The Contamination Lab as a Possible Pathway to Make Agricultural Engineering Raise its Academic Prominence and Centrality in Italian

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The Contamination Lab as a Possible Pathway to Make Agricultural Engineering Raise its Academic Prominence and Centrality in Italian Academia: Insights from a Case-Study

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Abstract

Italian Agricultural Engineering, while evolving toward the broader, inter-disciplinary field of Biosystems Engineering (which includes also the study of biomasses/biomaterials, field mechanization in difficult contexts and advanced post-harvest agri-food technologies), suffers from a structural critical issue due to its historical academic placement within the Agricultural rather than the Engineering Departments. This peripheral positioning limits the depth of the technical subjects proposed to the students, does not facilitate the necessary collaboration with core engineering disciplines in the research and didactics activities, thereby potentially slowing innovation in crucial fields like agro-bio-energies, precision agriculture and field robotics. To address this misalignment and foster inter-departmental synergy, this study proposes adopting the Contamination Lab (C-Lab) model as the archetype of a possible framework of academic and professional networking involving the Agricultural Engineering. C-Labs (transdisciplinary platforms proposed by the Italian Ministry of University and Research, MUR) function as experiential laboratories, gathering students from Engineering, Agronomy, Computer Science, and Economics to collaboratively develop solutions to real-world challenges posed by industry stakeholders. The integration of a permanent, thematic C-Lab focused on agri-forestry and food machinery, supported by methodologies for enhancing creativity in technical fields, such as the Design Thinking, represents an effective (and necessary) strategy to make Agricultural Engineering recover a higher visibility on the Italian (and international) scenario and, in prospect, relocate it the at the centre of any research involving the technological and technical aspects of agriculture, forestry and food. It is concluded that this initiative can serve as an institutional bridge for hybrid training, which is essential for aligning academic competencies with the growing demands for innovation and multidisciplinary professionalism in the national agrifood-tech sector.

Keywords

Agricultural Engineering, Biosystems Engineering, Contamination Lab (C-Lab), Multidisciplinarity, Hybrid Training, Agrifood-tech, Agricultural and Forest Mechanization, Food Machinery, Structural Criticality in University Education.

1. Introduction

1.1 The Agricultural Engineering: ambit and declination of this subject in Italy

Agricultural Engineering today is increasingly recognized as a specialized branch within the broader and rapidly evolving domain of Biosystems Engineering, an interdisciplinary field that integrates engineering principles with biological and environmental sciences to develop sustainable solutions for living systems (AgriSTUFF, 2025; ASABE, 2025a) (Fig. 1). Biosystems

Engineering encompasses a wide range of applications, including agricultural production, food and biomass processing, environmental protection, energy systems, and the management of natural resources (AgriNext Conference Team, 2024; Foppa-Pedretti et al., 2010; Jongebreur & Speelman, 1997). Within this framework, Agricultural Engineering maintains its historical identity focused on the mechanization and optimization of agricultural practices and technologies, while simultaneously contributing to broader biosystemic goals such as climate-smart agriculture, circular bioeconomy, highly-efficient bioprocessing industry and ecosystem resilience (Bietresato & Mazzetto, 2018). The evolution from Agricultural to Biosystems Engineering reflects a paradigmatic shift from sectoral problem-solving toward systems-oriented innovation, acknowledging the complexity and interdependence of biophysical, technical, and socio-economic processes (Aguado et al., 2011; ASABE, 2025b; Briassoulis et al., 2008; CIGR - International Commission of Agricultural and Biosystems Engineering, 2025; Dokmen & Aslan, 2016; Febo & Comparetti, 2013). As such, Agricultural Engineering serves both as a foundational component and as a practical interface of Biosystems Engineering, particularly in the design, implementation, and dissemination of technological innovations for agri-food, forestry, and rural systems (ASABE, 2025a).

