three main approaches to teaching a machine to play tic-tac-toe are introduced:

- **Imperative approach**: In this approach, the machine is instructed explicitly by the programmer on what actions to take. An example of a program written in Python is provided. The students are asked to write a code snippet on a padlet, providing instructions for exiting the classroom from their current position, using only three words: move one step forward/backward, stop, and rotate a certain number of degrees to the right or left. They are reminded to write each instruction in a single line, ending the sentence with a semicolon. Returning to the game of tic-tac-toe, during the execution, the teacher shows that the data (the configurations on the board) are systematically checked by the machine and the instructions are executed step by step. In this way, the teacher can highlight the very reasoning structure of this paradigm; for example, given a configuration of the board 1) the machine checks if there is a move that allows to win; in this case, it makes that move; 2) if not, it checks if the opponent can win and, in this case, prevents her/him to win; 3) and so on.

- **Declarative approach**: In this approach, propositional logic is employed. Facts are declared, and each move is governed by inference rules. Before the Tic-Tac-Toe, a first simple example is presented and implemented in Prolog, explicating the facts(“Giovanni is Anna’s father”, ”Carlo is Antonio’s father”, ”Andrea is Carlo’s father”, ”Andrea is Giovanni’s father”), the rules(implications that considered to be correct, e.g. ”If it is true that X is the father of Y and Y is the father of Z, then X is the grandfather of Z”), the question(”Is Andrea Anna’s grandfather?”) and the conclusions(T / F answers to questions related to ‘being a grandfather of’). The teacher then displays the code for tic-tac-toe written in Prolog, highlighting the difference between the imperative approach based on rules and the declarative approach based on a knowledge base and inference rules. This approach allows for greater generalization, and the Prolog code is shorter and more convenient compared to the Python code seen earlier.

- **Machine learning approach**: A neural network Tic-Tac-Toe player (NN player) has been coded in Matlab, specifically written to be trained from different databases and to let it play against different opponents (another neural network, an ‘imperative’ player, and a random player). The training dataset can include random-random, imperative-imperative, or random-imperative games, played n times. The teacher shows some examples, and after several matches, two characteristics are highlighted: (1) the NN player wins more games increasing the number of games examples it is trained on, also when the database is built with games between random players, and (2) the efficacy of the NN player increases with the variety of games examples: when trained upon a database of games between only perfect imperative algorithms, the NN player does not know what to do against a random player, this is the problem of the “overfitting” mentioned in the previous meeting.

Day 5 - Towards futures studies

The fifth meeting revolves around the topic of the future and the capability to predict, hypothesize, and imagine the future. It was mainly held by Teacher B with the collaboration of Teacher A who deepened some concepts and posed and answered questions from the students.

The main learning objectives were:

- Enhancing the ability to envision different possible futures
- Understanding the relationships between the involved agents
- Becoming aware of how the human-machine relationship changes in different situations.

During the lecture, it is explained that this module was developed as part of the I SEE project, which originated from a shared philosophy among multiple European partners. This philosophy centers around the challenging relationship with the temporal dimension, particularly how we perceive and imagine the future. In this “society of acceleration”, the future is often seen as uncertain or a threat, which can create anxiety. Researchers and teachers in STEM disciplines have wondered how to manage this uncertainty and view it as a turning point (possible scenarios).

There are two perspectives within physics on these topics: (1) In classical physics, the future is predictable in a deterministic way, and uncertainty is considered merely instrumental and usually reducible. (2) With complexity, there is a new approach to the future, involving unpredictability in future evolution due to the fact that small variations in initial conditions can lead to significant changes, and there is circular causality. ”Scenarios” is the new concept introduced with complex systems, where there is no longer a single future but multiple possible futures. With artificial intelligence, we encounter this discourse when considering the different approaches to programming introduced:

- Imperative and Declarative approaches: deterministic and with linear causality.
- Example-based approach, based on statistics and circular causality.

“Future studies” is a branch of sociology that focuses on studying how to teach the future: there are multiple futures to consider, and it is important to explore methods of prediction, hypothesis, and anticipation.

The difference between “forecast” and “foresight” is explained. “Forecast” involves making a prediction and obtaining a unique outcome, while ”foresight” involves projecting and considering multiple scenarios. A scenario refers to the description of a possible future situation. The objective is not to predict the future with certainty but to provide an image of a possible future. The concept of the cone of futures is introduced, which includes the categories of probable, plausible, possible, and preferable.

- Preferable: the future we desire.
- Probable: The prediction of the model.
- Plausible: Based on what we know and the data we have.
- Possible: it takes into account imagination, is the most visionary and, therefore, the broadest.

We are accustomed to the idea of a future that progresses in a single direction. However, in this complex society, even small changes and decisions (contingencies) are becoming important. As agents in society, we can act to move towards desirable futures. It is the science of complex systems itself that provides this interpretation, as it incorporates probability and the idea of possible futures.

Then, two activities were carried out:

- “The town of Ada 1”: A sheet is provided to the students with a detailed description of Ada, a small imaginary city, living an extraordinary season in terms of opportunities for future development. The description includes the city urban structure, the people who live there, and the operating companies, the most important of which is “Babbage”, an emerging company that produces hardware for AI systems. The improvements in the AI field can give new impetus both to the company and the city; in this perspective, Babbage makes a proposal to the city administration. The proposal focuses on the concept of connectivity and involves the development of key areas such as transportation, services, tourism, and, on the other hand, the distribution of microchips or personalized badges that allow connection to healthcare, recreational, and educational services. The Mayor must decide whether to: remove certain urban planning constraints for the expansion of the company, initiate the construction of a technological hub, and grant prior authorization for the distribution of microchips to all citizens. The Mayor has to make decisions that interweave both private and collective interests. The students are required at first to recognize the stakeholders involved in any possible decision, the needs and interests of the different stakeholders, and the interactions between them. In a second moment, they have to assume the role of Ada’s Mayor and make a decision about Babbage's proposal. The students were divided into five groups, and from the analysis of their responses, a fairly balanced situation emerged between the groups in favor of the proposal and those against it (specifically: 2 in favor, 1 against, and two undecided). The pros highlighted by the groups are an increase in tourism

and improved transportation efficiency, while the cons highlighted include the risk of isolation with a decrease in social interactions among citizens, pollution, and harm to the local economy.
- “The town of Ada 2”: three future scenarios were presented to students: a hyper-technological scenario, a rural scenario, and a balanced one. They are asked to analyze them, identifying the pros and cons of each and choosing the preferred scenario. From the analysis of the responses, surprisingly, the rural scenario is the most chosen (specifically, two groups chose scenario B, and three groups chose scenario C). In the rural scenario, aspects such as sharing, community, interpersonal relationships, and connection with nature are appreciated. In the hyper-technological scenario, the circularity of the human-machine relationship is emphasized: humans can no longer exist without machines, there is no longer autonomy and independence of humans from machines, and it is impossible to go back.

Day 6 - Action competence activity

The sixth day was dedicated to a teamwork activity called “the town of Ada 3”. The instructions for conducting the activity were provided by Teacher B.

The main learning objectives were:

- Enhancing the ability to envision a desirable future
- Enhancing the ability to “backcast”
- Enhancing the ability to plan actions to reach that desirable future : each person, based on their role, must be able to understand the actions they can take and the impact they can have in solving a specific problem.

During the activity, the students are asked to work in groups and imagine a “desirable scenario” of a city in 2040. They have to identify a significant problem in the present and then move forward to a desirable future in 2040 where the problem has been solved thanks to AI. Afterward, they must return to the present and find an original idea (a leverage point) to solve the problem and plan the actions that can be undertaken in the present time to achieve that future. The stages of the activity can be summarized as follows

- Students are asked to identify the problem
- Idea generation: Students individually think of ideas on how to use AI to solve the problem. Then, within the group, they discuss and vote for the best and worst ideas.
- Each group goes to a separate room and explores both the best and worst ideas, discussing why they like or dislike them. The goal is to see how an idea can be enriched and understand in which areas it can have an impact (social, political, scientific, etc.).
- Students in each group are asked to act as agents and plan actions that can solve the problem. Each person assumes a role (political decision-maker, scientist, company, etc.) and acts accordingly to make the idea a reality (”action competence”).
- Storytelling in 2040 through ”backcasting”: Each group must create a presentation of their story, such as a video or enactment. The idea is as follows: it is 2040, and the problem has been solved. Using ”backcasting,” they need to explain how the actions that led to solving the problem by 2040 were developed in the present, considering the actors involved.

The problems chosen by the various groups included waste differentiation, marine pollution, improvement of healthcare services, and mental health.

Day 7 - Predictions and Scenarios (Networks and Simulations to Investigate the Complexity of Reality): a seminar by Professor Vespignani

This year, at the conclusion of the course on AI, the “Liceo Einstein” in Rimini hosted physicist Alessandro Vespignani, one of the world's leading experts in epidemiological modeling and forecasting science, in an online connection from Northeastern University in Boston. The meeting lasted about two hours and mainly focused on the concept of networks and the use of algorithms for making predictions and scenarios.

The main learning objectives were:

- Understanding the applications of AI in interdisciplinary fields
- Becoming aware of the numerous areas of our lives where AI impacts
- Becoming aware of the opportunities and risks offered by AI

The lecture begins with the presentation of an editorial from the magazine "Wired" titled "The End of Theory." The article claims that for many years, science has been conducted by collecting data and trying to obtain models that describe phenomena. However, with the revolution of big data, we can now collect vast amounts of data that are processed by computer algorithms, which provide us with results. The article provocatively concludes by stating that it is time for science to learn from Google.

Building on this, the professor explains that in 2008, "Google Flu Trends" emerged. The idea is to identify web searches that contain keywords such as "fever" or "cough" in order to quantify the number of people who likely have the flu. Through an algorithm, real-time information about the flu season can be obtained. However, the problem with this algorithm is that many people, even during a pandemic, search for flu-related information out of curiosity or to stay informed. Apart from this, the importance of combining various data to obtain systems that monitor the situation is emphasized. For example, important data for estimating flu activity can also include last-minute cancellations on online restaurant booking platforms.

Drawing upon Poincaré's quote, "The accumulation of data is no more science than a pile of bricks is a house," we can emphasize that merely amassing data does not equate to having a comprehensive understanding of the situation at hand. There exists a wide array of crucial information that cannot be obtained through artificial intelligence alone. One of the challenges posed by AI becomes evident through the paradox of the "black box," wherein algorithms take in data and provide results, yet the underlying reasons behind these outcomes remain unknown. This limitation can be explored through Polanyi's paradox, which suggests that we possess knowledge beyond our ability to explicitly explain it and so our brains can be seen as black boxes. In present times, substantial research efforts are dedicated to achieving algorithmic transparency, aiming to comprehend the rationale behind the answers provided by specific algorithms.

Algorithms can be classified into mechanistic and black box algorithms. The former contains the laws that govern the system, while the latter seeks correlations in data that we cannot develop analytically and explicitly.

From this, two elements emerge:

1. The importance of having algorithms that can analyze data.
2. The importance of having data.

But what kind of data? Machines use data that are actually networks. The professor provides some examples:

- Air transportation network: different geographic areas that come into contact.
- Daily movements in urban areas: commuting patterns.

Overall, a social interaction network is generated from our personal interactions.

How are these networks constructed? Starting from a network composed of households with their activities and movements (e.g., school, work), a bipartite network is generated. On one side, there are individuals, and on the other side, there are the places where individuals meet, eventually leading to a network of interactions between individuals who have spent time together. Enormous networks of individuals interacting on different levels (family, school, work) are generated, defining our relationships. In recent years, another level has been added: the computer network. Today, we also communicate through personal interactions mediated by social media, and these networks are highly dynamic. These data are important because of their relationships, and with social media, we can now also look at the content of these relationships.

Today, we are constantly surrounded by algorithms that make predictions for us (e.g., predicting what music we will like). The predictive power of these algorithms is due to the fact that they collect data from a large number of people and can cross-reference our data with those of similar individuals, i.e., by examining the network. We are "augmented intelligences," living in symbiosis with algorithms: the more we use algorithms, the better and more precise they become, and consequently, we use them even more. We also experience a physical dependence on mobile devices. For example, if we forget our cell phone at home, we perceive it as a physical discomfort, almost like a disability. An example is now shown of a network that connects museums through the artists who have exhibited there. By examining the trajectory of artists in this network, we can predict which artists will become successful after a few years. This is because the perception of an artist's skill is determined by the reaction of the network to their work. Therefore, various predictions can be made: about books, and artists, but also predictions of conflicts or electoral outcomes.

In the social system, these algorithms work on constructing "artificial worlds": synthetic worlds within which experiments are conducted and maps of possible futures of society are created.

An animation is now shown representing the city of Boston, with "bubbles" that expand and shrink based on the number of people populating a particular area. What is observed is that during the COVID period, many of these lights go out due to the lockdown, as connections between individuals are interrupted. In reality, it is seen that even after the end of the lockdown, during the first year, society did not return to normal because it is malleable, and the construction of the social network is not an immediate process.

Now, let's consider a question: during the years of the COVID pandemic, it appeared as though our understanding was limited. However, can we truly be certain of that? The perception of limited understanding was primarily a result of inaccurate media communication. In actuality, "epidemiological intelligence" had been making predictions and developing models that, by mid-February, provided indications that the epidemic had already extended beyond China, with infections spreading in Europe and the United States. The reason we failed to perceive this reality was simply because we were not actively searching for it. During that period, testing was primarily focused on individuals returning from China, thus overlooking the broader scope of infections occurring elsewhere. Now, a statement from a politician is shown as evidence of this disconnect between science and decision-makers: "Decisions should be based on things that actually happen, not the result of some mathematical equation." This is not true because we continuously make decisions based on algorithms (what movie to watch, what book to read, etc.). In the case of weather forecasts, even if they are not precise, there is trust in making decisions because there is a visible threat (e.g., photos of an approaching hurricane), which is not the case for epidemics.

Now, the issue of uncertainty is explained: models inherently contain uncertainty. In the case of weather forecasts, each model of a hurricane movement generates a different trajectory, and the same applies to epidemiological models. Consequently, to formulate a prediction, one does not rely solely on a single model, but rather combines multiple models to generate ensemble models. These predictions are accompanied by a range of uncertainty, often represented as gray areas. This is what has been attempted, for example, in the United States for COVID, where different teams worked independently but communicated their results to a team within the Centers for Disease Control and Prevention that generated predictive ensembles.

The primary distinction between weather forecasting models and epidemiological models lies in the fact that while we are unable to alter the path of a hurricane, we have the ability to influence the course of an epidemic through on-the-ground interventions. Consequently, utilizing these algorithms allows us to move beyond mere predictions and instead generate conditional projections based on assumptions regarding future human behavior, interventions, vaccination campaigns, or variants. These projections are called “scenarios” and act as maps of the future, providing us with tools to reason about potential outcomes, but we cannot interpret them as predictions. Decision-makers will then need to navigate the system in certain areas of these future maps. As a result, we will have multiple potential futures, but none of them will be the exact future. The actual future will fall within the spectrum of these potential cases.

In the coming years, we will face even more existential challenges than the pandemic: climate change, human-technology interaction, resource depletion, environmental degradation, overpopulation, and increased social inequality. The solution begins with learning to read the maps of the future.

Now, space is given for questions from the students of the three schools that participated in the seminar. From the discussion, some interesting reflections emerge. In response to a question regarding collaboration within research teams, the professor explains that these teams are highly interdisciplinary, consisting of individuals with diverse expertise: economists, biologists, physicists, as well as experts in the field of social sciences. The only requirement is computational literacy, meaning having some familiarity with programming in order to interact with the world of informatics. A student asks how to convince people of the validity of the data obtained through models. The professor reiterates that the main problem is communication. While we have become accustomed to meteorology, there is a lot of skepticism when it comes to epidemics. Decision-makers also need to become more familiar with these tools and approaches to increase their awareness.

3.3 The AI Atelier

The AI Atelier is an interdisciplinary laboratory/Atelier on Artificial Intelligence, also recognized as a PCTO activity, that takes place over 15 hours between February and April 2023 and involves the participation of 10 students of the third, fourth, and fifth grade.

The AI Atelier aims to reflect on the theme of human creativity, through the languages of contemporary art applied to OpenAI platforms.

Before describing the structure of the AI Atelier and the main contents delivered during the meetings, I present an overview on the generative algorithms whose operating principle is at the foundation of two Open AI platforms mainly used during the AI Atelier, Chat GPT and DALL-E, together with other platforms like Midjourney and "this person does not exist."

3.3.1. Generative Artificial Intelligence

The rapid proliferation of AI systems has extended their influence to a core facet of human expression: art. Notably, significant advancements have been made in revealing the "creative" capabilities of AI, leading to its application in fields such as visual art, literature, poetry, and music. At present, multiple AI systems are available for producing images and texts offering effortless access to users from diverse backgrounds, beyond just experts or artists. (Gagliardi et al., 2023)
These types of algorithms are called Generative Artificial Intelligences (GAIs).

GAIs pertain to a category of artificial intelligence models capable of producing novel data through the utilization of patterns and structures gleaned from existing information. These models possess the capacity to craft content spanning diverse domains, including text, images, music, and more (Gozalo-Brizuela and Garrido-Merchan, 2023)
Generative AI models hinge on deep learning methodologies and neural networks to scrutinize, comprehend, and produce content closely mirroring outputs generated by humans (Ray, 2023). For instance, ChatGPT is a language model for building conversational AI systems, which can efficiently understand and respond to human language inputs in a meaningful way. Moreover, DALL-E-2 is another GAI model, which is capable of creating unique and high-quality images from textual descriptions (Cao et al., 2023).

The process of generating new data with a generative algorithm generally involves the following steps:

Training: The generative algorithm is trained on a large set of example data, such as images, texts, or sounds. This allows the algorithm to learn the patterns and regularities present in the data and to acquire the intrinsic structure and diversity of the training data. The algorithm iteratively updates its model parameters to minimize the loss function and improve the quality of generated content.

Sampling: The generative algorithm generates new data by sampling from the learned distribution. This can be done using a random number generator to generate a set of input values, which are then fed into the algorithm to generate the corresponding output. The generated data can be different and original, but should also be consistent with the training data and conform to the same underlying distribution.

Evaluation: The generated data is evaluated by a separate algorithm or a human evaluator to assess its quality and realism. This feedback is used to guide the generative algorithm and improve its ability to generate realistic data. The evaluation process can be ongoing, allowing the algorithm to learn and adapt in real-time as it generates new data.

The key components of a generative algorithm typically include a **generator, a discriminator, and a training algorithm**. The generator is a trained neural network used to generate new data similar

to the training data. It takes as input a set of random numbers, known as the **latent space**, which is a lower-dimensional representation of the data, and produces corresponding generated data as output. The generator can be trained using a variety of techniques, such as supervised learning, unsupervised learning, or reinforcement learning. The discriminator is a separate neural network trained to distinguish between generated data and real data. It takes the generated and real data as input and produces an output score indicating how similar or dissimilar the two inputs are. The discriminator can be trained using a variety of techniques, such as supervised learning, unsupervised learning, or semi-supervised learning.
The training algorithm is a set of rules or a learning algorithm used to adjust the parameters of the generator and discriminator based on their performance [14].

Generative AI can be quite diverse, encompassing techniques like Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs), and generative pre-trained transformers (GPTs). Each technique might have its own specific components and nuances (Cao et al., 2023)

The framework of Generative Adversarial Networks (GANs), introduced by Goodfellow et al. (2014), constitutes a deep learning architecture. It comprises two interlinked neural networks: a generator network (G) and a discriminator network (D). The generator's objective is to fabricate synthetic data that closely resembles authentic data, while the discriminator aims to differentiate between real and generated data. This setup initiates a dynamic interplay: the discriminator endeavors to distinguish between actual and fabricated data, while the generator strives to produce data that deceive the discriminator into perceiving them as genuine. Ultimately, this results in the generator network generating data that are virtually indistinguishable from authentic data in the eyes of the discriminator. (Liu et al., 2021).