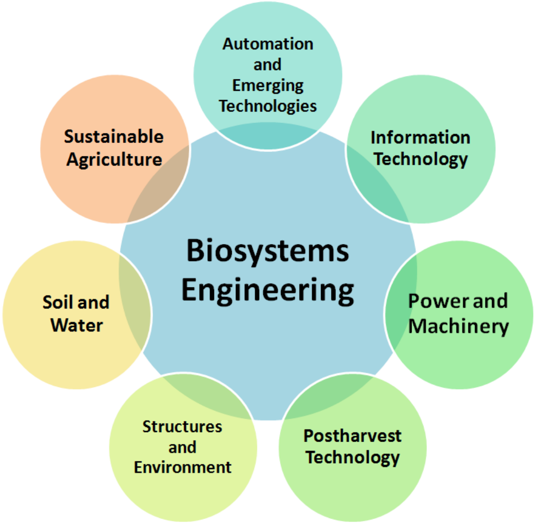

Figure 1. Topics composing the UniMAP's Biosystems Engineering Programme (School of Bioprocess Engineering, 2012).

The Agricultural Engineering, as an academic and professional discipline, encompasses the application of engineering principles to agricultural and forestry production systems, post-harvest (food-)processing chains, and rural infrastructures, with the overarching aim of enhancing productivity, sustainability, and technological innovation across agri-food and bioresource sectors.

In Italy, the field has evolved in close connection with the country's diverse agro-ecological regions, particularly within Mediterranean and Alpine contexts, requiring site-specific mechanization strategies and technological responses (Pellizzi, 2000; Santini, 2025). The Italian declination of Agricultural Engineering, named “Agricultural Mechanics” since its first apparition in the academia, dated back to 1870 in Milan, 1875 in Portici - Napoli (Santini, 2025), includes not only conventional areas such as mechanical power generation and delivery, tillage, seeding, irrigation, and harvesting, but also significantly incorporates forest mechanization and post-harvest processing technologies (Bietresato & Mazzetto, 2018). Forest mechanization—ranging from timber harvesting to transportation and biomass handling—has assumed increasing importance in the Italian context, especially in mountainous and fragile territories where complex terrain morphology necessitates specialized equipment. Forestry machines such as cable yarders, harvester-forwarder systems, and slope-adapted multifunctional tractors are widely studied within national research initiatives, particularly through collaborations involving CREA

(Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria) (Magagnotti & Spinelli, 2011). The emphasis is placed on low-impact and high-efficiency operations that align with national forestry strategy and EU Green Deal priorities.

Simultaneously, machines and equipment used in post-harvest processing and food industry applications represent a cornerstone of Agricultural Engineering (Bhooshan et al., 2024), especially in Italy. These systems include machinery e.g. for processing (i.e., cleaning, drying, grading, pressing, fermenting, milling), and packaging a wide spectrum of agricultural commodities, and products derived from them —from grains and fruits to oils, juices and wines. Beyond product preservation and food safety, these technologies are designed to ensure energy efficiency, process traceability, and environmental compliance under circular economy principles (Zhang et al., 2022). Significant attention is also devoted to the engineering of systems for by-product valorisation and industrial symbiosis.

Academically, these domains are addressed within the Italian university system under the coordination of the "*Associazione Italiana di Ingegneria Agraria*" (AIIA, 2025) and formally categorized under the scientific-disciplinary sector "AGRI-04/B" (formerly "AGR/09") "*Meccanica Agraria*" (Agricultural Mechanics) (Comparetti et al., 2005), part of the Academic Recruitment Field "07/AGRI-04" (formerly "07/C1") "*Ingegneria Agraria, Forestale e dei Biosistemi*" (Agricultural, Forest and Biosystems Engineering), in turn part of the Area 07 "*Agricultural and Veterinary Sciences*", as defined by the Italian Ministry of University and Research (MUR - Ministero dell'Univesità e della Ricerca, 2024). Italian curricula in the field "07/AGRI-04" reflect a system-oriented and interdisciplinary philosophy, which integrates mechanization, process engineering, and environmental management to address the complex needs of the agri-food and forestry sectors.

However, the teaching of Agricultural Engineering and its subdomains in Italy faces considerable structural and institutional challenges, requiring prompt answers, no longer subject to postponement. One of the most critical issues lies in the disciplinary placement of these subjects. Unlike in many other countries—such as Germany, the United States, or the Netherlands—where Agricultural Engineering is institutionally embedded within the Schools of Engineering, in Italy it is historically placed within Departments of Agricultural Sciences and related subjects (e.g., Environmental, Food, and Animal Sciences). Just to state the misalignment of Italy with most of the other countries, ASABE, i.e. probably the most important international association for Agricultural and Biological Engineering (founded in the USA, with members from 100 countries) (ASABE, 2025b), of which many Italian researchers in Agricultural Engineering are part, is one of 35 professional societies that comprise ABET, i.e. the Accrediting Board for Engineering and Technology, primarily in the United States, but expanding across the globe (ABET, 2021). The Italian legacy, rooted in post-war agricultural development policies (Vaquero Piñeiro, 2024), has resulted in Agricultural Engineering (and related subjects) nowadays being taught almost exclusively to non-engineering students, who often lack the foundational technical training in mechanics and physics required for an in-depth development of the subject (Pastukhov et al., 2020). Consequently, academic staff teaching these disciplines must frequently adapt course content to the background of students enrolled in Agricultural, Forest, or Food Science degree programs. This pedagogical constraint risks diluting the scientific rigor and technological innovation that characterizes Agricultural Engineering as a discipline, and enlarging the gap between the requests that the professors receive from agri-food mechanical manufacturing companies and the preparation given to the students. At the same time, students of Engineering Degree programs are often unaware of the existence and potential of Agricultural Engineering, due to its peripheral placement within the Italian university system and, above of all, the insulation from the other engineering disciplines. This leads to a significant disconnect between the competencies of graduates and the multidisciplinary demands of the labour market. Moreover, the institutional separation between Agricultural and Engineering Departments limits opportunities for cross-disciplinary collaboration, joint research initiatives, and co-supervised degree programs. This is particularly detrimental in emerging fields such as agricultural robotics, smart farming, and automation in food processing—areas that inherently require synergies among agronomists, mechanical engineers, and data scientists (Fountas et al., 2015). The result of this insulation and complete lack of visibility of Agricultural Engineering sector in Italy has resulted, for example, in two courses in engineering showing the words "*Agricultural Engineering*" in their title (MSc in Agritech Engineering at PoliTO, MSc in Agricultural Engineering at PoliMI) but without the direct participation of any of the professors belonging to AGRI-04/B – "*Meccanica Agraria*". Both those courses are strangely positioned within the Master's degree class LM-26 ("*Safety Engineering*", according to the Italian classification of university courses), implicitly demonstrating a degree of indecision in the positioning of that MSc courses within the engineering disciplines, which clearly do not include now Agricultural Engineering, being it currently positioned within the Area 07 "*Agricultural and Veterinary Sciences*". Furthermore, there are some subjects belonging to the AGRI-04/B sector (spec. related to Food Machinery/Equipment) in the study-plan of the BSc and MSc course belonging to the degree class "L-26" and "LM-70" ("*Food Sciences and Technologies*"), but not in other MSc courses proposed within the Italian engineering schools, e.g. in "*Engineering for the food industry*" (at the University of Parma), "*Engineering of Food Processes*" (at the University of Neaples), "*Food Engineering*" (at the University of Salerno and at Polimi), "*Food Industry Engineering*" (at the University of Padova), "*Food Engineering*" (at University of Calabria), or in the curriculum "*Management of food production*" for the MSc in "*Management Engineering*" (at University Tor Vergata).

Apart from the complete exclusion of the AGRI-04/B sector from all these degree courses, within which this sector could have given for sure a contribution beside the other sectors already present there, the problem at institutional level stems from some decrees approved by the Italian Ministry of University and Scientific Research regarding the list of the Scientific-Disciplinary Sectors (SSDs) involved in the "*Attività formative caratterizzanti*" (emg. "Characterising learning activities") (Ministero dell'Università e della Ricerca Scientifica, 2024a, 2024b). In those decrees of the AGRI-04/B sector is never mentioned outside of the BSc and MSc courses related to the Agrifood.