VAEs, or Variational Autoencoders, introduced by Kingma and Welling (2013), are another type of neural network architecture used for data generation and manipulation. VAEs are an approach to probabilistic generative modeling that combines elements of autoencoder neural networks and Variational Inference (VI) (Asperti and Brolli, 2016; Kingma and Welling, 2019; Asperti and Ravaglia, 2019).
An autoencoder is a neural network composed of two parts: an encoder and a decoder. The encoder transforms input data into the latent space, reducing the dimensionality of the data. The decoder, on the other hand, reconstructs the input data from the latent space (Asperti and Brolli, 2016; Asperti and Ravaglia, 2019). According to Asperti and Ravaglia (2019), the overall structure of the VAE remains unchanged, but unlike autoencoders, the encoder of a VAE doesn't produce a deterministic latent representation but a probability distribution over points in the latent space. Specifically, the encoder will generate two vectors: a vector of means μ and a vector of variances Σ. A vector z is then generated using the $N(\mu i, \Sigma i)$ distribution, which will be the points in the latent space. Thanks to this sampling, the process becomes stochastic, and therefore, even the encoding of the same input data multiple times will not necessarily be identical, but will vary around the mean according to its variance. VAEs use variational inference techniques to train the model. The objective is to make the distribution in the latent space as close as possible to a known reference distribution (usually a Gaussian). This is done by minimizing a divergence metric, typically the Kullback-Leibler (KL) divergence, between the estimated distribution and the reference distribution (Asperti and Ravaglia, 2019).

Pre-trained generative transformers, commonly referred to as GPTs, constitute a family of neural network models that leverage the transformer architecture and are pre-trained on large amounts of data for text generation tasks. These models are trained to predict the next words in a text sequence, which requires a detailed understanding of language and text structures (Ray et al., 2023; Cao et al.,

[14] https://www.intelligenzaartificialeitalia.net/post/cosa-sono-gli-algoritmi-generativi-tutto-quello-che-devi-sapere

2023). According to Cao et al. (2023), this approach was initially introduced to address the limitations of conventional models in effectively handling sequences of varying lengths and contextual nuances. The transformer architecture centers around a multi-head self-attention mechanism. This component allows the model to consider relationships between different words in a sequence of text. The self-attention mechanism assigns weights to each word based on the surrounding words, enabling the model to acquire contextual understanding of the data (Cao et al., 2023). The architecture comprises both an encoder and a decoder. The encoder processes the input sequence to generate hidden representations, while the decoder employs these representations to produce the output sequence. Each layer of the encoder and decoder performs multi-head self-attention and feedforward operations (Cao et al., 2023).

The development of the GPT models can be attributed to OpenAI. Founded on December 11, 2015, OpenAI operates as a research laboratory led by a group of dedicated researchers and engineers. Their central mission revolves around the advancement of safe and beneficial artificial general intelligence (AGI) for the betterment of humanity. Esteemed individuals including Elon Musk (Tesla CEO), Gwynne Shotwell (SpaceX President), Reid Hoffman (LinkedIn co-founder), and venture capitalists Peter Thiel and Sam Altman collaboratively established this organization (Zhang et al., 2023).

The GPT models have been released in various versions, increasing in complexity and size as they were developed. The original version was GPT-1, followed by GPT-2 and GPT-3, which is one of the largest and most powerful language processing AI models to date, with 175 billion parameters (Ray et al., 2023; Taecharungroj, 2023). ChatGPT has been trained starting from the GPT-3.5 model, which is a modified and smaller version of the GPT-3 model, with 6.7 billion parameters (Ray et al., 2023). On March 14, 2023, OpenAI released GPT 4, the new version of ChatGPT. GPT4 is a multimodal and large-scale model that accepts images and text as input and can produce text output (Aydın and Karaarslan, 2023).

As ChatGPT gains widespread usage, increasing attention is being directed toward the ethical concerns it raises. Bias, when considering extensive language models like GPT, refers to the manifestation of systematic distortions, attribution inaccuracies, or factual misrepresentations that lead to the preferential treatment of specific groups or concepts, the perpetuation of stereotypes, or the formation of erroneous assumptions based on learned patterns (Ferrara et al., 2023).

According to Ferrara et al. (2023), the emergence of bias in such models can be attributed to various factors.

One contributing factor is the training data itself. Biases existing in the source material or introduced during data selection can be assimilated by the language model and subsequently reflected in its behavior. Additionally, biases can be introduced through the algorithms used for data processing and learning. For instance, if an algorithm assigns disproportionate significance to certain attributes or data points, it may inadvertently introduce or amplify existing biases present in the data. In scenarios involving (semi)supervised learning, where human annotators provide labels or annotations for the training data, biases may stem from the subjective judgments of these annotators, influencing the model's comprehension of the data.

Large language models, often trained on extensive text data found on the internet, inevitably absorb the biases present in these data sources. These biases manifest in various ways. Demographic biases arise when training data disproportionately represents or underrepresents certain demographic groups, causing the model to exhibit biased behavior towards specific genders, races, ethnicities, or other social groups. Cultural biases emerge as these models learn and propagate cultural stereotypes and biases, commonly present in the training data, potentially leading to outputs that reinforce or amplify existing cultural biases. Linguistic biases emerge due to the prevalence of content in dominant languages such as English on the internet, rendering large language models more proficient in these languages (Ferrara et al., 2023).

In addition to natural language generation, GAIs can involve the creation of other digital content, such as images and music (Cao et al., 2023). Text-to-image models, for example, can take a text prompt as input and produce an image as output (Gozalo-Brizuela and Garrido-Merchan, 2023). The architectures of text-to-image models can vary, but they often include GANs or VAEs, and more recently, transformers (Cao et al., 2023). An example of the latter case includes DALL-E. DALL-E is a 12-billion parameter transformer developed by OpenAI, capable of generating images based on textual descriptions. Employing an advanced deep learning model, DALL-E produces intricate, high-quality images applicable across various domains, from product design to advertising. The potential offered by DALL-E is captivating, ushering in novel realms of creativity and artistic expression (Zhou et al., 2023; Cho et al., 2022).
However, the utilization of AI-generated images, as exemplified by DALL-E, raises significant ethical concerns related to bias and discrimination. AI systems are trained on extensive datasets, potentially absorbing and reinforcing biases present in the data. Consequently, AI-generated images may inadvertently perpetuate harmful stereotypes and foster discrimination based on factors such as race and gender. For instance, an AI algorithm trained on a dataset dominated by images of individuals of white ethnicity could generate images depicting them as the norm, while portraying people of color as atypical or exotic. This exacerbates detrimental stereotypes, contributing to systemic discrimination.
Furthermore, AI algorithms might also learn from datasets that bolster damaging gender stereotypes, portraying women in passive or objectified roles (Zhou et al., 2023).

In general, in addition to biases, there are other ethical and legal issues that concern GAI, like the copyright and the reproduction rights linked to the data sources on which the AI is trained (Floridi, 2023). According to Floridi (2023), the first lawsuits have already begun, and there have already been the first plagiarism scandals. Moreover, there are human costs. Floridi (2023) talked about the use of contractors in Kenya, paid less than $2/hour to label harmful content to train ChatGPT; they could not access adequate mental health resources, and many have been left traumatized. The Washington Post has published an article[15] on the fact that more than 2 million people in the Philippines label images so AI can generate representations of politicians and celebrities; they edit chunks of text to ensure language models like ChatGPT don’t churn out "gibberish." According to this article, at least 10,000 of these workers do this labor on a platform called Remotasks, which is owned by the $7 billion San Francisco start-up Scale AI. Scale AI, which does work for firms like Meta, Microsoft, and generative AI companies like Open AI, has paid these workers at extremely low rates, routinely delayed or withheld payments, and provided few channels for workers to seek recourse, according to interviews with workers, internal company messages, payment records, and financial statements.

The numerous implications of the GAI in various areas of human life generate reflections among philosophers about critically orienting themselves and maintaining control of their thoughts in a transformed and now hybrid world. According to Floridi (2023), we will need to understand and learn to interact with artificial agents created by us, considering forms of "agency" never seen before, alien to any past culture. There will be many fundamental questions to reflect upon, questions that have already arisen and questions that will emerge. Among these: What will be our uniqueness as producers of meaning, significance, and new content? What will be our ability to interact with systems that in their production are increasingly indistinguishable from humans? Will we be replaceable as readers, interpreters, translators, synthesizers, and evaluators of content? How will we react to the fragmentation of shared experience? (For instance, AI can easily produce a unique novel on-demand for a single reader.)

[15] https://www.washingtonpost.com/world/2023/08/28/scale-ai-remotasks-philippines-artificial-intelligence/

3.3.2 Description of the AI Atelier

The AI Atelier mainly had a laboratory character. It was preceded by an introductory phase during which Teacher D carried out some observations using examples primarily drawn from art history. These were accompanied by analyses of works by artists who are working with AI. Also in this phase, Teacher E delivered a lecture on the topic: Artificial Intelligence and Philosophy. Teachers A, B and C intervened during these introductory moments by engaging participants in discussions, and raising or highlighting additional scientific and computer-related aspects. Their aim was to ensure a proper understanding of the technology under discussion.

Subsequently, students were invited to creatively reinterpret the concepts that had most impacted them or to delve deeper into and realize some of the creative ideas proposed during the first phase. The laboratory was managed in a way that progressively refined the ideas, ensuring conceptual clarity regarding the theme of the Atelier, as well as the scientific accuracy of the knowledge concerning the artificial intelligence systems that hypotheses and artistic conceptualizations were based upon.

Finally, in addition to considering the meanings that could be added to the various works to better define them from the perspective of communicative effectiveness through precise exhibition choices, all participants were asked to create texts about the laboratory experience and its content conveyed through the artworks. Such texts have been included in a catalog[16] in which the teachers involved in the project participated with their contributions on the addressed topics.

At the end of the atelier, an exhibition was held on May 18, 2023, where the students showcased the artworks they created.

In Table 3.4, I present an overview of the structure of each meeting of the AI atelier

Table 3.4: Overview of the AI atelier

Day	Name of the activity	Kind of activity	Main contents	Lecturers
1	Introductory lesson: AI and creativity	Interactive lecture	• The meaning of creativity • Relationship between the artist and the context • Combination of elements by AI • Artist's access to reality	Teacher D
2	AI and philosophy: What does it mean to think?	Interactive lecture	• Current of functionalism • Current of connectionism • Human thought vs AI: intention, connection to a body, asking questions	Teacher E

[16] https://www.einsteinrimini.edu.it/wp-content/uploads/2023/05/Atelier-sito.pdf

3-8	Elaboration of the artworks by students	Team works	The artworks: ● "A chance encounter", realized with DALL.E 2 ● "Degas' foot", realized with DALL.E 2 ● "The intruder", realized with Chat GPT, Midjourney and "This person does not exist" platform ● "Sentiment analysis" realized with OpenAI platform for sentiment analysis ● "Ancestral groove" realized using the software "VCV Rack" ● "AI quiz game", realized with Chat GPT	Teachers A, B, C and D as consultants

In the following, I present the main learning objectives of the different activities, and the content.

Day 1 - Introductory lesson: AI and creativity

The introductory lesson was held by Teacher D and was mainly dedicated to the meaning of creativity and how AI questions its fundamental aspects.

The main learning objectives were:

- Becoming aware that AI impacts a wide spectrum of realities and fields of human endeavor, including art
- Gaining an understanding of the factors that define the creativity of an artwork and exploring the potential role of AI in this context.

At the beginning, Teacher D introduced students to the main objective of the course through the quote of David Foster Wallace:

«There are two fish swimming, and at a certain point, they encounter an elderly fish swimming in the opposite direction. The elderly fish nods and says, "Hello, boys. How's the water?" The two young fish continue swimming for a while, then one looks at the other and says, "What the hell is water?" »

By revisiting this quote in this context, it aims to underline how we are immersed in technology and, like fish with water, struggle to recognize it because we are within it.

Artificial intelligence raises the issue of the meaning of creativity. In class, an artistic product created by DALL-E ("the puppet master"), commissioned by a magazine to produce a work of art in the style of the artist Cattelan, is analyzed (Figure 3.2: a). ChatGPT was asked to provide a critique of the work, which resulted in a text describing the work as a wooden sculpture from 1998 and attempting to give it meaning. The work created by DALL-E takes inspiration from Cattelan's typical style of the hanging marionette, and in class, efforts were made to understand what the AI might have done:

- Probably, it selected this recurrence of ”hanging objects” and used it for its creation.
- The fact that the marionette is elegant (wearing a tuxedo) is not clear where the AI got it from, perhaps from the term ”elegance” it may have found somewhere.
- The characteristic of the elongated nose may have been derived from the fact that Cattelan has a long nose.

Now, a real sculpture by Cattelan is being analyzed: “la rivoluzione siamo noi” (Figure 3.2: b). The work represents a small puppet, a self-portrait of Cattelan, hanging on a coat hanger. It is noted that the title “la rivoluzione siamo noi” is the same title as the work by Joseph Beuys (Figure 3.2: c), an artist from the 1970s who advocated for the role of artists engaged in society and politics, contributing to the evolution of society through their works. The title is not the only reference to Beuys' work; the puppet's felt suit is a clear reference to Beuys, who frequently used this material. The pose assumed by Beuys in this work is also a reference to the socialist painting ”il quarto stato” (the fourth estate). Returning to Cattelan, it is crucial to understand the historical-cultural **context** in which he exists. In the 2000s, the artist was significant in the art market and the economic sector but did not want to influence society. With his work, Cattelan reflected on his ”status” as a successful but seemingly useless artist in a contemporary context. To mock his role, he drew inspiration from an artist (Beuys) who believed in his revolutionary function and ridiculed it. The creative process has a conceptual dimension that reflects on the artist's identity, role, and function of art, which a machine cannot possess. This becomes evident when comparing Cattelan's work with that of DALL-E: the AI's work is superficial, merely reproducing the marionette with strings, while Cattelan's work carries significant reflection.

(a) *(b)* *(c)*

Figure 3.2: (a) “The puppet master” generated by an AI using Cattelan's style; (b) “La rivoluzione siamo noi” by Cattelan; (c) “la rivoluzione siamo noi” by Beuys. (from the slides of the AI Atelier)

Now, the issue of falsification is raised. It is not a problem limited to the present day. An anecdote is explained about the discovery in 1984 of some heads attributed to the sculptor Modigliani in a river, but they were actually created by a group of students as a joke, imitating the artist's style. Experts and art critics initially attributed these sculptures to Modigliani, and it was the students who later revealed the prank. An example is proposed: if we take our photo and ask DALL-E to recreate it in the style of Modigliani, our artistic work consists of the conceptual reflection behind this request, questioning the theme of authenticity. As technology advances, thought will become increasingly important in art, and manual labor will become merely a technical skill. What truly matters is the thought behind it.

Returning to the topic of creativity, some examples are presented:

- Combination of elements: AI takes various elements from previous labels and processes them to produce something new. **Combinatorial art** is a type of creativity; humans always create based on something that already exists. While combinatorial art exists in AI, the latter does not concern itself with producing something ”beautiful” or representing hidden truths. The case of Midjourney is shown, as an AI that creates images that could be considered “surrealistic.” Original surrealism always worked with the unconscious, but in the images created by this AI, there is a cold aesthetic that does not aim to evoke our anxieties.
- “L’Assenzio” by Degas: If artificial intelligence had existed during Degas’ time, it would not have been able to create this painting through the combination of elements that existed up until that moment. Degas personally went to a bar and captured a piece of **reality** in his painting. AI only has access to reality through labels; it is a transfigured reality.

Now, a reflection is raised on a possible objection to the use of AI in art: If an artist has a machine to create artwork, he is not truly an artist because he ”does nothing” himself. To respond to this objection, the example of Duchamp is shown, the creator of the ready-made, who drew mustaches on the Mona Lisa or took a urinal and displayed it in a gallery.

Now, some artists who work with AI are presented: Sofia Crespo, who creates an ”alternative nature” with AI; Refik Anadol, who took artworks from the MOMA collection, classified them, and had an AI reinterpret them in relation to meteorological data; Trevor Paglen, who worked with image labeling using the ImageNet database.
Referring back to Trevor Paglen, the issue of image classification is raised. The artist, using AI to label images of people, revealed all our biases and our way of seeing the world, which does not correspond to reality.
Finally, an example is shown where a machine is asked to create an image of girls at a party. The created image is very realistic, but upon close examination, it is noticeable that they are all the same person. The same model was used to create them.

Day 2 - AI and philosophy: what does it mean to think?

This lesson was held by Teacher E and revolved around the philosophical reflection on the issues raised by AI, especially regarding the meaning and origin of human thought.

The main learning objectives were:

- Reflecting on the differences between human mind and AI
- Developing a critical perspective regarding the essence of thought

The lesson begins with a question: “What can philosophy tell us about AI?”. Teacher E specifies that he has recently been involved with AI, and what interested him was trying to understand what artificial intelligences allow us to comprehend about ourselves, and how our brain and thinking work.

The topic of “imaginary” about artificial intelligence is introduced. This “imaginary” can be constructed, for example, based on literature or cinema, which are full of representations of artificial intelligence, seen with fascination or fear. A series of examples of the use of AI is presented: the case of “The Turk” is shown, constructed in the 1700s as a machine for playing chess, but actually operated from within by a small person; the image of Kasparov being defeated in chess by DeepBlue is shown; and finally, the case of Zeta is presented, a magazine written by Chatgpt.

Artificial intelligence, a term coined for the first time by John McCarthy, is divided into strong AI and weak AI. Strong AI refers to machines that become minds themselves, with a cognitive capacity indistinguishable from that of humans. Weak AI refers to machines as useful tools for human beings, but they do not attempt to replicate human intelligence. The concept of strong AI has connected to the philosophical current of **functionalism**: the mind is a series of functions that can operate independently of the physical support that sustains them (the brain). If one embraces this philosophy, it is possible to compare the human mind to artificial intelligence. On the other hand, the philosophical current of **connectionism** asserts that the mind is the brain, it is one with biological support.

The philosophical debate on artificial intelligence began in 1950 when the logician and mathematician Alan Turing posed the question: Can machines think? To answer this question, he developed the Turing test. After briefly explaining what the test entails, the students are asked to reflect on the conception of intelligence that underlies this test: According to Turing, if the machine simulates human intelligence, then it is intelligent. John Searle devised a test, called the “Chinese Room Test,” as a counterpoint to the Turing test. In this test, an individual does not know Chinese but has a book of instructions in front of him explaining how to combine Chinese symbols to form a sentence; thanks to the book, the person can compose meaningful Chinese sentences, but he does not actually know Chinese. No system that merely manipulates symbols according to instructions can be considered a thinking being; thinking involves intentionality and awareness. An example is proposed: in the sentence “The apple is red,” if one lacks the **intention** to eat and does not have a **body** that experiences ”hunger,” that sentence is meaningless because it is not associated with intention and lacks an understanding of its meaning. Descartes’ idea that the mind is made of a substance separate from the body and can develop independently from it is in stark contrast to Searle’s idea of a mind that needs a body. The professor prompts the students to reflect on the fact that a machine solves problems, but it is only humans who **ask the questions**. Humans ask questions because they have a body with its biological needs, shortcomings, limits, and defects; machines lack human purpose.

Lastly, the theme of **thought** is addressed: the professor explains that human thought originates and tends towards what is not there, unlike a machine that starts and arrives at what already exists. Human thought creates experience, new data, and new meanings. The quote by Wittgenstein, “Whereof one cannot speak, thereof one must be silent,” is mentioned, and the professor would reverse the phrase to achieve creativity: it is precisely what we cannot say that is the origin of all our words and thoughts; we continue to speak and think because we have not fully understood the meaning of what we are.

Days 3-8 - Elaboration of the artworks

During the following meetings of the AI Atelier, the students divided into groups, brainstormed ideas for creating an artwork and its artistic meaning, and started working.

The main learning objectives were:

- Understanding what it means to create a work of art using AI
- Learning to reflect on the artistic meaning of a work
- Learning to use AI platforms and leverage their potential

Initially, Teacher D held the thread of the discussion and resumed the observations made during the introductory phase, inviting the students to reflect on the key/themes that had been addressed. He suggested some ideas to the students on which they could work:

1. Combinatorial art: AI works through a combinatorial process of re-elaboration of existing images and contents; this generative action, therefore, to rise to an artistic level, must have a human reflection behind it since it is the intellectual depth of the proposal that creates an artistic work. An idea could be to use AI to generate an image that realizes the definition of surrealism.
2. Image classification: unmasking a machine bias, for example, of a racial or gender type, due to the fact that it learns to classify images from labeled examples provided by the programmer and, therefore, revealing our prejudices.
3. Concepts of intentionality and awareness with which one creates a work of art: Referring back to the example of Degas' Absinthe seen in the introductory lesson and the artist's attitude towards unveiling reality, the professor proposes to work on DALL-E and expanding the Absinthe painting, reconstructing its outline, to see the awareness of AI on the context.
4. The imaginary: the artist can confront an AI on some important themes through a chat with the AI itself.
5. Consciousness: The professor takes up the concept of "repetentia", or consciousness, discussed by Lucretius. Human consciousness derives from experience, this information sediments by not only accumulating but also creating voids: humans are also constituted by nostalgia and the things they lack. The "repetentia" of a computer is reduced to a stack of information books. The idea that can arise from this reflection is to ask the machine to create a family photo album with synthetic memories (birthdays, vacations, etc.).
6. Music: The professor refers to the 1968 film "2001: A Space Odyssey", to the scenes in which the supercomputer HAL, while being deactivated by astronaut David Bowman due to serious malfunctions, regresses to its primordial state and resurrects its ancient memories, including the song "Daisy Bell". This song was written by Harry Dacre in 1892 and is known to have been the first song sung by an electronic computer: it was indeed sung by an IBM computer in 1961. The idea that can arise from this is to use an AI to work on this music, transforming or rewriting its lyrics.

Subsequently, based on these ideas, the students divided into groups and, assisted and advised by Teachers A, B, C and D created the works presented during the AI atelier exhibition on May 18, 2023. Referring to the catalog of works from the AI Atelier[17], I summarize below the various works created:

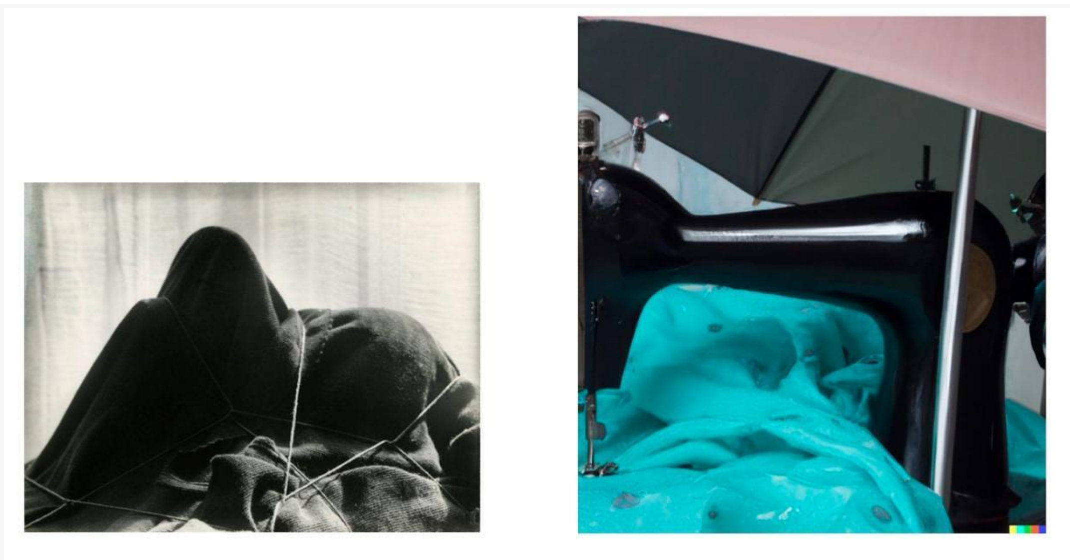
[17] https://www.einsteinrimini.edu.it/wp-content/uploads/2023/05/Atelier-sito.pdf

A chance encounter

A student, inspired by a work proposal that emerged during the Atelier, utilizes Max Ernst's famous definition of new surrealist beauty, originally present in a work by the poet Isidore Ducasse, and employs it as a prompt on an Open AI image generation platform: "beautiful as the chance encounter of a sewing machine and an umbrella on an operating table".

The generated images (one example is illustrated in Figure 3.3: b) are then printed and assembled in sequence without any further interventions or modifications compared to those created by artificial intelligence in the first session. The choice to employ such a definition arises from the observation that the majority of images visible on the internet and processed in prominent AI word-to-image platforms tend to possess a fantastical nature. These images often exploit the eccentric and spectacular potentials offered by such systems through unexpected combinations of various elements. As a result, the characteristics of these images can be seen as assimilating to a new surrealist aesthetic with strong pop or fantasy influences.

However, the proposed artwork aims to evoke a deeper reflection in the viewer. It explores a fundamental difference between the eccentricity of images produced by the surrealist movement and those generated artificially. Surrealist exploration involves free associations of words, thoughts, and images without inhibitory restraints, delving into the hidden aspects of the psyche without betraying its enigmatic and fundamentally unattainable nature. An example of this is the “Enigma of Isidore Ducasse” from 1920 by Man Ray (depicted in Figure 3.3: a), which photographs a sewing machine wrapped in a blanket and tied with string. The idea of using a sewing machine is inspired by the same phrase by Ducasse, as clearly indicated by the title. Man Ray's interpretation of the phrase primarily involves presenting us with an object wrapped like a mystery, and the word “Enigma” in the title characterizes it as not easily interpretable. In contrast, the associations in AI-generated images can only superficially resemble historical surrealism unless one assumes that the machine possesses an unconscious.



(a) *(b)*

Figure 3.3: (a) the “Enigma of Isidore Ducasse”, by Man Ray; (b) an AI generated image starting from the definition of surrealism. (Figure taken from the AI Atelier catalog)

Degas' foot

The work proposed by another student was created using a function called Outpainting on the Open AI DALL-E 2 platform, which allows for expanding the contours of a given image and visualizing what is outside the frame. This expansion is calculated based on probabilities that take into account existing visual elements of the image, including shadows, reflections, and textures, in order to maintain the original context while developing it according to the style of the original artist.

The starting artwork is Degas' painting, "L'Absinthe" (depicted in Figure 3.4: a). The painting originally has an interesting structure as the two depicted figures are not centered but only occupy a portion of the painting, leaving a lot of space for seemingly peripheral elements like the café tables. The presence, in particular, of the slice of table occupying the left corner of the image serves as the perspective point from which the eye obliquely frames the subjects and reminds us of the presence of the observer within the scene. There have been various hypotheses about who this gaze actually belongs to, but the most credible one is that it is the artist's gaze, who, not by chance, places his signature on that table. The digital expansion of the painting ideally corresponds to the investigation or verification of this hypothesis and finally allows us to imagine and portray who is sitting at that table.

One of the images produced by AI was very interesting because, even though it still does not fully reveal the figure of the observer, it seems to indicate his presence with a hint of a foot and a shadow interpretable as his knee (Figure 3.4: c).

(a) *(b)* *(c)*

Figure 3.4: (a) the Degas' painting "l'Absinthe"; (b) and (c) AI generated images starting from the Degas' painting "l'Absinthe"using the Outpainting function. (from the catalog of the AI Atelier)

At the beginning, achieving the desired result was challenging. Without a specific prompt, the areas of the image that the artificial intelligence was supposed to complete ended up filled with absurd elements. Some images were dominated by vibrant fruits and vegetables. However, when provided with the correct prompt, such as requesting Degas' typical stylistic features, the generated results became more stylistically faithful to the original image. Despite this improvement, several images consistently depicted ballerinas, which is a recurring subject in the artist's works but out of place in the context of "L'Absinthe" (an example is shown in Figure 3.4: b). This demonstrates how AI exercises its creativity by searching through millions of available internet data to find the most relevant information for the request, sometimes without distinguishing the relevance in relation to the specific context.

The Intruder

In "Simulacra and Simulation," Baudrillard predicts the liberation of the simulacrum from simulation, attaining a state of autonomy. According to the philosopher, this marks the final stage of a process that starts with the creation of a copy and culminates in the complete separation of the copy from the simulated object, leading to hyper-reality.

Using artificial intelligence, a student has generated the profile of an author/artist who was active in the 1960s and served as a precursor to the use of new technologies, Gioele Santarelli. The biographical profile, generated through Chat GPT, includes the artist's portrait created by the "This Person Does Not Exist" platform (Figure 3.5: b), as well as images of his works created with Midjourney. Alongside this virtual artistic identity, a real artist, Nanni Balestrini, who lived and worked during the same historical period is presented (a photo of Nanni Balestrini is presented in Figure 3.5: a). The viewer is thus prompted to consider these two entities as overlapping realities, both claiming to be true.

On the contrary, the refraction of an artist's life in the world of information, as well as the media perception of his work, can be equally false regardless of the concrete existence of the artwork and the individual.

(a) *(b)*

Figure 3.5: (a) a photo of the poet Nanni Balestrini, (b) a portrait of a non-existent artist, Gioele Santarelli, generated with the "This Person Does Not Exist" platform. (from the AI Atelier catalog)

Sentiment analysis

Each time a new technology emerges, especially one that seems to replace activities previously carried out by humans, it sparks a debate that influences our perception of human limitations and the strategies we have employed to overcome them. Consider the advent of photography, for instance, and its impact on portrait painting. These novel developments elicit fears and concerns about human marginalization, while also fostering excitement and utopian visions of the future.

Artificial intelligence follows the same pattern, triggering a range of responses within public opinion, often divided between apocalyptic and integrated perspectives. This can be observed in the comments left by users on popular social networks in response to articles or news related to this evolving technological domain.

A group of students has taken the initiative to collect and showcase a selection of these comments. Using open AI platforms, they have reprocessed this same set of comments in order to potentially classify them. The system evaluates the comments based on gender and political orientation, employing a combination of words as distinguishing factors, similar to how platforms increasingly make decisions on behalf of humans, such as career assessments for job seekers or gauging public opinion on a commercial product or political figure.

The comments utilized in the artwork are sourced from various social media platforms, including Facebook and Twitter. Following this, sentiment analysis AI was applied to these social media user comments, and the results were visualized through an animation created in Premiere Pro.

Ancestral Groove

There are numerous cases in which sound art renounces the potential of music to compete with other art forms based on established duration or narrative development and instead gravitates towards a much broader and sensitive perceptual arrangement: that of sound in space.

A student employs electronic programming to shape sound, allowing Artificial Intelligence to merge the samples inserted into the software. The sound installation also interacts with the steps of the visitor in space, capturing the vibrations they emit through floor contact microphones. Based on the intensity of these vibrations, impulses are generated, altering the flow and duration of the sound. The artwork aims to establish a connection between the primitive interaction of humans with space and sound, usually accompanied by dance and percussive sounds achieved through rhythmic foot movements striking the ground, and the most advanced technological instruments in music and sound generation.

AI Quiz Game

Can a machine ask us questions? Moreover, can it 'question' or assert something about its own essence?

From this reflection and the references made during the Atelier to various types of tests, such as the Turing test, through which science and philosophy have sought to answer the question: "Can machines think?", a student’s work takes its starting point. She asked chatGPT to generate phrases that explicitly raise doubt in the reader about their origin. These statements revolve around the theme of the relationship between human and artificial creativity. In the game, artificially generated statements are mixed with concepts drawn from various authors and their reflections on the technological leap that AI represents. The game consists of a question posed to the visitor, inviting them to distinguish what is human from what is the product of an artificial neural network.

It is interesting to note that even during the creation of the "quiz game" itself, limitations in understanding and interpretation by artificial intelligence have emerged, which led us to reformulate our request multiple times before obtaining what we wanted. For example, initially, when prompted to generate questions about itself and the challenges it poses in the field of the human, the AI refused, justifying its difficulty with the following reason: "I cannot ask questions about artificial intelligence being an artificial intelligence."

Chapter 4 - The Study on Co-teaching: Research Approach and Methods

As already said, the core of this thesis is to study the model of co-teaching implemented in the AI course and in the AI Atelier. The study has been carried out to answer the following research questions:

RQ1 *How are co-planning and co-teaching methodologies implemented in the development of a course about an interdisciplinary topic, such as artificial intelligence, in high schools?*

RQ2 *What are the contextual factors and relationships, including those outside of school, that can promote the implementation of co-planning and co-teaching methodologies?*

In order to contribute to these research questions, three sources of data were used:

- the notes and a research log taken day by day during my participation in the course and atelier, containing the content of the seminar as well as my observations and annotations about how the classroom co-teaching process took place and how the teachers interacted with each other;
- the catalog/document prepared by the high school teachers involved in the experience to present the AI Atelier, as direct access to the teachers' own words regarding their objectives on the experience[18];
- interviews constructed by us and then administered to the teachers to investigate, among other aspects, how the co-planning and co-teaching processes were organized and managed, the difficulties that were encountered, and what the relationships with the involved institutions (school management, university) were in the implementation of this experience.

In section 4.1, I will explain in detail how the interview protocol was constructed, and in section 4.2, I will explain the methods adopted to analyze the data.

4.1 The Goals and the Design of the Interview Protocol

The individual interviews represented the main tool for my investigation. The interviews were individually conducted, either online or in person, with the teachers who co-designed and co-taught the course on AI and the AI Atelier. The interviews were semi-structured and comprised general questions and more specific sub-questions. The interviewers were left free to discuss their experience, the more relevant issues as well as the most fruitful aspects. The interviews were carried out during the months of May and June and were audio-recorded and transcribed. The data were processed according to Art. 13 of Regulation (EU) 2016/679 (General Data Protection Regulation)[19]. The University of Bologna is the Data Controller and processes personal data by the

[18] https://www.einsteinrimini.edu.it/wp-content/uploads/2023/05/Atelier-sito.pdf
[19] Regulation (EU) 2016/679 https://eur-lex.europa.eu/legal-content/IT/TXT/PDF/?uri=CELEX:02016R0679-20160504

requirements of Regulation (EU) 2016 / 679 (General Data Protection Regulation) and of the legislative decree 30 June 2003, n. 196 and subsequent amendments and additions (Code regarding the protection of personal data)[20].

The interview protocol was structured following a formulation in 'areas' that have been investigated to answer the two research questions.
As regards the first research question, the areas were:

1. Evolution of the course on AI from the original I SEE module to the present until the introduction of the AI Atelier.
2. Implementation of co-planning and co-teaching in an interdisciplinary approach.
3. Students' reactions to the course on AI and AI Atelier.

For the construction of the questions related to this area, a preliminary research was conducted on materials and information provided by teachers A, B, and C regarding past editions of the course. This allowed us to compile a list in advance of the major changes the course underwent, enabling us to create more targeted questions to investigate these changes in detail.

The questions related to the second area are theoretically oriented and constructed based on some articles found in the literature. In particular, the article by Cook and Friend (1995) was used to understand the dynamics of co-teaching and the major challenges that teachers face during co-teaching. The papers by Pratt et al. (2017), Murawski et al. (2012) and Alsarawi et al. (2019) helped in constructing more specific questions about how co-planning was managed and organized, and the major difficulties encountered. The paper by Aarno et al. (2021) provided insights into the relationship between co-teachers, particularly the types of support present, including informational, instrumental, and emotional support.

The questions related to the third area are constructed to study the perception that teachers had about students' reactions during the course and atelier and how, from their point of view, these reactions have changed over the various years in which the course was offered. It should be noted that the students who attended the course and those who participated in the atelier were different; only two students took part in both PCTOs.

The interview protocol is composed by some common questions, posed to all the teachers, as well as some specific questions based on the role assumed by the teachers and the kind of participation in the experiences. To teachers A, B, and C, teachers of mathematics and physics who participated in the design and development of the AI course across its various editions, from the original version of the I SEE module to the current one including the AI Atelier, specific questions were posed about the course's evolution and the implementation of the co-planning and co-teaching methodologies during the course and the AI Atelier. These three teachers developed the AI course and held most of the activities (as reported in Table 3.3), while in the AI Atelier, they participated as scientific consultants in the introductory phase, and actively took part in the laboratory part by providing advice and suggestions to the students during the creation of the artworks. To teacher D, the literature teacher who had already collaborated last year with teachers A, B, and C to realize the Quantum Atelier, the interview questions were adapted to the context of the AI atelier, in which he implemented the co-planning and co-teaching methodologies. Finally, to teacher E, the philosophy teacher who is collaborating with the other teachers for the first time, a few questions were asked regarding the role he played during the AI Atelier and how he found collaborating with other

[20] D.Lgs 30 giugno 2003, n. 196
https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo:2003-06-30;196!vig=

teachers. We started with a 'pilot' interview with Teacher. B. This pilot interview was very useful for us in understanding the effectiveness of the questions. The protocol was therefore refined to obtain more specific insight for the other interviews. In particular, a few questions were added, after the pilot interview, regarding the differences between the Quantum and AI Atelier, the meaning of co-planning and co-teaching, and the possibilities to include the extra-curricular course in curricular hours.

In Table 4.1, the general questions corresponding to the investigated areas of RQ1 are reported, alongside the teachers to whom the questions were directed.

Table 4.1: General questions corresponding to the investigated areas of RQ1 alongside the teachers

AREAS	QUESTIONS	TEACHERS
1. Evolution of the course on artificial intelligence from the original I SEE module to the present until the introduction of the AI Atelier	1) In these years, what have been the most significant changes in the AI course? How has the course evolved?	Teachers A, B and C
	2) How did the AI Atelier initiative originate? What were the differences compared to the Quantum Atelier?	Teachers A, C and D (the question originated from the refinement of the pilot interview, so it was not asked to Teacher B)
2. Implementation of co-planning and co-teaching in an interdisciplinary approach	3) In your opinion, what do the terms co-planning and co-teaching mean?	Teachers A, C, D and E (the question originated from the refinement of the pilot interview, so it was not asked to Teacher B)
	4) How was the co-planning carried out? 5) How was the co-teaching conducted? 6) What difficulties did you encounter in organizing and implementing this course and atelier?	Teachers A, B, C, D and E (Teacher D and E answers only in reference to the AI Atelier)

	7) How were the relationships with other involved professors? How did you support each other?	
	8) What advice would you give to colleagues from other schools who want to start offering courses of this kind?	Teachers A, B and C
3. Students' reactions	9) How did the students respond to the course and atelier? Has it changed over the years?	Teachers A, B, C and D (Teacher D answers only for the students who attended the AI Atelier).

The investigated areas related to the second research question were:

4. The relationships between teachers and school management, and between teachers and the University of Bologna.
5. Possible improvements for a future re-proposal of the course and atelier, considering the school reality in which they are situated.

The questions related to the relationship between teachers and school management are theoretically oriented and constructed considering the article by Harkki et al. (2021), which investigated co-teaching within the school context, its barriers, and relationships.

To construct the questions regarding the relationship between Liceo Einstein and the University of Bologna, it was considered the well-established collaboration that the two institutions have from the I SEE project. The course was initially designed and developed by the University of Bologna in collaboration with the teachers of Liceo Einsteins who continued to refine and offer the course within the school context. Liceo Einstein has a long history of collaboration with the University of Bologna, which began in 2016 with the I SEE project. Due to this characteristic, it was deemed important to investigate the relationship with the University of Bologna and how it has evolved, particularly concerning the implementation of the AI course from its first edition to the present.