Paradoxically, this academic misalignment persists de-spite strong and growing interest from private companies in the agri-tech, food machinery, and forestry equipment sectors, which are increasingly seeking engineers with hybrid expertise in mechanical systems and biological processes. Moreover, in some countries, where Agricultural Engineering is a degree course placed within the university faculties of agriculture, a recognized identity crisis of the figure of Agricultural Engineer is occurring, as it is not recognised as a "real engineer" (Ajwang, 2017). Therefore, other countries have embraced the interdisciplinary nature of the field through dedicated degree programs (in "*Biosystems Engineering*", "*Agro-industrial Engineering*", or "*Precision Agriculture Engineering*"), typically offered within Engineering faculties and supported by integrated research platforms (EduRank, 2025).

1.2 Need for multidisciplinary initiatives to promote Agricultural Engineering

Given the institutional and didactic challenges outlined above—particularly the marginal placement of Agricultural Engineering within non-engineering faculties and the resulting fragmentation of expertise—there is a pressing need to promote multi-disciplinary initiatives capable of bridging these structural divides. As highlighted, Agricultural and Agroforestry Engineering in Italy are currently taught predominantly to students from agronomic or food science backgrounds, limiting both the technical depth of instruction and the discipline's integration into broader engineering and technological ecosystems. This isolation stands in stark contrast to the inherently interdisciplinary nature of the field, which demands the convergence of mechanical design, control systems, environmental engineering, and biological sciences to address contemporary challenges such as precision agriculture, digital farming, and sustainable agro-industrial processing (Cathcart et al., 2005; Fountas et al., 2015; Opara, 2004).

Internationally, countries such as the United States (Master of Engineering in Digital Agriculture and Master of Science in Agricultural and Biological Engineering, University of Illinois Urbana-Champaign – The Grainger College of Engineering, MSc in Agricultural Engineering and Ph.D. in Biological and Agricultural Engineering, University of Georgia, College of Engineering), France

(Master of Science and Engineering in Smart Farming and Sustainable Agriculture, Junia Graduate School of Engineering), and the Netherlands (MSc in Crop Biotechnology and Engineering, Maastricht University, Faculty of Science and Engineering) have successfully institutionalized Agricultural Engineering within their Schools of Engineering, supported by cross-departmental centres and multidisciplinary degree pro-grams in "*Biosystems Engineering*" or "*Agro-industrial Engineering*" (Educations.com, 2025). These models demonstrate the benefits of structurally embedding collaboration across disciplines and training profiles, thereby enhancing the scientific visibility and industrial relevance of the field.

In Italy, overcoming the historical confinement of the sector AGRI-04/B – "*Meccanica Agraria*" within Agricultural departments will require systemic reforms revising current curricula to include cross-disciplinary modules, and hence national strategic investment in joint MSc and PhD programs, shared research infrastructures, and coordinated efforts between Departments of Engineering and Agricultural Sciences. Such efforts are essential to enhance the visibility, scientific quality, and societal impact of the discipline and to align higher education with the innovation needs of Italy's agri-food and forestry sectors, particularly in the framework of the National Recovery and Resilience Plan (PNRR), the Common Agricultural Policy (CAP), and Horizon Europe. Therefore, these multidisciplinary initiatives are essential not only to strengthen the academic identity of Agricultural Engineering, but also to meet the growing demand from private sectors for hybrid professionals capable of operating across technical, environmental, and biological domains. Ultimately, fostering such integration will enhance Italy's capacity to contribute to the agroecological and digital transitions envisioned in national and European innovation agendas.