The questions related to the fifth area are constructed to explore the improvements that, according to the professors, could be made to the course, considering the school's reality.

Just like with the questions regarding RQ1, these questions also varied based on the roles and characteristics of the teachers. For example, the questions about the relationship with the University of Bologna were posed only to Teachers A, B, and C, who have collaborated with the physics education research group at the University of Bologna for several years.

In Table 4.2, the general questions corresponding to the investigated areas of RQ2 are reported, alongside the teachers to whom the questions were directed.

Table 4.2: General questions corresponding to the investigated areas of RQ2 alongside the teachers

AREA	QUESTIONS	TEACHERS
4. The relationships between teachers and school management,and between teachers and the University of Bologna.	10) Did the school management support you? If yes, in what way?	Teachers A, B, and C
	11) What was the role of the University of Bologna? How has it evolved over the years?	Teachers A, B and C
5. Possible improvements for a future re-proposal of the course and atelier, considering the school reality in which they are situated.	12) How would you comment on this edition of the course? If you were to do it again, what would you change or improve?	Teachers A,B, C and D
	13) In your opinion, what is the best placement for these projects? Within the regular morning curriculum or as extracurricular activities in the afternoon?	Teachers A, B, C, D, E
	14) What was the reaction of the teachers at Liceo Einstein who were not involved in the course and atelier?	Teachers A, B and C

4.2 Methods of Data Analysis

The analysis was carried out following a qualitative approach. The goal of the analysis was to thoroughly examine a specific experience of co-planning and co-teaching conducted in a school and find a way to characterize it. More specifically, the analysis we carried out is a thematic analysis. According to Braun and Clarke (2006), a thematic analysis is "a method for identifying, analysing and reporting patterns (**themes**) within data" (p. 79).
This kind of analysis, therefore, entails the search for and identification of common threads that extend across an entire interview or set of interviews (Vaismoradi et al., 2013). The thematic analysis provides accessible and systematic procedures for generating codes and themes from qualitative data. **Codes** are the smallest unit of analysis that capture interesting features of the data

(potentially) relevant to the research question. Codes are the building blocks for themes, (larger) patterns of meaning, underpinned by a central organising concept; a shared core idea. Themes provide a framework for organising and reporting the researcher's analytic observations. (Clarke et al., 2015). Each theme may have some **subthemes** as subdivisions to obtain a more detailed view of the data (Vaismoradi et al., 2016).
In Figure 4.1 the table containing the steps for thematic analysis proposed by Braun and Clarke (2006) is reported.

Phase	Description of the process
1. Familiarizing yourself with your data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2. Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3. Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes:	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5. Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6. Producing the report:	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Figure 4.1: Phases of thematic analysis and their descriptions (from Braun and Clarke, 2006; p. 87)

According to Braun and Clarke (2006), themes or patterns within the data can be identified in one of two primary ways in thematic analysis: inductively or "**bottom-up**", or theoretically or deductively or **"top-down"**.

For the analysis, we used an inductive (bottom-up) approach, which means, as explained by Braun and Clarke (2006), that the identified themes are closely linked to the data itself.

In this type of study, the themes would not even be driven by the researcher's theoretical interest. Inductive analysis is thus a process of coding the data without trying to fit it into a pre-existing coding framework or the researcher's analytical preconceptions (data-driven analysis). However, as also highlighted by Braun and Clarke (2006), it is important to note that researchers cannot free themselves from their theoretical and epistemological commitments, and the data are not coded in an epistemological vacuum.

I will describe in detail how our data have been analyzed in the next chapter.

To strengthen the validity and reliability of the findings, the method of triangulation was employed. Triangulation is a method used in qualitative research to test the validity of procedures and results by employing multiple methods or data sources (Carter et al., 2014).
In this study, we applied two types of triangulations first identified by Denzin (1978) and Patton (1999) and reported by Carter et al. (2014): method triangulation and investigation triangulation.
Method triangulation involves the use of multiple methods of data collection about the same phenomenon. This type of triangulation, frequently used in qualitative studies, may include interviews, observation, and field notes. As I said, for this study we used three methods of data collection: interviews, the notes, and the document of the AI atelier.
Investigator triangulation involves the participation of two or more researchers in the same study to provide multiple observations and conclusions. This type of triangulation can bring both confirmation of findings and different perspectives, adding breadth to the phenomenon of interest.

The results that I found in this study were initially triangulated with Professor Satanassi, and subsequently with Professors Barelli and Levrini.

Once the study was completed, there was also a phase of member checking. According to Birt et al. (2016), member checking, also known as participant or respondent validation, is a technique for exploring the credibility of results. Data or results are returned to participants to check for accuracy and resonance with their experiences. In our case, once the thesis was completed, it was sent, requesting comments and feedback, to the teachers who participated in the AI course and the AI Atelier and who were interviewed by us, namely teachers A, B, C, D, and E. Kindly, the teachers read my thesis, giving me positive feedback and providing me with some clarifications which I incorporated into the thesis.

Chapter 5 - Data Analysis and Discussion

In this chapter, we will analyze and discuss the main results obtained in order to address RQ1 and RQ2.

As I said, we used 3 different sources of data. The interviews, our main source, were first transcribed and the sense of the whole is obtained reading the transcriptions several times. They were then synthesized, with responses from various teachers reorganized under the corresponding questions. Once this was done, the main themes were sought using a bottom-up approach, namely they were identified starting from the synthesized data. After the individuation of the main themes, the original transcriptions were revisited to characterize the themes and find the details that might have been missed in the synthesis.The data provided by notes and the presentation document of the AI Atelier, prepared by the teachers, were read only after identifying the main themes from the interview syntheses and utilized to reinforce and characterize the themes prior to conducting the analysis.

5.1 Addressing RQ1

5.1.1 Data Synthesis

In this section , the synthesized answers to the questions related to RQ1 are presented. In particular, I report, organized per question, the key elements - the basis for pointing out the themes - highlighted by the teachers.
The thematic analysis carried out focuses only on the content of teachers' answers and not, for example, the gestures, the tones, and the way in which teachers introduced some aspects, or other aspects that characterize the discourse.

Question 1: In recent years, what have been the most significant changes in the course on artificial intelligence? How has the course evolved? (This question was posed to Teachers A, B, and C)

Teacher A
Teacher A argued that the structure of the course has not fundamentally changed, maintaining the two parts: the more technical part (addressing the symbolic and sub-symbolic approaches) and the activity on the city of Ada. However, the emphasis given to different parts has changed. Artificial intelligence has made rapid progress in recent years, and things that seemed novel at the beginning of the course are no longer so. The topic gains acceleration when discussing more interdisciplinary issues related to the social and ethical aspects. Therefore, the scenarios of the city of Ada have also been modified to reflect technological advancements.
Teacher B

Teacher B discussed that the structure of the module has remained fairly unchanged. There was an initial overview of the topic, followed by a central and technical part related to programming, and finally, the last part focused on the future. However, there have been some changes during the years: 1. An introductory activity to expand the imagination regarding artificial intelligence was removed this year because the teachers realized that, even in just a few years, artificial intelligence was no longer a novel idea, and the students were already fully immersed in this world. 2. The theme of complexity has always been present, but more dedicated space and attention were given to it in later editions because the teachers recognized the need to focus on the complexity-related concepts with the students. 3. Concerning the risks and opportunities of artificial intelligence, there was always a space reserved within the introductory activity. However, from this year, it has been given a specific moment during the second meeting. 4. Regarding programming paradigms, the logic one has not been thoroughly explored this year due to organizational issues, although Teacher C also presented this paradigm using the programming language Prolog during the fourth meeting. 5. Reflection on the relationship between artificial intelligence and art was present in previous editions, but it materialized particularly this year within the AI Atelier thanks to the advent of generative algorithms. The theme of creativity and the human-machine relationship was explored in depth. 6. The scenarios of the city of Ada have been modified because artificial intelligence has changed significantly in just a few years. A more hyper-technological scenario has been created, and the intermediate scenario has been modified, while the rural scenario remains the same.
Teacher C
According to teacher C, the course has evolved because society has evolved rapidly, and even as citizens, we are aware of the spread of artificial intelligence. He explained that in the early years of teaching this course, he and his colleagues (Teachers A and B) had to provide students with sheets or materials to familiarize themselves with the topic. Now, this work is no longer necessary as their lives are already "permeated" by AI. However, he explained, the part on the exploration of the difference between symbolic and sub-symbolic languages remains, as well as the discussion about the city of Ada, which the students really enjoy. According to Teacher C, the phase of discussion and interaction among the students regarding ethical problems is still very important.

Question 2: How did the initiative of the AI Atelier come about? What were the differences compared to the Quantum Atelier? (Question posed to Teachers A, C and D)

Teacher A
According to Teacher A, this initiative was born following the work on the Quantum Atelier, with the difference that the Quantum Atelier aimed to translate scientific concepts into artistic form, and the students had to have completed a course on quantum mechanics beforehand. On the contrary, the AI Atelier has also been opened to students who have not taken the course on AI and addressed themes related to creativity and how creativity can be applied to a machine. According

to this teacher, during its execution, the AI Atelier became a laboratory of thought related to how not only creativity but also humanity is changing in this new digital world. Hence, the philosophy teacher intervened to discuss what it means to think. Therefore, the two ateliers are quite different, including the required competencies to participate.
Teacher C
Teacher C states that the shared objective of the two ateliers was to integrate artistic and scientific elements. However, notable distinctions arise. In the AI Atelier the students were not prepared on the topic of AI. At most, they had gathered some information on their own, so it was not the level of preparation he had hoped for. Moreover, it was not easy to involve the students because they were slow to grasp the concept of artistic creation with artificial intelligence.
Teacher D
For the teacher, the experience of Quantum Atelier was very positive and, at the end of it, he was motivated to repeat the experience. Teacher D discussed the importance of understanding the kind of contribution he could give before starting to organize the AI Atelier. According to the teacher, the Quantum Atelier was a work of translation, where quantum mechanics was translated from the language of mathematics into another language, that of art, in a free and artistic way. In the AI Atelier, things are different because art is inherently creative and among the infinite applications of artificial intelligence, creativity is also present. Therefore, there is no need for translation but rather a comparison. In this comparison between how machines think and how humans think, it emerged that theories already known about creativity become more evident and powerful. In this comparison, the human-specific aspects appear with greater prominence and strength. From this comparison, both machines and humans gain insights into each other, and it is possible to see the limitations and advantages of technology as well as the limitations and advantages of human nature. Another difference highlighted by teacher D is that in the Quantum Atelier, the students were more prepared, while during the AI Atelier they were not very responsive, perhaps because there was no preliminary preparation. Additionally, the AI Atelier took the form of a PCTO (Pathways for Transversal Skills and Orientation) activity favoring the need to earn credits rather than genuine interest. However, this teacher claimed that, during the final exhibition, he had to reconsider his position because the students explained the artworks very well, demonstrating a good understanding. They managed the discussion and questions with a level of awareness that surprised him.

Question 3: In your opinion, what is the meaning of the terms co-planning and co-teaching? (Question posed to Teachers A,C,D and E)

Teacher A
In talking about co-planning, teacher A emphasized the long experience that has with teachers B and C and the design principles that have been shared since I SEE project. Regarding co-teaching, Teacher A highlighted the need to be attentive to balances, not only in terms of knowledge but also psychological and participatory aspects. According to him, teachers must be careful not to step on

each other's toes, give the right space, and trust in what the other person does. Co-design is done on paper, while co-teaching is done in practice. Teacher A emphasized that, in this experience, he had the responsibility and honor of serving as a coordinating element between the university and teachers. In this somewhat intermediary role, he realized how challenging it is to maintain balances among teachers, not just in terms of knowledge or one's own discipline, but also from psychological, emotional, and relevance perspectives. It is important to mediate and coordinate, considering also the effort that teachers face in their daily commitment to lessons.
Teacher C
According to teacher C, co-planning and co-teaching cannot be separated and the ideal scenario is that the teachers who co-plan are the ones who co-teach. Moreover, there needs to be a "feeling" among the teachers involved. Projects can be implemented by combining one's own expertise, aiming to enhance the skills and abilities of each teacher.
Teacher D
Teacher D defined co-planning and co-teaching as a continuous exchange, which he found very interesting. He claimed that, beyond benefiting from the solid expertise of colleagues, they had a small chat where whenever someone found an interesting article, he would share it, and the topic would be seen from multiple perspectives (artistic, humanistic, philosophical, scientific, etc.). They would then discuss it, each contributing from his own perspective and expertise. However, he believes that this exchange of contributions and opinions depends a lot on who it is done with because there has been talk of interdisciplinarity in schools for a long time, but dialogue among colleagues can be challenging. It truly depends on the individuals involved, their curiosity, and their interest. In this experience, he felt that interdisciplinarity was a "real thing." There was genuine exchange, and he learned a lot from it. Additionally, he affirmed that this exchange influenced his traditional lessons as well, as he has been able to enrich them with insights derived from what he has learned from these experiences. According to him, through dialogues and exchanges among colleagues, these experiences serve as enrichment and create bridges to various perspectives. Additionally, Teacher D talked about a sentiment of “trust” established between him and the other co-teachers. He specified that when he mentions trust, he means feeling comfortable in an open and curious environment. It arises from a personal, professional, and even friendly relationship (although a friendly relationship alone is not enough and working well together is essential). According to him, one puts himself at stake by addressing topics that may not be familiar with, but there must be certainty and trust to do so in a context of listening and exchange. One teacher brings his own ideas, and the others provide feedback and expand their possibilities for thinking about certain issues.
Teacher E
Teacher E found co-planning and co-teaching fundamental both for students who can approach the subject from unconventional directions and viewpoints, and they can grasp the unity of knowledge, and for teachers who can open their mind to different experiences and enrich the teaching of their own discipline (e.g. a lesson about modern philosophy and artificial intelligence). He, then, claimed that in high schools there are too few of these co-planning and co-teaching projects, at least in his experience, maybe because each teacher tends to go their own way due to the highly specialized nature of the subjects. However, he has noticed that the deeper one delves into the epistemological aspect of the disciplines, the more they converge.

Question 4: How was the co-planning carried out? (Question posed to Teachers A,B,C,D and E)

Teacher A
Teacher A specifically talked about his experience in co-planning the course on AI along with Teacher B and Teacher C. He explained that they met outside of school, conducted extensive readings individually, and then shared and discussed them, both via email and in person. He emphasized that, to carry out such work, a great understanding is required.
Teacher B
Teacher B explained that he, teacher A and teacher C, propose the module on AI in September, and then they began working on it concretely starting in December. They decided to start the meetings at the end of January. Around December, they planned the dates and organized the bureaucratic aspects, issuing circulars and the calendar for the students. After that, they meet whenever possible, in the afternoon, sometimes even on days off or during free periods. They decided which aspects can be deepened by one or the other, and they exchanged materials. Teacher B explained that there was a division of task: He took care of many bureaucratic aspects, Teacher C has dealt with the more technical part and Teacher A's presence was crucial for coordination because he keeps the work on track and maintains connections with the University of Bologna, partly due to having more time since he is retired.
Teacher C
Teacher C emphasized that with Teachers A and B, they have been working together for a long time, and they work very well. For planning the course on AI, they have met periodically to discuss how to work, how to guide themselves, and various doubts. He explained that he is more inclined toward the technical side, while Teachers A and B are more theoretical and skilled in managing organizational aspects. Together, they function well.
Teacher D
Teacher D specifically talked about his experience in organizing the AI Atelier. He explained that, at the beginning, He was somewhat skeptical because in the relationship between art and science, there is a risk that the humanistic aspect ends up playing a decorative and superficial role. So he made it clear from the start that he didn't want to have that role. During the planning of the atelier, he realized that this project touches on fundamental questions such as "what does it mean to think? What is nature? What is reality?" So, he considered it important to involve a philosophy teacher, Teacher E, asking for confirmation of certain ideas so they wouldn't be incorrect or out of place. He specified that, since the students of the AI Atelier were not the same as those who took the course on AI, he tried to "immerse" them in this mainly artistic aspect by relying on the expertise of colleagues in AI.
Teacher E
Teacher E specifically talked about his involvement in the co-planning of the AI Atelier. He explained that there was a preliminary phase of discussion between him and Teacher D about what philosophy, art, and literature have to do with AI and how they can dialogue. They then tried to understand how teacher E’s lesson could help students achieve something practical, like creating the artworks during the laboratory.

Their goal was to help students find forms of creativity that would bring together human thinking and AI. For teacher E, this goal was realized through a more abstract lesson, to foster a reflection and comparison between AI and human thought, while with Teacher D, there were many lessons involving direct interaction with students in the lab part. Teacher E emphasized that these projects can be done when there is the possibility of interaction within the school, based on a genuine connection between teachers. It's not just about friendship but about freely sharing interests and perspectives. If this ability to share is lacking, it is difficult to carry out these projects. To undertake these projects, one must be willing to step out of their comfort zone, be open to dialogue, love their own discipline, and try to share interests as much as possible. He explained that since he has been working in the scientific field, he has realized that his mind is continually opening up. Confronting apparently distant disciplines provides him with a great deal, especially in his teaching.

Question 5: How was the co-teaching implemented? (Question posed specifically to Teachers B and C; Teachers A,D and E has already answered in the questions before)

Teacher B
Teacher B explained that, regarding the course on AI, having had the past experiences of collaboration with teachers A and C, it was relatively easy because as a group, they were well-coordinated and in sync. When there are other colleagues involved, like in the case of the AI Atelier, this camaraderie needs to be built gradually, based on shared experiences and work philosophy.
Teacher C
Teacher C, regarding his co-teaching experience during the course on AI, explained that it comes somewhat naturally to them. Each of them has delved deeper into certain topics, so they addressed those and managed to complement each other. The pre-class discussions are important because they allow them to organize various points and ensure meticulous preparation. He explained that, immediately after each class session, they discuss how it went, relying mainly on student responses and reactions. Feedback is crucial for them.

Question 6: What difficulties did you encounter in organizing and delivering the course/the atelier? (Question posed to Teacher A, B, C,D and E)

Teacher A
Teacher A explained that during the course on AI they did not encounter any difficulties because there was already a well-established project. They only met to focus attention on certain aspects and exchange ideas, but it wasn't very demanding. According to teacher A, the atelier was more difficult to prepare because there were different people. For example, teacher D has a precise artistic thread, so more work was needed to coordinate the scientific and artistic aspects. Coordination with the philosophy teacher, Teacher E, took place mainly with Teacher D, with whom he primarily collaborated. According to teacher A, these projects are demanding and require extra work, which needs to be coordinated with the morning's regular work. Teaching now is very demanding for teachers, and this additional work brings satisfaction but also requires psychological and intellectual effort.

Teacher B
Teacher B explained that the main problem is finding time. He emphasized that he was fortunate this year because he had four hours of extra support, which reduced his regular workload of 18 hours to 14 hours in the classroom. This gave him much-needed breathing room, and he finally had time to dedicate to the project. In general, he thinks in order to manage project work well, it would be beneficial to have a reduction in classroom hours.
Teacher C
Teacher C explained that the most complicated aspect is scheduling appointments with the students, which always ends up being last minute. There were some organizational issues, especially with the newly involved teachers.
Teacher D
According to teacher D, one very delicate aspect is that, with a lab of this nature, it’s impossible to predict students’ feedback, which is always unpredictable. He emphasized that it is impossible to know what questions they'll ask or the ideas and reasoning they'll propose. The teacher must manage their responses in the moment, deciding how much weight to give to their insights, what he can support, and how to proceed with the lesson. According to teacher D, this is something one can't plan for, it's always a risk, but it's also fun.
Teacher E
According to Teacher E, the difficulty lies in stepping into an unknown continent. Until now, He only knew a little about AI from reading articles here and there. Teacher E explained how he prepared himself for delivering his lecture: he had limited time, so he read works by philosophers who had addressed AI, such as Searle and Ferraris. Then he read "The Ethics of Artificial Intelligence" by an Italian philosopher, Luciano Floridi, who teaches at Oxford. He also read some interesting texts by an American sociologist who had a critical perspective on AI due to its ethical implications. Additionally, he read texts from non-philosophical, more scientific backgrounds and sought recommendations for journals and articles to understand the field he was entering. He, finally, emphasized that through this preparation, he realized the importance of interdisciplinarity and enjoyed exploring texts from different domains. He would like to delve deeper into a topic that has always fascinated him: how consciousness arises from the neural structures of our brain. This is clearly an interdisciplinary research area. He explained that, first he needs to study and gather more information, but then he would like to bring these new insights when discussing modern philosophy and the mind-body relationship in Descartes and Spinoza. He believe it would make the approach to these philosophers less boring and more contemporary, both for him and the students.

Question 7: How were the relationships with the other professors involved? How did you support each other? (Question posed to Teachers A, B, C, D and E)

Teacher A
Teacher A explained they supported each other, in the sense that when one of them felt a bit demoralized, maybe due to the effort and students' reactions, the others provided support, and vice

versa. Teacher A explained that they organized themselves based on their competencies, as well as their tastes and interests, trying to leave the choice of the topic for each person to delve into. He focused more on the theme of complexity, Teacher C handled the technical part and Teacher B focused on the ethical and social aspects.
Teacher B
Teacher B emphasized that it was important for him to know that he could rely on others, so it was not obligatory for him to know everything. This reassured him over time. He focused more on his interests, particularly the conceptual and ethical dimension. He delved into those parts through books, articles, and readings due to his genuine interest, believing he could contribute meaningfully from that vantage point. As for the technical programming facet, he endeavored to grasp its essence and expressed an aspiration to delve even further into this aspect. In essence, a distribution of responsibilities was established among them.
Teacher C
Teacher C explained that he and his colleagues (Teacher A and B) are able to complement each other, so if something is missing for someone, they discuss it, and there's always a significant conversational phase behind the presentation that takes place in the classroom. The teacher explicitly states that even before starting a new cycle of lessons, the teachers question and discuss to understand if there was something wrong the previous time.
Teacher D
According to teacher D, they supported each other mainly in terms of materials (exchanging books and using a chat to share articles), but there weren't any specific meetings except for informal encounters, quick chats in the hallway, or having coffee together, but nothing systematic.
Teacher E
Teacher E explained that he got along very well with his colleagues and that they were very welcoming. He had frequent discussions with Teacher D, trying to organize the lessons as best as possible through material and information exchanges. Unfortunately, he was able to meet with the other teachers a bit less. He believed, and he also discussed this with another philosophy colleague, that collaboration between the physics and philosophy departments should be intensified. The philosophers can learn a lot from physics, but physicists can also find new approaches to the subject matter, less mechanical and more reflective and self-reflective. He claimed that he is very happy because he has only been at this school for two years, but he has been involved professionally and personally, which is a beautiful thing. According to him, there is always room for improvement, but this is already a good start.

Question 8: What advice would you give to colleagues from other schools who want to start offering courses of this kind? (Question posed to Teachers A, B and C)

Teacher A
According to teacher A, for the co-planning phase teachers need to have a clear idea of what they want to convey, what kind of course they want to offer, and therefore, they must share a way of

looking at and thinking about education, as well as the competencies they want the students to have. Co-teaching is something that they can learn on the field, facing difficulties and psychological barriers. They must overcome distrust and feel comfortable, which can vary from person to person. They need to be willing to take risks, not be afraid of judgment, and, of course, be competent. All of this is not easy.
Teacher B
According to Teacher B, thinking about how they experienced it, an initial phase of building the course is necessary, where the teachers delve into the theme from a content perspective. Once they identify the thread they want to follow, they can delve into the specific activities to create. The structure of the I SEE modules can serve as inspiration. Naturally, it's important to be able to work with people who share the same work philosophy and can distribute tasks so that there is a sense of tranquility and comfort when putting oneself out there.
Teacher C
According to Teacher C, first of all, teachers must choose a theme to address. Then, they must start co-planning, realizing that it requires dedicating time, ideas, and resources. The most challenging part is asking teachers for additional time on top of what they are already doing, but, if this course is a priority to them, it can be both challenging and enjoyable.

Question 9: How did you perceive the response of the students to the course and atelier? (Question posed to Teachers A, B, C; Teacher D has already answered during the questions before)

Teacher A
Regarding the course on AI, Teacher A claimed that he and the other co-teachers tried to observe the students to understand why some of them participated less. According to him, teacher B also tried to involve the students from his class who participated in the course on AI by asking them to present the project to the rest of the class. Regarding the AI Atelier, for Teacher A it was well-received. Of course, there were students who experienced it with greater awareness and those with less. Teacher A was particularly impressed by the student who worked on the music project, despite his decision to leave Liceo Einstein next year, as well as the students who worked on the imitation game and the students who worked on the comments. Teacher A claimed that he would like to interview them to understand their motivations and the impact the atelier had on them. The student who left Liceo Einstein conveyed to Teacher A that he has always been creative and that with this music project, for the first time, people were interested in his knowledge, asking him many questions about his work and design. According to teacher A, on one hand, the school did not know how to give him space and value his talents, and on the other hand, it was unable to incorporate him into a broader knowledge.
Teacher B
Regarding the course on AI, Teacher B claimed that, in general, students have shown in various editions that they appreciate the part of the course focused on future activities, where they can challenge themselves, discuss, and reason among peers, although, over the years, he has recognized their difficulty in staying anchored to the present and not being able to detach

themselves. This year, Teacher B was surprised by the fact that many students chose the rural scenario compared to past editions. Regarding the AI Atelier, the more creative part, where the students must take risks, has created some difficulties because perhaps they are asked to do something they are not used to. Teacher B stated that even for him, it is challenging to be creative in a short period and come up with new ideas. According to teacher B, in general the students are so immersed in technology that they don't realize what it truly means. Even the students in the atelier who didn't participate in the course on AI could be seen lacking an understanding of the revolution brought by machine learning.
Teacher C
Teacher C, talking about the students that attended the course on AI, stated that he found them a bit less responsive compared to previous years, where they had a higher level of participation and active involvement. It's an attitude he noticed in his classes as well, and it has also been observed by other colleagues. So perhaps it's a more generalized trend rather than specific to the PCTO course on AI. According to him, maybe it would have been better to focus less on technical issues or address them in a slightly less detailed manner (such as the difference between symbolic and sub-symbolic) and engage them more in activities to encourage participation and dialogue. In short, there was a lack of communication from their side.

5.1.2 The Individuation of the Main Themes

Starting from the interviews' data synthesized in the previous paragraph, the main **themes** characterizing the three investigated areas of the first research question were extrapolated. They are reported in Table 5.1 alongside the area they are referred to.

Table 5.1: Main themes extrapolated through the bottom-up thematic analysis.

AREAS	THEMES
area 1: Evolution of the AI module	• the need to introduce the topic of AI in schools • the relevance of the I SEE backbone structure of the AI module • the changes in the AI module regarding both aspects of the structure and the content
area 2: Implementation of co-planning and co-teaching in an interdisciplinary approach	• the importance of an interdisciplinary approach to teach the topic of AI • the benefits in implementing co-planning and co-teaching methodologies • necessity of "feeling" and a relationship of trust among co-teachers • phases of co-planning and co-teaching

	● challenges of the methodologies
area 3: students' reactions	● students' preparation ● students' participation and engagement ● students' perceptions on the topic of AI

5.1.3 Data Analysis

The identified themes were characterized by revisiting the original interview transcriptions, notes, and the AI Atelier presentation document. In this way, the sub-themes that characterize the themes were better identified. The following sections will present the conducted analysis.

AREA 1 - EVOLUTION OF THE AI MODULE

As regards the evolution of the course on artificial intelligence from the original I SEE module to the present until the introduction of the AI Atelier (area 1), the teachers highlighted some aspects that suggest the role that the school should have in contemporary society.

As stressed in the AI Atelier official document as well as in teachers' interviews, it is relevant to introduce the topic of artificial intelligence in schools since today young people are digital natives, namely they are so immersed in the digital world shaped by ICT (Information and Communication Technologies) that they may not even realize it. They may not fully understand not only the benefits but also the associated risks. In this regard, the opening quote of the AI Atelier document is significant:

"There are two fish swimming, and at some point, they meet an old fish swimming in the opposite direction. The old fish nods and says, 'Hey, boys. How's the water?' The two young fish swim on for a bit, and then one looks at the other and says, 'What the hell is water?'" (David Foster Wallace, from the commencement speech given at Kenyon College, Gambier, Ohio, May 21, 2005)

The aim of both the AI course and the AI Atelier, an aim that for these teachers should be pursued by the schools, is to make students capable of "reading the world" they live in and develop critical thinking and skills that can help them better engage with contemporary society, so as not to remain "simple AI users".

The three teachers that developed the AI course emphasize that the structure of the course remained almost the same because they have not changed their stance regarding the relevance and meaning of the course, even though the topics of the activities changed to take the pace of the rapid changes in society ("Society of Acceleration").
The common aspects among the different implementations were particularly emphasized by teacher B.

'In my opinion, the structure of the module has remained fairly unchanged. There was an initial overview of the topic, followed by a central and technical part related to programming, and finally, the last part focused on the future. However, there have been some changes… [...].
In my opinion, these milestones represented by complexity and the theme of uncertainty and the future can be incorporated, regardless of the topic we decide to address. Therefore, the structure of the I SEE module can also serve as inspiration, where there is an initial overview and a part where

the students work from a more technical rather than experimental point of view, and then this part oriented towards the future.' (Teacher B)

The teacher stresses that they continue to follow the structure of the module developed during the I SEE project, which includes:

1. An initial overview of the topic;
2. A technical part related to programming approaches;
3. A final part composed of future-oriented activities.

This structure is an effective backbone, but the course on AI has to be updated:

- in the structure itself, which can be expanded with workshops, as seen in the example of the AI atelier, involving professors from other disciplines. This concept is emphasized by the words of Teachers B and A:

  "This discourse on intelligences and art was also present in previous editions because even in the very first module, we explored intelligence and art, including references to music… However, I would say that this year it has truly taken off with the possibility of using these algorithms (the generative algorithms), which has been made available to everyone. This has brought up the issue even more prominently. So, we were interested in trying to interpret this question, looking at it from both the perspective of art and our contemplation of human-machine interaction." (Teacher B)

  "It has indeed become a laboratory of thought… As a result, there was an intervention, which had not been planned initially, by the philosophy teacher regarding what it means to think." (Teacher A).

- in the content of the course, which needs to be modified based on new studies and applications of artificial intelligence in the "Society of Acceleration" and on how students' perception and knowledge about the subject change (today's students are defined as 'digital natives,' and their perception of artificial intelligence is very different from that of students a few years ago). About this Teacher C argued:

  "The course has evolved because society has evolved rapidly; even as citizens, we have noticed the spread of artificial intelligence. In the early years when we conducted this course, we had to initially provide students with handouts or materials to get them engaged with the topic. Now, this effort is no longer necessary as their lives are already permeated by these artificial intelligences." (Teacher C)

From the analysis, the main changes that teachers made , in comparison with the first edition of the course held in 2018, are:

a) The introductory activity that aimed to open the students' imagination regarding the topic of artificial intelligence has been removed. This is because it was realized that, even in just a few years, artificial intelligence was no longer something new. On the contrary, the students were already completely immersed in it.
b) Greater importance has been given to the opportunities but especially the risks of artificial intelligence, dedicating a specific lesson to it.
c) The scenarios of the city of Ada have changed as a consequence of the rapid evolution of society. In particular, the hyper-technological scenario has been modified to be even more

advanced, further reducing the gap between humans and machines, while the intermediate and rural scenarios remained largely unchanged.

d) The AI Atelier has been introduced. Initially, it was intended to replicate the previous experience of the Quantum Atelier and to further reflect on the relationship between artificial intelligence and creativity. However, in the organization and implementation by Teacher D, it has taken on a deeper significance regarding the human-machine relationship and the meaning of human thinking leading to the involvement of Teacher E to obtain a philosophical perspective.

In Figure 5.1, the results just mentioned are schematized:

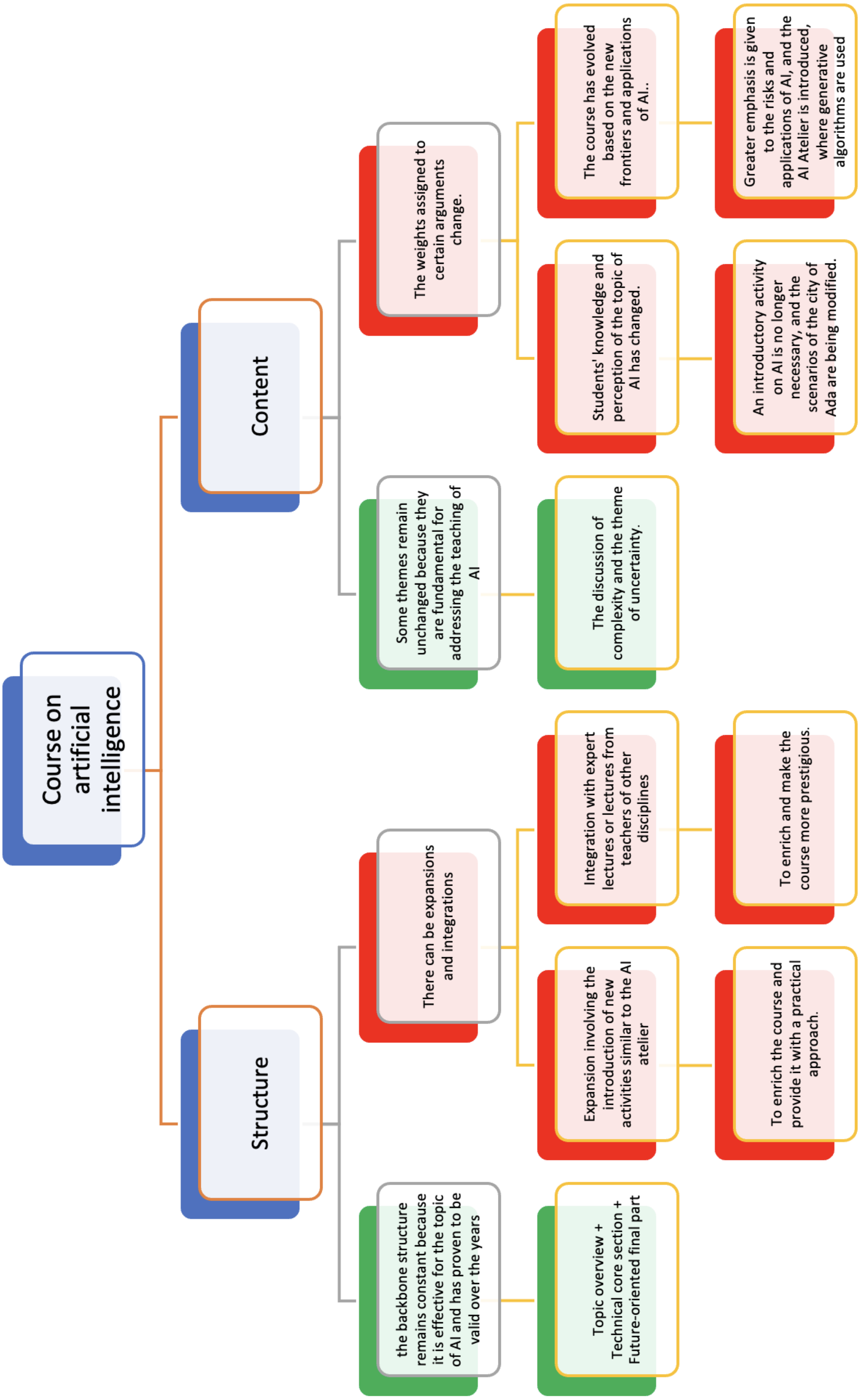


Figure 5.1: The graph displays the content and structure of the course. In green, aspects that have remained unchanged across different editions are shown, while in red, aspects that have changed are indicated, along with the reasons.

AREA 2 - IMPLEMENTATION OF AN INTERDISCIPLINARY APPROACH THROUGH CO-PLANNING AND CO-TEACHING METHODOLOGIES

As regards the implementation of co-planning and co-teaching in an interdisciplinary approach (area 2), the teachers stressed the importance of an interdisciplinary approach to teaching the topic of AI since it does not belong to any specific discipline. The topic of AI has been addressed from artistic, philosophical, and scientific perspectives, with each teacher contributing based on their expertise. This was particularly stressed by Teacher D:

“The subject was approached from multiple perspectives, artistic, humanistic, philosophical, scientific…, then it was discussed, each person contributed from their own perspective and expertise... In this experience, I felt that it was something real (interdisciplinarity), there was a true exchange.” (Teacher D)

Among the main **benefits** of choosing an interdisciplinary approach and its implementation through co-planning and co-teaching methodologies, one is that each teacher does not feel obligated to know everything, but rather shares the responsibility of teaching a new topic, such as AI, with other colleagues, as stressed by teacher B:

“It was very important to know, however, that you can also rely on other people, so it's not obligatory to know everything. This reassured me quite a bit over time, so I approached this topic aware of my limitations and abilities. At the beginning, I was quite frightened because it seemed like a tough subject and one for which I needed to know something, even at the level of programming. In reality, I believe that within the working group, there can be the more technical aspects, for example, in my case, I followed my interests, so more of a conceptual reflection, focusing on various dimensions—ethical, social, rather than just the technical aspects…However, we divided the responsibilities.” (Teacher B)

Another benefit is certainly that students, by seeing the same topic approached from different perspectives, can grasp the "unity of knowledge", as highlighted by Teacher E:

“I've seen this particularly in this experience, that co-teaching is crucial both for the students, who in some way approach the discipline from unusual directions and perspectives, and on the other hand, it serves them, in some way, in the experience I've had, to grasp the unity of knowledge.” (Teacher E)

Furthermore, the implementation of these methodologies has also the benefit of opening teachers’ minds since it can “enrich” their teaching in their traditional lessons, as stressed by Teacher E.

"Opening one's mind to different experiences and adopting a different approach to one's discipline has personally given me a lot. I had never dealt with artificial intelligence before, and now I have started reading and delving into it, which enriches my teaching. In the sense that when I explain modern philosophy, artificial intelligence is already there as a perspective, and this is an enrichment I have discovered." (Teacher E)

All the teachers emphasized the importance and necessity of ***"feeling"*** and a relationship of trust among all the teachers participating in the project. To work well together, there needs to be a good personal, professional, and friendly relationship, as stressed by Teacher E.

"A genuine connection among teachers, not just in terms of friendship, but a free sharing of interests and perspectives. If there is no capacity for sharing, it is difficult to carry out these projects." (Teacher E)

Furthermore, as Teachers B argued, to effectively collaborate it is also very important to share the same work philosophy. In Teachers B words:

"Certainly, based on my experience, the ability to work with individuals who share the same work philosophy and to distribute tasks in a way that promotes a sense of calmness has been essential. It allows one to engage and take risks, while also operating in a comfortable environment." (Teacher B)

From teachers' answers, we identified some phases that the teachers follow for the **co-planning** of the course:

1) ***Exploring the topic*** with the aim of understanding the kind of contribution that each teacher can give;
2) ***Involving experts*** outside the school context, namely outsourcing some activities and lectures to give the possibility to students to hear different voices and approaches.
3) Since the STEAM (Science, Technology, Engineering, Arts and Mathematics) topic, it is possible to integrate SSH (Social Sciences and Humanities) disciplines by ***involving other colleagues***, like the literature and art teachers. This led to the development of the AI Atelier about the interdisciplinarity between art and science**,** with the aim of widening students' perspectives about AI and its implications. In particular, given the scope of the theme and how is questioning the nature of man today and its relationship with technology, the teachers decided to involve the teacher of philosophy, as emphasized by Teacher D.