1.3 The Role of the Contamination Lab in Supporting Multidisciplinary Integration and Innovation in Agricultural Engineering

In light of the structural fragmentation and disciplinary isolation described above, the "*Contamination Lab*" (C-Lab) model can offer a promising, scalable solution to foster multidisciplinarity, didactic innovation, and university–industry collaboration in Agricultural and Agroforestry Engineering. A Contamination Lab is an educational and innovation-oriented platform that brings together students from different academic disciplines—e.g. engineering, agronomy, economics, design, and computer science—to collaboratively address real-world challenges posed by private companies, public administrations, and civil society organizations (Fig. 2). These challenges are tackled through "project-based, team-oriented, and time-constrained activities" that simulate professional innovation environments, with a strong focus on prototyping, entrepreneurial thinking, and co-design processes (Governo Italiano, 2016; Graham, 2018; Ministero dell'Istruzione dell'Università e della Ricerca (MIUR), 2016; Proença, 2025; Secundo et al., 2020). Activities within a Contamination Lab typically include intensive innovation bootcamps, hackathons, design thinking sessions, and collaborative workshops focused on generating viable solutions—ranging from conceptual prototypes to pre-commercial demonstrators. These are often supported by mentors from both academia and industry and are structured around iterative design methodologies such as the Lean Start-up (Ries, 2011) or Agile Development (Agile Alliance, 2025) paradigms. Importantly, C-Labs emphasize "learning-by-doing", but differ from traditional laboratory courses or internship programs by being explicitly interdisciplinary, problem-driven, and mission-oriented. Unlike FabLabs, which, instead, focus primarily on digital fabrication and technological prototyping, or Living Labs, which often involve co-creation with end-users in open environments, Contamination Labs serve as "transdisciplinary innovation ecosystems" embedded within academic institutions, directly tied to educational objectives and third mission outcomes (Pallot et al., 2010; Proença, 2025).

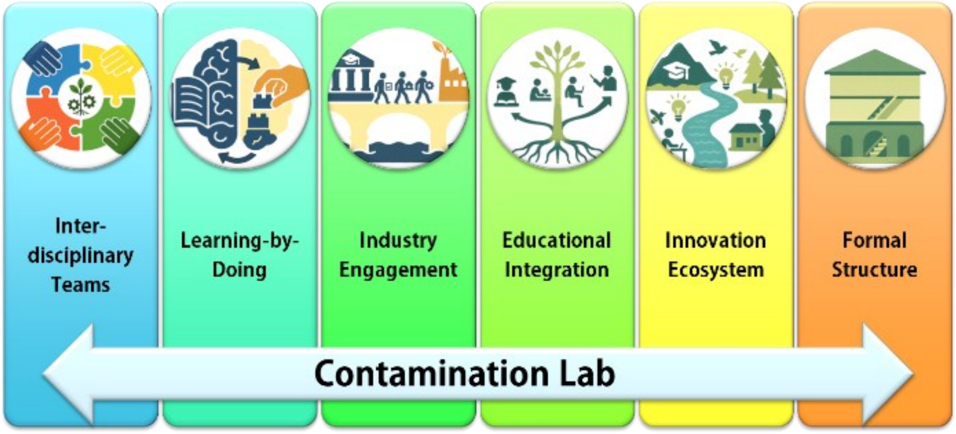

Figure 2. The six “pillars” of a contamination lab.

The key characteristics of a Contamination Lab are:

- *Multidisciplinarity and "Contamination"*: the name "Contamination Lab" comes just from the idea of encouraging the "contamination" of ideas and skills among students/participants coming from different disciplines/having different backgrounds (engineering, economics, humanities, arts, etc.). The goal is to generate innovative solutions that arise from the meeting of diverse perspectives.
- *Entrepreneurial Training and Guidance*: CLabs offer experiential training programs, often extracurricular, aimed at developing entrepreneurial skills, problem-solving abilities, teamwork, and idea presentation skills. Innovative teaching models like Design Thinking and Business Modelling are utilized.
- *Development of Concrete Projects*: students, possibly organized into teams that are as much multidisciplinary as possible, work on concrete project ideas with the support of expert tutors and mentors (entrepreneurs, managers, academics);the objective is to transform these ideas into feasible or real prototypes or viable, scalable, and sustainable business models.
- *Networking and Connection with the Territory*: CLabs act as a bridge between the university and the external world, facilitating relationships with companies, startups, incubators, investors, and other local stakeholders; this allows students to expand their network and engage with market demands and local opportunities.
- *Physical and Virtual Spaces*: CLabs can be both physical spaces dedicated to coworking, collaboration, and prototyping, as well as virtual platforms for sharing ideas and resources.
- *Start-up Support*: many CLabs offer pre-incubation services and access to resources and tools to help teams transform their ideas into innovative start-ups.