   "I realized that these projects touch on fundamental questions such as 'what does it mean to think?' 'what is nature?' 'what is reality?' So, I considered it important to involve the philosophy teacher, asking for his confirmation on certain ideas of mine to ensure they were not incorrect or out of place." (Teacher D)

More operationally, from the analysis the following sub-themes emerged as pivotal in the organization of the course and collaboration among the involved colleagues:

- ***Individual preparation*** with reading of texts and articles on the topic.
- ***Support and collaboration among teachers***: All the teachers confirmed that they worked well together and supported each other. This includes the exchange of materials (books and articles shared even through chat), as well as the sharing of information based on each person's specific expertise. The teachers also highlight the psychological and emotional support they provided in moments of demoralization, which may be related to the challenges of the work.
- ***Division of roles***: The teachers state that they organized themselves based on their skills, preferences, and interests. However, they emphasize the need for each person to have a clear role, both in terms of organization (a coordinator, someone in contact with the university, and someone managing administrative tasks) and in terms of content (each teacher delves into a specific aspect of interest, such as technical aspects, complexity, ethics, artistic aspects). The importance of assistance from technical staff is emphasized. This is particularly stressed by Teacher B:

"So, Teacher A's presence is crucial for coordination. Also, because she keeps track of the work and is part of the university research group, so from a certain point onwards, she's very much the intermediary. She keeps an eye on what's happening in Bologna and what's happening at the school. The fact that she has "more time" because she doesn't have classes allows her to manage the work effectively. I handle quite a bit of the administrative side because I'm comfortable with it... We rely on Teacher C for the more technical part, programming,.. Then, concerning the technical aspect, we also have two technicians who help us if needed, and that's also very important. Knowing that we can rely on the technical assistants, there's a friendly rapport there as well." (Teacher B)

➢ ***Balance among teachers***: No one should be underestimated, and each person should have an equally important and relevant role compared to others. This concept is particularly emphasized by Teacher D.

  "I was already convinced that I would go there and they would ask me to be the decorator because in these relationships between art and science, there is always this notion that humanities play a decorative or superficial role in science. Since I dislike that, and I'm always a bit skeptical, I made it clear from the beginning." (Teacher D)

As regards the **co-teaching**, from the analysis we have individuated the following sub-themes:

1) ***Collaboration, balance, and respect*** are some key values that characterize co-teaching and the space of "co-teaching", intended as the atmosphere that is established in the classroom. Unlike co-planning, co-teaching is learned on the field, based on one's experience, as is particularly stressed by teacher A. It is important to evaluate it based on students' feedback and to have discussions with colleagues after the lessons and activities.

   "Co-teaching implements different aspects, for example, one must be attentive to balances, not only in terms of knowledge but also psychologically and in terms of participation. Other factors come into play that are quite delicate because in co-teaching, it's important to be cautious about not stepping on each other's toes, giving the right amount of space, and trusting what the other person is doing; Co-design is done somewhat on paper, and co-teaching is done in the field." (Teacher A)

2) As highlighted in my notes, I noticed a great level of participation, collaboration, and ***complicity*** among the teachers, especially between Teachers A, B, and C, who have been collaborating together for years. When one teacher gave a lesson on the agreed-upon topic, the colleagues were attentive and ready to intervene with probing questions to the students or making connections. This sub-theme is also emphasized by Teacher B during the interview:

   "*Regarding AI, with these past experiences of collaboration, it was quite easy, as I mentioned before. In the sense that we were quite experienced as a group and we often relied on Teacher A's expertise. However, we were very much in tune with each other. So, on some occasions, it seemed to me that when Teacher A or Teacher C spoke, they were saying the things I would have said at that moment. We knew where to focus our attention, especially when there was a student's input or a concept we wanted to emphasize. We already knew which concepts interested us, and if there was an aspect that one of us missed at that moment, another would bring it up. It seems to me that we worked in this way. Later, when there are other colleagues, this process needs to be gradually built." (Teacher B)*

In general, the teachers argued that the implementation of the co-planning and co-teaching methodologies is **challenging**. Difficulties are highlighted, especially due to the limited time and the professional commitments of the teachers, as well as the students' own commitments. Concerns are also expressed about tackling new topics and not knowing the possible feedback from the students. Teachers B and C emphasized the issue of the lack of time:

"In my opinion, in order to handle a portion of the design work well, there should be a reduction in the classroom workload. I particularly cared about it this year, and the principal granted my request." (Teacher B)

"The most difficult thing is to ask for extra time beyond the work you already do, because if you don't consider that, you won't accomplish anything." (Teacher C)

In Figure 5.2, I present the main results obtained.

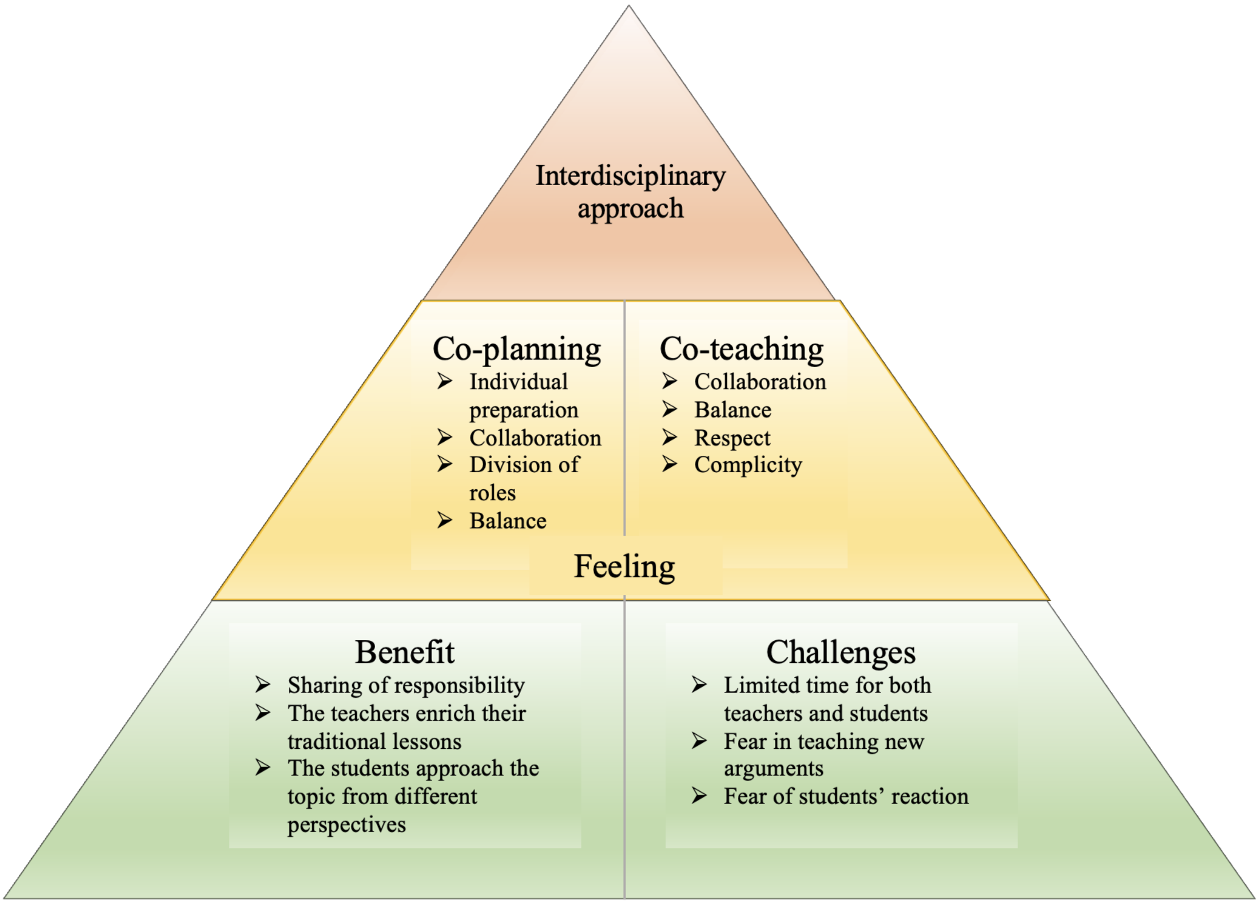


Figure 5.2:In this figure, the necessary conditions for co-planning and co-teaching are depicted, along with the benefits and challenges of these methodologies.

AREA 3 - STUDENTS' REACTIONS

From the third area analyzed, three themes emerge concerning the type of reaction from students that the teachers highlighted in the interviews. These themes are:

- ***Student preparation***: The teachers highlighted that students participating in the AI Atelier lacked the basic preparation provided by the AI course, which would have been useful for approaching the atelier's activities with greater awareness. Therefore, they suggest that in the future, the students of the course and those of the subsequent atelier should be the same.

- ***Student participation and engagement***: According to most teachers, students of the AI course have shown appreciation for the activities related to the town of Ada, where they could engage and reflect on their opinions, choices, as well as their doubts and fears about the future. Regarding the AI Atelier, some teachers have noticed that students faced some difficulties, probably because they were asked to do something they were not accustomed to, like highlighted by Teacher B.

  "Even the more creative part where they challenge themselves, this has generally created a bit of difficulty because perhaps they are asked to do something they are not accustomed to working on. For example, for me as well, it's difficult in terms of approach and attitude to be creative in a short amount of time and come up with new ideas." (Teacher B)

  In relation to the Atelier, some students seemed more engaged than others. However, during the final exhibition, most of them demonstrated a good understanding of the concepts by managing discussions and questions with a good level of awareness. The teachers were particularly impressed by the reactions of a student who, despite having left the Liceo Einstein, still wanted to participate in the AI Atelier. He created a very interesting project on music (see Section 3.3.2, "Ancestral Groove"). He expressed to teacher A that this project made him feel appreciated and valued by people, something that the school had not managed to do, in teacher A's words:

  "I told him that I want to talk to him, to interview him because I'm curious to know and understand. He mentioned that he really enjoyed it, that it was a very pleasant experience for him, and that finally people were interested in his knowledge. That is, how he put together this musical work he presented there. So, for him, it was a very significant educational moment." (Teacher A)

- ***Student perception on the topic of AI***: Some teachers were surprised by the fact that this year, compared to previous editions, many students chose the "rural" scenario in the activities related to the city of Ada, namely a scenario in which nature takes back its space and the technologies are almost absent. A probable explanation for this is an increased perception that a hyper-technological world also entails negative aspects. In Teacher B words:

  "We were surprised this year by the fact that many students chose the rural scenario. This is a notable difference compared to previous editions, where the rural scenario was chosen by one or two students in the class. This year, many of them have chosen it, and this highlights the need for relationships, the need not to be constantly under the influence of technology, and the feeling of being isolated with only virtual connections. They all perceive it as a burden, so it seems that their preferred future scenario is one with a less overwhelming presence of technology. This is surprising because the hyper-technological scenario scares them a lot, especially now with these generative systems, as we are facing yet another new revolution." (Teacher B)

  As highlighted in my notes taken during my participation in the AI course, the students, in their contributions, have justified their choice of the rural scenario by emphasizing the importance they place on interpersonal relationships, sharing, a sense of community, and their connection with nature. In the hyper-technological scenario, the almost symbiotic relationship between humans and machines is emphasized, which raises concerns about a loss of autonomy and independence from machines, leading to a situation of no return that is frightening.

The main themes found during the analysis are schematized in Figure 5.3.

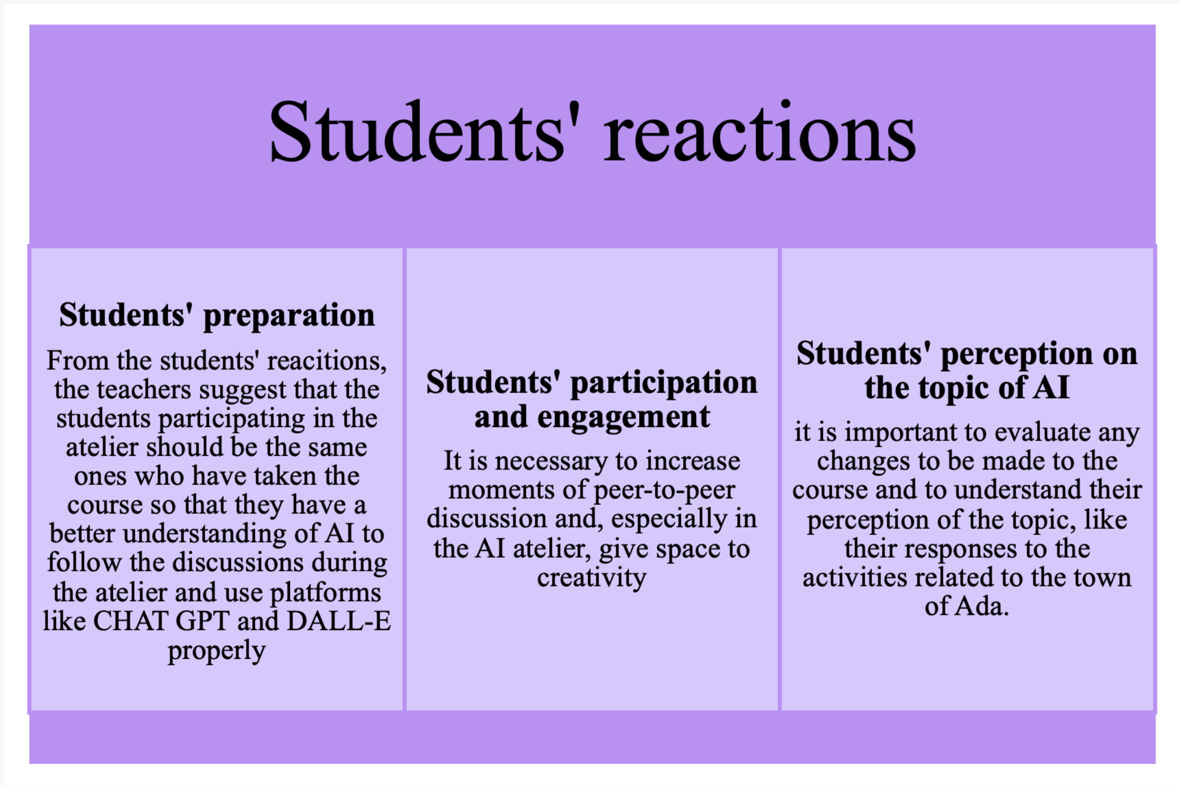


Figure 5.3: in this figure, the three main themes that emerged by evaluating the students' reactions are presented.

5.1.4 Comparison with the Literature

In literature, co-planning and co-teaching are mainly used in special education, specifically between general education and special education teachers, as we have seen in the papers of Cook and Friend (1995) and Alsarawi et al. (2019). The use of co-teaching to address interdisciplinary themes is less studied and mainly focuses on the field of higher education (Morelock et al., 2017). An example of interdisciplinary co-teaching at the university level is, however, provided by Maranzano's thesis (2022) that analysed the co-planning and co-teaching methodologies implemented by three different professors (one of physics education, one of geometry, and one of philosophy and theories of languages) for a module on the paradoxes of the space-time from the three different perspectives. At the secondary school level, we found the use of interdisciplinary co-teaching in the works of Harkki et al. (2021) and Aarnio et al. (2021); both studies were conducted following a reform introduced in 2014 by the Finnish National Core Curriculum for Basic Education (NCCBE) to meet the needs of the future. Similarly, the research work of the present thesis aims to provide an example of how co-planning and co-teaching can be implemented at the secondary school level. In particular, these methodologies were used to design and develop an interdisciplinary approach to introduce a STEAM topic that is not yet included in the school curriculum and does not belong to any specific subject.

From the comparison with the research literature in the field of special education, our study confirms:

- The need for a mutual trust relationship between co-teachers, as emphasized by Cook and Friend (1995)
- The major difficulties faced by co-teachers, especially in the co-planning phase, regarding finding the time and managing the workload alongside traditional duties, as reported by Alsarawi et al. (2019).

However, this study differs from the articles found in the field of special education in the following points:

- The **equal importance of co-teachers** in this study: in the application of co-planning and co-teaching within an interdisciplinary approach, all teachers have equal importance and responsibility as each of them brings a different perspective on the same subject. This parity of roles is lost in the context of special education, even though both teachers (the support teacher and the general teacher), as emphasized by Cook and Friend (1995), actively participate in the course implementation they do not have an equal status, especially in the first four models of co-teaching. The closest arrangement to the level of parity achieved by the teachers in Cook and Friend's study is 'team teaching,' where teachers have a higher level of collaboration.
- The ***benefit*** of approaching a topic in an interdisciplinary manner. This added value materializes in enrichment for teachers concerning their own knowledge and the teaching of their discipline, and for students who can grasp the unity of knowledge and have a comprehensive view of the subject they are addressing.

The study by Maranzano (2022) concerning an experience of interdisciplinary co-planning and co-teaching at the university level certainly takes place in a very different context from that of a secondary school; nevertheless, it highlights an aspect that brings together that university experience with our study, namely the necessity for each discipline to have its own purpose and its specific position within the project.

From the comparison with the research article of Aarnio et al. (2021) and Harkki et al. (2021), concerning the use of co-planning and co-teaching in an interdisciplinary approach, emerged that:

- The theme of the **"*benefit*"** is also addressed by Harkki et al. (2021), when they talk about the *teachers' professional development*, although it only considers the development of teachers and not an enrichment for students as well.
- This study confirms the support required between co-teachers, as categorized by Aarnio et al. (2021):
    a) Emotional support
    b) Instrumental support
    c) Informational support

In general, what is lacking in the analyzed papers is a focus on the **students' reaction**. In this study, we noticed a lot of attention from the teachers to students' feedback, trying to see the challenges of this year as opportunities for improvement in the coming years. This feedback is crucial as it determines the success of the course and suggests the modifications and refinements of the course's structure and/or content for future implementations.

Indeed, a possible expansion of this study could include **interviews with students**, in order to get their point of view and their thoughts about the course in which they participated and their ideas about multi-voice activities and seminars.

5.2 Addressing RQ2

5.2.1 Data Synthesis

In this section, the synthesized responses to the questions related to RQ2 are presented, organized per question, to point out the main themes that characterize teachers' answers.

Question 10: Did the school administration provide support? If yes, in what ways? (Question posed to teachers A,B, and C)

Teacher A
Teacher A claimed that the school administration supported the teachers by giving them the approval to conduct the course on AI and the AI Atelier. However, according to Teacher A, the more challenging question is: "What should a school administrator do to ensure that these things are more widely shared and become more structured?" The answer to this question is very difficult and depends a lot on the school principal, their ideas, personality, and willingness to impose certain things or give free rein. Some principals have a clear vision of the school and tend to select projects based on that vision, while others give free rein to everyone's ideas.
Teacher B
Teacher B stated that they felt supported in terms of sharing and closeness. However, according to Teacher B, what is lacking is the opportunity to bring people together. It is important for the school to make it clear that it wants to take a clear direction and promote, in a practical way, even just one or two projects.
Teacher C
Teacher C claimed that the school management supported them by granting what they asked for and that it was very flexible and understanding.

Question 11: What role has the University of Bologna played? How has it evolved over the years? (Question posed to Teachers A, B, and C)

Teacher A
Teacher A argued that the relationship with the University of Bologna has changed in the sense that the course on AI has become more autonomous. Teacher A stated that, even for Eleonora Barelli's lecture, he and teachers B and C could have prepared the material themselves, but they wanted to bring in a voice from the university. The university definitely provided initial guidelines, but now they are quite independent. According to teacher A, this is a great

achievement and means that the university has done what it was supposed to do: providing the teachers the tools to carry out the course on their own.
Teacher B
Teacher B stated that it was initially a great difficulty for him to address the AI topic, as it seemed unthinkable to conduct the course on AI without external experts from the University of Bologna. However, gradually, he claimed that he gained a sense of ownership over the content and became more confident. Important factors were dividing tasks, being able to work well together, and sharing the philosophy. They had the slides and the material, which made them feel more confident in reflecting on artificial intelligence based on the work done. According to teacher B, they wanted to maintain the relationship with the University of Bologna because it was important for the students to have an external reference involved in research. Speaking about the other experts who participated in the course on AI, Teacher B explained that when he contacted Professor Vespignani, they involved other colleagues teaching in other cities: a teacher from Padua and a teacher from Monfalcone. Teacher B explained that he knew the colleague from Padua who connected him with the colleague from Monfalcone. From this discussion emerged that there is now a national network of high schools focused on data science with the professor from Monfalcone as its promoter. Additionally, Professor Vespignani held a meeting for teachers as part of a training course of this network, which was attended by several schools, including teacher B. After we asked for more details about this new "network", Teacher B explained that the idea of creating a national network among schools started with a colleague from Monfalcone, in collaboration with the school principal, during the pandemic years and has gradually been structured. From next year, several high schools will participate, although Liceo Einstein has not joined the network yet.
Teacher C
Teacher C explained that the project was born within the University of Bologna, which has always been a reference point. He claimed that he and his colleagues (Teachers A and B) tried to become somewhat autonomous in certain phases to better adapt to the school reality but the exchange of ideas and the possibility of seeking guidance from Bologna during specific steps or for any doubts have not changed. According to Teacher C, from the second year onwards, he and his colleagues tried to become more independent, while still maintaining collaboration with Bologna.

Question 12: How would you comment on this edition of the course? If you were to do it again, what would you change or improve? (Question posed to Teachers A, B, C and D)

Teacher A
According to teacher A, it would have been better to keep the same students in the course and in the Atelier. But the atelier was proposed late, without properly considering the timing and the fact that students were already very busy at that point in the year. It was an evaluation error; the student should have attended the course on AI before participating in the atelier, because certain aspects, such as the transition from the symbolic to the sub-symbolic, needed to be explained beforehand to have a successful atelier.
Teacher B

Teacher B talking about the course on AI, stated that he liked the entire first and middle parts. Regarding the activity on Ada's city, he thinks it requires more time because it's an activity that involves students discussing and engaging with each other. Unfortunately, this year they didn't have many opportunities to let the students work on it. Talking about the AI Atelier, teacher B considered it an “experimentation”, so, according to him, it needs to be rethought. The moments in which the students can work and be creative need to be reconsidered because this year, due to the limited time, the students relied heavily on the teacher's suggestions, and the atelier became a highly guided activity. According to teacher B, first, the teachers need to refine their collaboration as teachers to understand how to bring out the students' ideas and how to encourage them. According to teacher B, it's important to understand what inputs and situations to create so that the students can understand the desired outcome (which wasn't very clear this year) and feel free to create.
Teacher C
According to teacher C, the students who attend the AI Atelier should be more “aware”, and it would be better if they were the same ones who took the course on AI. According to him, it needs improvement in terms of student engagement by proposing simpler activities so that they can interact and communicate more.
Teacher D
Teacher D claimed that they could better select the students by understanding who is truly motivated, for example, through an interview. However, this can only be done if there are many students interested and you can choose, or by discussing it with colleagues (clearly, if there are interested students, the work takes a different turn). Teacher D stated that he tried to improve the atelier by incorporating philosophical aspects because it completed the whole experience, and they can further open up to contributions from other disciplines (e.g., music and electronics).

Question 13: In your opinion, what is the best placement for these projects? Within the regular morning curriculum or as extracurricular activities in the afternoon?
(Question posed to Teachers A, B, C, D and E)

Teacher A
According to teacher A, interdisciplinary courses could be scheduled during the mandatory morning hours of civic education. According to him, there may be differences between the various types of school as regards the use of these hours and the possibility of proposing interdisciplinary modules that are already fairly structured. Probably in lyceums where the teachers are predominantly teachers of basic and non-professional subjects (history, art, philosophy, physics, Latin...) more coordination and mediation work is needed than in more professionalised technical institutes. Each teacher has his or her own cultural (in a broad sense, not only professional) and disciplinary vision (sometimes very disciplinary, sometimes more interdisciplinary) and each must mediate his or her vision with that of the others.
Teacher B

The discourse about the placement of these projects was brought up spontaneously by teacher B when we asked him about his intention to repeat the course and the atelier the next year. Teacher B claimed that he would like to rethink the whole discussion about artificial intelligence and see what kind of approach to give it and, if it's possible, to incorporate it into the morning hours where the teachers of the council can work on it. According to teacher B, currently, there is a huge proliferation of afternoon projects like PCTO, but this means that students choose these paths not out of genuine interest but to fulfill the required hours. From an organizational standpoint, managing an afternoon project is increasingly demanding because students are overwhelmed with work. From an educational standpoint, treating the topic of AI as a curricular subject would offer the opportunity to approach it from many different perspectives and gradually transform and expand it (as exemplified by the atelier) to fill the entire school year. According to Teacher B, the curricular spaces are limited, so either there needs to be a push from higher levels to change the curriculum or, at the moment, they can work within the hours of civic education. According to him, the principal would agree, and surely other colleagues would as well, but it is necessary to start rethinking and planning the project right away. Moreover, teacher B explained that an experience he had in collaboration with the philosophy teacher of his class was to have the students who attended the AI course present the contents they had covered to the rest of the class. Teacher B also wrote an essay topic on this subject for a simulated State exam. There have been created a series of moments in which the topic of AI was explored from different perspectives and for teacher B this is important because, in talking with some students who took the course, he felt that it remained just an experience that wasn't fully internalized. Therefore, if there is the opportunity to revisit the course and have the students speak and write about it, it would be better.
Teacher C
According to teacher C, an attempt has already been made this year to incorporate this project into civic education classes, involving all classes and all teachers. However, this project partially failed because only a few teachers participated in the meeting to discuss it, perhaps because it is demanding to grasp the topic of AI and carry it forward. Teacher C would also agree to incorporate these projects into the curriculum by utilizing the hours allocated for civic education. This would avoid the problems associated with offering these courses outside of regular curriculum hours. Schools are filled with commitments, and students have many projects. According to teacher C, certainly, it would be more convenient for teachers to continue with their usual unchanging lessons, but they need to be aware that society has become so complex that ignoring certain aspects and topics can be worrisome and dangerous. For teacher C, he would pursue both the path of curricular and extracurricular hours because he fears that proposing it solely within civic education may limit the depth of exploration that could be achieved in the afternoon with more motivated students.
Teacher D
Teacher D stated that he would really like these experiences to be integrated into the structure and schedule of the morning. He claimed that there is a lot of talk about educational innovation, and this seems like a serious proposal compared to many others, because, for him, it is a true cultural experience. However, according to teacher D, there are many difficulties; in particular, one doesn't get to choose his colleagues or the council class. According to teacher D, these projects would provide some breathing space for traditional schooling, and they could also be done in the morning with some afternoon sessions. According to teacher D, the problem of the afternoon is that there is a multitude of projects bombarding the school. The idea of this teacher would be, in his words, "few but good" calling for a selection of the many projects. According to him, it shouldn't be just a

"pay-to-participate" situation like it is in the PCTO activities, but rather a question of genuine interest.
Teacher E
According to teacher E, the teachers were thinking about it, and they also discussed it with the principal, including this interdisciplinary course on artificial intelligence within the scope of civic education hours. This way, the topic of artificial intelligence can be approached from different perspectives (e.g., philosophy and artificial intelligence, physics and artificial intelligence, computer science, and artificial intelligence). Moreover, it could be a good way to connect civic education hours and make them more consistent on an interdisciplinary topic. Of course, it is necessary to reach an agreement within the class council, which is not easy because different colleagues have different ideas. Some are interested in these activities, while others are not. According to him, theoretically, school management and schools, in general, are moving in this direction, even though there are differences among schools; some offer more interdisciplinary courses, while others need more encouragement, depending on the leadership, the liveliness of the teaching staff, and the willingness to get involved. Teacher E suggests that these projects have the potential to be executed both as part of the curriculum and outside regular classes. Implementing them as extracurricular activities might yield greater success, as they cater to individuals who display heightened interest and willingly opt to engage. Integrating them into the curriculum might require some adjustment in teaching methods, but it would certainly be more productive and effective for a greater number of students. The proposal for civic education, in fact, falls into the second category, and certain topics could be approached collaboratively. However, this doesn't mean that extracurricular in-depth programs with real workshops for more interested students couldn't also be implemented.

Question 14: What was the reaction of the teachers at Liceo Einstein who were not involved in the course and atelier? (Question posed to Teachers A, B, and C)

Teacher A
According to teacher A, within the school, the relationship between teachers is complex, and there are really many projects. Each teacher tends to advocate for and promote their own project, so when one announces the presentation of his work, the other instead of responding with enthusiasm tends to present his own project as well. According to teacher A when someone has put in a lot of effort, they want to highlight the importance of their own work.
Teacher B
According to teacher B, it obviously depends. He explained that he had collaborated with the philosophy colleague of his class because there was harmony and shared intent and work philosophy between them. Thinking about many other colleagues, Teacher B claimed that there is undoubtedly difficulty. For example, he had a meeting in December where he presented the module on artificial intelligence to the other colleagues, but participation was very limited. In this sense, according to teacher B, an intervention at the school management level is needed, where a shared vision is decided upon, and people are brought together.
Teacher C

Teacher C explained that he thinks that his colleagues perceive the course on AI simply as one of the many activities carried out at Einstein.

5.2.2 The Individuation of the Main Themes

Starting from the interviews' data synthesized in the previous paragraph, the main **themes** characterizing the two investigated areas of the second research question were extrapolated. They are reported in Table 5.2 alongside the area they are referred to.

Table 5.2: The main themes of RQ2

AREAS	THEMES
area 4: The relationships	● relationship with the University of Bologna ● relationship and collaboration with different high schools ● relationships with the school management ● figure of a coordinator between these agents
area 5: the school context	● constraints due to the school context ● proposal to enhance the placement of these projects within the school context

5.2.3 Data Analysis

The identified themes were characterized by revisiting the original interview transcriptions, the notes, and the AI Atelier presentation document. In this way, the sub-themes that characterize the themes were better identified. In the following sections, I will present the conducted analysis.

AREA 4 - RELATIONSHIPS

From the interviews, it emerged that the relationships that teachers undertake, during the planning and the delivery of the course on AI and the AI Atelier, mainly involve 3 entities and have these features:

1) **Relationship with the University of Bologna**: The project was born from the collaboration between the research group in physics education at the University of Bologna and the Liceo Einstein. The university certainly provided the guidelines and tools to develop the course, but gradually the high school became more autonomous and capable of organizing, and managing the course on its own, as well as making significant modifications, as stated by teacher A. However, the teachers highlighted the importance of maintaining collaboration with the university through interventions and masterclasses by experts. In addition to the

valuable intervention that experts provide, these interactions offer students a significant opportunity to connect with the world of research, as emphasized by teacher B. The role of a teacher who acts as a coordinator between the university and the school is also emphasized during the interview with Teacher B.

"The relationship with the University of Bologna has changed in the sense that the course has become more autonomous. Even for Eleonora's lecture, we could have had the material to do it ourselves, but we wanted to have a university voice, an expert's voice. The university certainly gave us a starting point by providing guidelines to follow, but now we are independent enough. This is a great achievement and it means that the university has done what it was supposed to do, giving us the tools to do it ourselves." (Teacher A)

"We wanted to keep the contributions from Eleonora and others because it seemed very important to us for the students to have an external reference, someone engaged in research, so this was definitely an added value." (Teacher B)

2) **The collaboration between different schools**. Teacher B stressed that different schools are working on AI themes and how it is increasingly important to establish new collaborations. A national network of high schools is now being created with the initiative of bringing AI into schools and providing teacher training courses.

3) **Relationship with school management**: All the teachers highlighted that the school management has supported and endorsed the initiative of AI course and AI Atelier. However, teacher B stressed that it is necessary for the school management to be more involved by facilitating meetings among teachers and providing clear direction on which courses to offer and which not. This is to avoid having an excessive number of courses that could diminish their importance and lead to scheduling conflicts, thereby creating difficulties for students who are already burdened with numerous commitments. These ideas are emphasized by the words of teachers B and D.

"We have to deal with the excessive number of projects that bombard the school; my idea would be 'few things but good ones,' we need to make a selection." (Teacher D)

"We feel supported in terms of sharing and closeness, in my opinion, what is missing is the opportunity for people to meet, because it's important for the school to convey that it wants to take a clear direction, rather than having teachers working on one project while others work on something else. The school should actively promote, in a practical manner, the work of even just a group of people." (Teacher B)

From the interviews, it emerged also the importance of a figure that can act as **coordinator** between the teachers and the other stakeholders. In this case, these roles are covered respectively by Teacher A as the coordinator between the teachers and the University, Teacher B as the coordinator between the teachers and the school management as well as between the Einstein school and the teachers of other schools of the national high school networks.

The relationship between the teachers and these entities is schematized in Figure 5.4

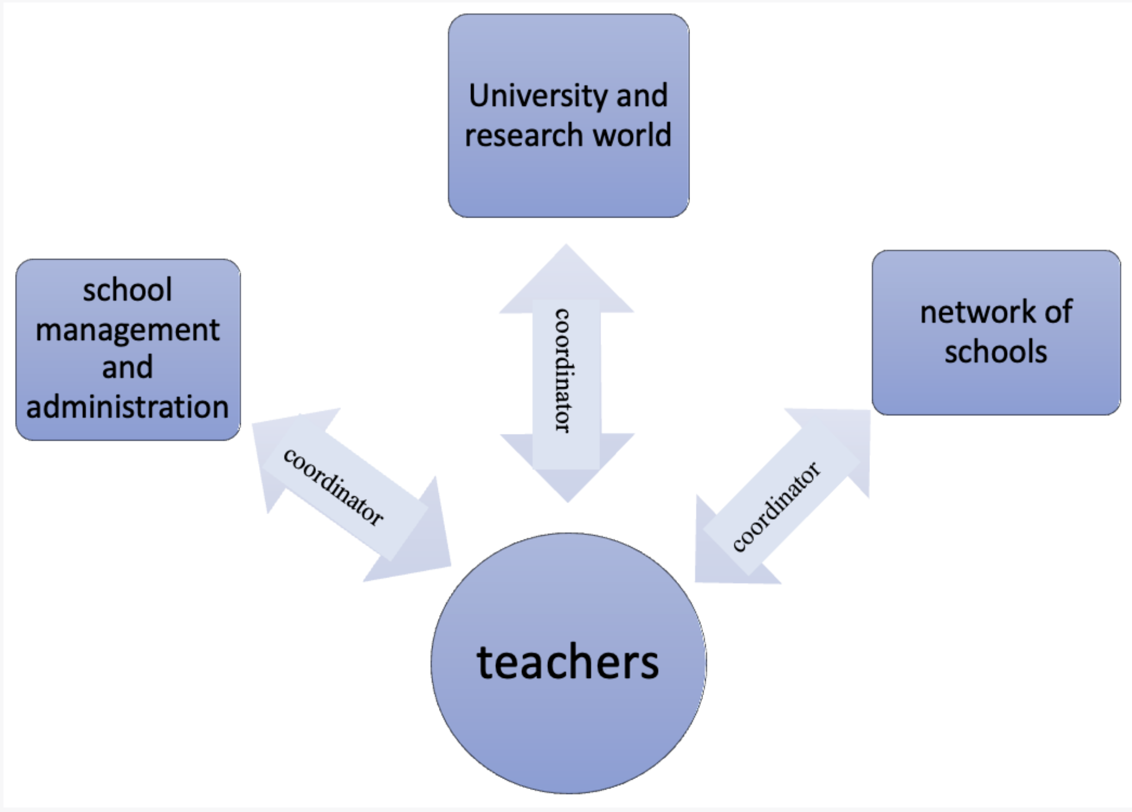


Figure 5.4: This diagram represents the relationships established between the teachers of the Liceo Einstein and the other agents, highlighting the figure of the coordinator.

AREA 5 - IMPROVEMENTS CONSIDERING THE SCHOOL CONTEXT

From the interviews, the teachers highlighted the importance of including the AI theme as a curricular topic. Nevertheless, the placement of these courses within the school reality encounters **constraints** structured on different levels, schematized in Fig. 5.5. These include

i. Constraints related to the **school as an institution** with its regulations, the legislative constraints governing it, and its rigidity (the outer level concerning in Figure 5.5).

ii. Constraints related to **school management**: Some principals are more innovative and open to changes, while others are more conservative. Some teachers advocate for 'active' support from the management, not limited to just giving approval for these courses but creating conditions for their implementation by providing the right spaces and time (the intermediate level in Figure 5.5).

iii. Constraints related to the resistance to change of more traditional **teachers** and the difficulties to involve them in promoting new initiatives (the inner level in Figure 5.5), as stressed by teachers A and B:

"In other words, there are the specialists who want to stay within their subject and provide that type of emphasis (because it's crucial for them to know Latin verbs because it's essential, etc.), and then there are those who have a more interdisciplinary cultural perspective." (Teacher A)

"Thinking about many other colleagues, there is an undeniable difficulty, so in practice, I don't know how this thing could be realized. We also had a meeting in December where we presented the module on AI and expanded it to both the department members and other teachers from the science department, for example, my colleague from philosophy participated, but the participation was very limited. It's challenging in this sense" (Teacher B)

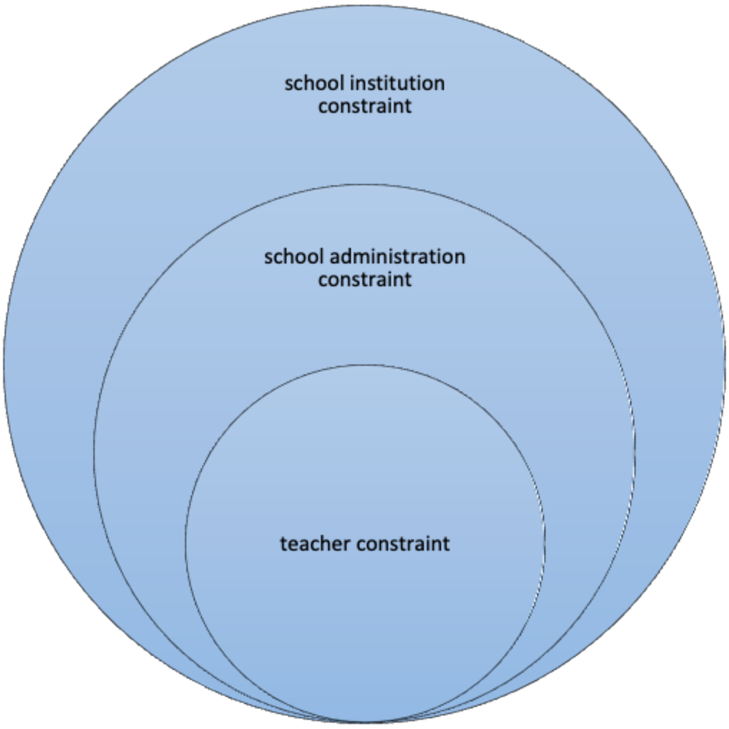


Figure 5.5: This figure represents the constraints in introducing these projects in the school context highlighted by the teachers of this study

Moreover, from the data analysis emerged the teachers' **proposal** of placing the course on artificial intelligence within the curricular schedule, as hours of civic education[21]. This proposal could solve some of the most problems shared by the teachers for the implementation of these courses, like:

- These courses would be extended to all students, perhaps with the possibility of further in-depth study sessions held in the afternoon for more interested students.
- It would make the management of civic education hours more consistent. Currently, as reported by the interviews, each teacher takes advantage of their allotted civic education hours to delve into topics related to their own discipline. With this proposal, civic education hours would be reserved for these current topics, in our case, artificial intelligence, which would be approached in an interdisciplinary manner as each teacher would develop the topic from the perspective of their discipline.

[21] The law of August 20, 2019, n. 92, stipulates that primary and secondary schools dedicate at least 33 hours per year to the teaching of "civic education," which may encompass three fundamental areas:
1. CONSTITUTION, law (both national and international), legality, and solidarity.
2. SUSTAINABLE DEVELOPMENT, environmental education, knowledge, and protection of heritage and territory.
3. DIGITAL CITIZENSHIP, understood as an individual's ability to consciously and responsibly utilize virtual communication means.
https://www.miur.gov.it/documents/20182/0/ALL.+Linee_guida_educazione_civica_dopoCSPI.pdf/8ed02589-e25e-1aed-1afb-291ce7cd119e?t=1592916355306

- An advantage would be that both students and teachers would have fewer extracurricular projects to manage and attend, which are increasingly challenging.
- Another important advantage would be that the topic of AI, covered during the morning school hours, would have greater significance, understood as the cognitive and educational importance of this subject.

The last two points are emphasized in the words of teacher B.

"From my point of view, managing an afternoon project is becoming increasingly challenging. This is from an organizational perspective, as the students are already burdened with work and are less receptive when it comes to dealing with it in the afternoon. Then there's a matter of significance, the actual cognitive and educational importance that this topic (AI) holds." (Teacher B)

It is also highlighted in this case the need for greater involvement of the school administration, which has to take a position and try to reach an agreement among the class and school councils on the need to include these topics in the school timetable.

A scheme to summarize all these points and to present this proposal is presented in Figure 5.6

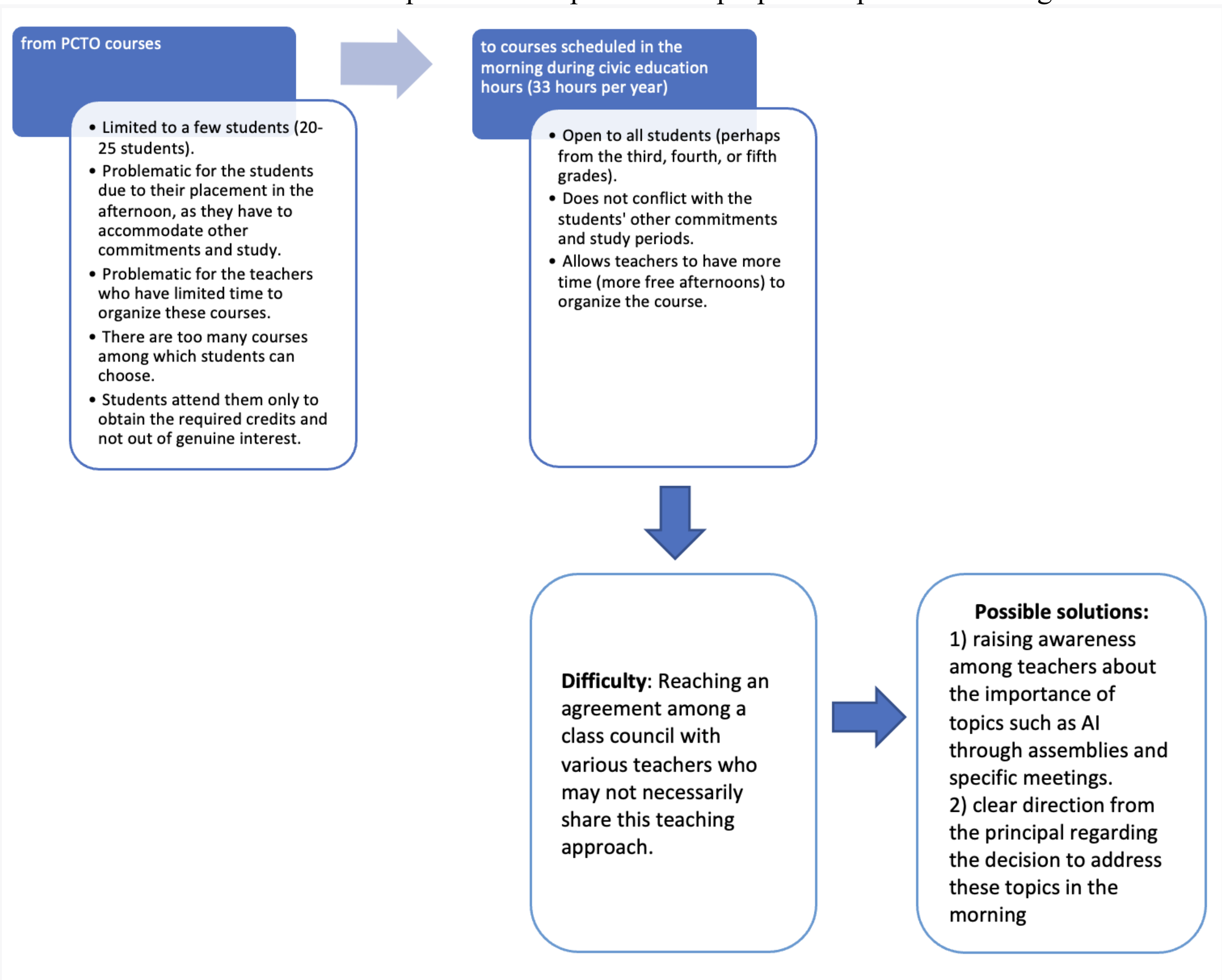


Figure 5.6: This diagram presents the teachers' proposal to place these projects during civic education hours, along with the benefits and challenges it would entail

5.2.4 Comparison with the Literature

Several studies in the literature focus on analyzing co-planning and co-teaching in isolation from the context in which they are implemented, considering only the relationships between the involved teachers (Cook and Friend, 1995; Alsarawi et al., 2019; Aarnio et al., 2021) or at least recognizing the importance of the support provided by the school administration.

The article by Harkki et al. (2021), on the other hand, analyzes co-teaching within the school context in which it is implemented. From a comparison between the results of this study and the paper by Harkki et al. (2021), the following points emerge:

- There is a similarity between the levels of **constraints** identified in this study and the *co-teaching barriers* identified in the article by Harkki et al. (2021).

- The role of the **school administration** is recognized as crucial for the implementation and promotion of courses using the co-teaching method, both in this study and in the article by Harkki et al. (2021).

Unlike the study of Harkki et al. (2021) in which co-teaching was analyzed to teach crafts (a curricular topic), in our study co-teaching is implemented to introduce a **non-curricular subject**, namely artificial intelligence. This study therefore poses the problem of **integrating these courses into the school hours**, highlighting more the constraints that characterize the school institution and seeking how to effectively integrate the course, taking into consideration both the difficulties of teachers and students.

Finally, this study analyzes the role of the University and the research world as facilitators for the implementation of these courses. In particular, it expands on the article by Harkki et al. (2021) in terms of **relationships**, incorporating both the relationship and collaboration with the **University** and collaboration with **other schools** in the area.

5.3 Discussion of the Results

The results extrapolated from the analysis can be interpreted from the perspective of "open schooling" and the levels of action identified by the open-schooling model elaborated within the FEDORA project:

- action at the level of content
- action at the level of interaction among the various stakeholders
- and action at the level of institutional transformation.

Regarding the first level of action, teachers clearly emphasize the relevance of the AI theme and the necessity of introducing it in schools. According to the teachers, the reasons for continuing to address the topic of AI remain the same as those for which it was initially chosen within the I SEE project: "The topic has been chosen for its increasing impact on society, for the epistemological change that AI underwent through its development over the 19th century up to the 'Big Data' sciences, and for its relevance for future-oriented activities." (I SEE, 2019b. p. 3).

In this year's edition, the teachers have highlighted more than ever the objective of the course, which is to make students aware of the digital environment in which they have been immersed since birth and which they tend to perceive as 'natural'. In fact, while on one hand these "digital natives" are able to use digital platforms more easily, on the other hand, they run the risk of using them without the necessary critical thinking.
The introduction of the AI Atelier, by demonstrating how artificial intelligence can be applied to art and highlighting the differences between human art (which is undoubtedly influenced by the historical-cultural context and the consciousness of the artist) and machine-generated art (resulting from the combination of information, data, and labels available online), has certainly contributed to increasing the students' sense of critical thinking regarding the use of these digital platforms that are increasingly capable of imitating human skills, such as creativity.

Once the content to be addressed is established, the results obtained in the paragraph "Evolution of the AI module" can provide insight into the operations that teachers need to undertake to construct and expand a course on AI to be implemented in schools.

Concerning the second level of action, the results obtained in the section "relationships" offer an insight into the importance and the role of the stakeholders involved and the types of relationships established that influenced the progress of this project. For example, the role of the University of Bologna was crucial, especially in the initial years, in providing teachers with the tools to carry forward the AI course. In fact, some teachers mentioned during the interviews that they initially felt uncertain about their knowledge and competencies in teaching AI. Subsequently, they became autonomous and, equipped with the co-planning and co-teaching methodologies, they became capable of effectively leading the course on their own, but they maintained this relationship to have a connection with the world of research. Furthermore, the establishment of a national network between high schools for teaching AI could promote its education in schools, promoting also teachers' training courses and joint projects.

Regarding the third level of action, the results from the section "improvement considering the school context" provide insight into the barriers posed by the school institution and a potential proposal to foster a change within the school: the inclusion of the project within the morning hours of civic education hours. This proposal would be a benefit for both teachers, who complain about the lack of time to organize these courses in the afternoon, and for the students, who have too many school commitments and other afternoon projects.
Addressing these topics within school hours would give them the same importance as other subjects and would be perceived by students not as an optional extra. Students could also be asked for feedback on the topics covered, such as a presentation or an essay, as was done by teacher B with the students in his class who attended the AI course. This kind of change could be decided by the school principal in agreement with the school and class councils, as the regulations already allow the inclusion of the topic of "Digital Citizenship" within civic education hours, and assessment is already a part of the regulations. However, one could hope for a genuine institutional change that involves the intervention of school governing bodies or the Ministry of Education, leading to a change in the school curriculum to make the teaching of AI mandatory, either as a separate subject, as a topic within the science subjects' program, or in other forms. Teacher B said:

"The spaces are not many, so either there is a push from above in terms of curriculum change, or for now, one can navigate within civic education." (Teacher B)

When, during my interview, teacher B talked about school networks, it emerged that a computer science teacher from Monfalcone asked Professor Vespignani to hold a training course for teachers on AIs. In light of this, it would be desirable for the governance to also promote training courses for teachers dedicated to this emerging topic.

In addition to these three levels of action, in this study, the importance of addressing the topic of AI in an interdisciplinary manner using the co-planning and co-teaching methodologies in high schools clearly emerges. Several significant benefits of these methodologies have emerged from the analysis.
Firstly, teachers can distribute responsibilities based on their competencies and interests, alleviating the need for them to possess comprehensive knowledge and preventing them from feeling unprepared when addressing a current and interdisciplinary subject like AI. The challenges related to teachers' competences and preparation to tackle the topic of AI in schools are highlighted by Chiu et al. (2020) and Yau et al. (2022) and the use of the methodologies of co-planning and co-teaching could be a solution.
Furthermore, the implementation of these methodologies allowed teachers to reshape their perception of their own disciplines, expanding them, and enriching their classroom teaching. Finally, all the teachers involved were able to contribute their perspectives, broadening the discussions and reflections on AI and providing students with a comprehensive view of the theme, spanning technical, ethical, philosophical, and artistic aspects. Clearly, difficulties related to the lack of time and the numerous commitments of both teachers and students have also emerged.
Moreover, the students' responses were fundamental to evaluating the success of the course and understanding what changes to make for a future proposal.
I noticed a lot of attention from the teachers toward students' responses, trying to see the challenges of this year as opportunities for improvement in the coming years (e.g. enriching the course with sections dedicated to the students' opinions and their mutual comparisons). The teachers attached great importance to the students, trying to meet their difficulties and academic commitments.

5.4 What should/could the Governance do? FEDORA Recommendations

Before concluding, it seems important to emphasize the significance of the governance's position regarding these projects.

Education policies can determine how future-oriented science education can be enacted in schools. Hence, understanding policymakers' views is directly relevant to the goals of FEDORA because those views inevitably shape the decision-making, enactment, and evaluation of proactive and anticipatory policies (Levrini et al., 2023). FEDORA conducted a study involving policymakers and professionals specialised in curriculum design, assessment, teacher education, and higher education to delve into their judgments and opinions about future-oriented science education (Levrini et al., 2023; Erduran and Chan, 2023).
According to Erduran and Chan (2023), it emerged that there is a high agreement among participants regarding the identification of challenges that 21st-century youth must face and the competences they need to navigate their future. However, concerning issues related to aspects of policymaking or reform, the study recorded divergent opinions with a relatively lower agreement level. Given the limited research and agreement on this important topic, particularly in relation to its connection to policymaking, FEDORA has offered valuable insights, novel opportunities, and potential directions for future research. Drawing from the pioneering FEDORA study, recommendations can be categorized in two ways (Erduran and Chan, 2023). First, stakeholders within the broader community should assess their policies and educational content in science

education. This could involve experts in curriculum design or those responsible for high-stakes national assessments reviewing how closely their current objectives align with common perspectives, and whether there are any significant deviations from the consensus formed in this study. Second, practitioners like school administrators, teachers, and educator trainers should contribute their viewpoints to enrich the conversation. Sharing a mutual understanding among stakeholder groups is a crucial step in fostering meaningful discussions and engagement. Having insight into policymakers' consensus empowers both practitioners and researchers to more effectively and constructively engage in discussions (Erduran and Chan, 2023).

Conclusion

This thesis is situated within the framework of the European project FEDORA, which aims, among its main objectives, to construct a pedagogical model for teaching sciences in high schools to "open" schools to the “Society of Acceleration”. Aligned with this goal, this thesis has investigated the educational methodologies of co-planning and co-teaching applied in an interdisciplinary approach to teaching artificial intelligence in upper secondary schools. The intention was to solidify their effectiveness and integrate them into the new pedagogical model that FEDORA was crafting.

The context for this study was provided by the implementation of an AI module supplemented by an interdisciplinary workshop called the "AI Atelier." This workshop involved the participation of various teachers from different subjects, including mathematics, physics, literature, and philosophy. To study the methodologies implemented during this project, a literature review was conducted first to understand the current state of these methodologies and formulate research questions for subsequent analysis.

In our study, the collected data are of a qualitative nature and have been examined through a bottom-up thematic analysis.

From this analysis, distinctive themes emerged that define co-planning and co-teaching, both in terms of internal interactions among participating teachers and challenges in implementing these methodologies. Additionally, the analysis revealed the relationships established between teachers and involved institutions and stakeholders, as well as the constraints that teachers encountered while implementing these methodologies in the educational context.

The results of this analysis were discussed both from the perspective of comparison with the state of the art in the literature to expand upon previous studies on these methodologies, and from the perspective of aligning with the concept of "open schooling" to contribute to the pedagogical model for teaching STEAM topics that FEDORA is developing. The results of this study were compared with the three levels of action that characterise the concept of open schooling elaborated in FEDORA: action at the content level, action at the level of agents and relationships, and action at the level of school structure and institutions.

The results confirmed the benefits of using these methodologies in the interdisciplinary approach. They highlighted advantages such as the division of responsibilities based on individual teachers' competences and interests, promoting a collaborative approach. Co-teaching emerged as a strategy that benefits both students, as it exposes them to different perspectives, and teachers, by broadening their disciplinary outlook.
However, challenges and barriers, which hinder the implementation of these methodologies in schools, were also evident. This study could be enhanced by also interviewing the students who participated in the project. Through the interviews, it would be possible to gain insight into their perspective regarding the benefits brought about by this project for their educational journey. Furthermore, investigating the challenges they encountered in integrating this project amidst their other academic commitments and studies would be particularly valuable. These challenges were partially highlighted in the interviews with the teachers.

The aim of my work was, therefore, to provide, albeit in a modest manner, points of reflection and suggestions to teachers interested in initiating similar projects, institutions seeking to integrate such methodologies into the school context, and researchers who will be interested in this type of study.

Ringraziamenti

Ed eccomi qua. Finalmente questa tesi che mi ha davvero impegnata anima e corpo è finita ed io sono soddisfatta ed orgogliosa del risultato finale.
Con immensa gratitudine voglio ora ringraziare quanti si sono adoperati alla buona riuscita di questo lavoro.

In primis, voglio ringraziare la mia relatrice, la professoressa Olivia Levrini, per aver avuto fiducia in me da affidarmi una tesi tanto importante quanto intrigante. Durante tutto il percorso non mi sono mai mancati il suo sostegno, i suoi suggerimenti e i suoi consigli. Ricordo molto bene l'ansia provata quando aspettavo che lei leggesse la stesura definitiva e la gioia quando a fine lettura mi ha scritto “la tesi va benissimo”.

Un immenso grazie con tutto il cuore alle mie correlatrici, la professoressa Eleonora Barelli e la professoressa Sara Satanassi. La prima mi ha accompagnato nella prima parte del lavoro aiutandomi ad introdurmi nel Liceo Einstein e soprattutto, con consigli pratici e precisi, nella stesura delle domande del questionario le cui risposte sarebbero stati i dati portanti della mia tesi; ricordo con simpatia i nostri viaggi in treno da Bologna a Rimini, con poi la professoressa Paola Fantini che ci veniva a prendere in stazione per accompagnarci al liceo Einstein.
La professoressa Satanassi, invece, mi ha accompagnato nella parte centrale e finale della mia tesi, quando proprio dovevo scriverla, i suoi consigli e i suoi suggerimenti sono stati per me preziosi e indispensabili, così come è stata importante per me la sua pazienza a rispondere a tutti i miei dubbi; una lavoratrice instancabile che ho visto guardare la mia tesi anche di sabato, domenica e notti di un agosto torrido.

Sono molto riconoscente anche al Liceo Einstein per avermi accolta con empatia e per avermi dato la possibilità di seguire l'iniziativa del corso e Atelier sulle IA.
Ringrazio in particolar modo le professoresse Paola Fantini e Michela Clementi e i professori Fabio Filippi, Maurizio Giuseppucci e Lorenzo Gianfelici, che, gentilmente, mi hanno permesso di partecipare alle lezioni con la mia ingombrante “attrezzatura” di registratore e videocamera. Ma, soprattutto, gli sono molto grata di avermi dedicato il loro tempo, rispondendo pazientemente, con precisione ed esaustività alle domande del questionario indispensabili per la mia tesi. Questo loro lavoro è stato bellissimo, interessantissimo e, soprattutto, all'avanguardia, con ottimi riscontri anche da parte degli studenti e questo gli rende onore e mostra la dedizione che hanno per i giovani e il loro futuro.
Un’ ammirazione particolare alla coordinatrice, la professoressa Fantini, che, pur essendo in pensione, continua a lavorare con entusiasmo mostrando il suo amore per la ricerca, per la scuola e per i giovani.

Non posso non ringraziare con tanto affetto la mia famiglia che mi ha supportato e sopportato durante non solo questo ultimo periodo, ma durante tutti gli anni di università, consentendomi di arrivare a questo traguardo; in particolare ringrazio mia mamma che davvero mi ha sostenuto incoraggiandomi nei momenti di sconforto, gioendo con me nei momenti belli e sopportando pazientemente i miei sbalzi di umore, riuscendo sempre a rompere la tensione con le sue orribili battute o facendo comparire una cioccolata al momento giusto.

E infine, un grazie particolare al mio cagnolino Bibi che ho trascurato tantissimo, soprattutto in questo ultimo periodo, privandolo delle sue passeggiate e coccole, mentre lui non si scollava da me guardandomi con quei suoi occhioni così dolci. Sono certa, però, che mi ha già perdonato e mi sta aspettando per giocare con me.

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