In the context of Agricultural Engineering, the C-Lab format is particularly well-suited to bridge existing gaps between agronomic knowledge and technological innovation, as it enables students to address real problems in agri-food systems—such as sustainable mechanization, digital agriculture, post-harvest optimization, and forest biomass valorisation—through exposure to diverse perspectives and industry practices (Murphy & Obenaus-Emler, 2025). A permanent C-Lab structure, embedded within or across Agricultural and Engineering departments, would not only facilitate institutional collaboration but also serve as a platform for engaging local and national companies in co-innovation processes. This supports the university’s third mission, facilitating knowledge transfer and strengthening links with stakeholders from sectors including agri-tech, food processing, machinery manufacturing, and environmental management.

1.4 Italian Regulatory Framework and Funding for Contamination Labs

In Italy, Contamination Labs have been primarily promoted and regulated by the (Italian) Ministry of Education, University and Research (MIUR), now (from 2022 on) the Ministry of University and Research (MUR) (Ministero dell'Università e della Ricerca, 2020). The main legislative references and initiatives that have driven the establishment and development of CLabs are:

- Ministerial Decree No. 436 of March 13, 2013: this was one of the first acts to allocate funds (€1 million) for the creation of Contamination Labs within universities; initially, the pilot project involved only some regions of Southern Italy (Campania, Puglia, Calabria, and Sicily) (PONREC, 2011).
- Guidelines on Contamination Labs (2016): The MUR published detailed guidelines for the creation and development of CLabs. These guidelines define the objectives, methodologies, desirable characteristics, and aims of Contamination Labs, emphasizing the importance of multidisciplinarity, entrepreneurial orientation, networking, and sustainability (Ministero dell'Istruzione dell'Università e della Ricerca (MIUR), 2016).
- Ministerial Decree No. 3158 of November 29, 2016 (Public notice for the submission of projects to support the creation and development of Contamination Labs); this decree launched a call for specific projects, with the aim of supporting the creation and development of CLabs and the establishment of a national CLab Network.
- Ministerial Decree of June 15, 2017, No. 1513 (Approval of rankings and implementation guidelines for projects for the creation and development of Contamination Labs and the CLab Network); this decree approved the rankings of projects funded following the 2016 call and defined the implementation guidelines, establishing the management, execution, obligations, and reporting procedures for universities admitted to funding. (Ministero dell'Istruzione e del Merito, 2017); the funds came from the Development and Cohesion Fund (FSC), as part of the National Research Program 2015-2020, in continuity with actions initiated in the previous programming (PAC Ricerca).

These legislative acts provided the regulatory framework for Italian universities that wished to establish a Contamination Lab, often including specific funding and the possibility of recognizing university credits (CFU) for participating students.

The situation of Contamination Labs in Italy is still active and evolving, though with some specific characteristics compared to their initial launch years. They continue to receive funding, but through different channels:

1. PNRR (National Recovery and Resilience Plan): this is the most significant and recent funding source for many CLabs and similar initiatives (Governo Italiano, 2021); under Mission 4 "Education and Research" and its components, the PNRR is allocating substantial resources to strengthen the innovation ecosystem, applied research, and technology transfer; many CLabs or initiatives that adopt their philosophy (such as the "Innovation Laboratories" or the "Innovators Community Labs" in some universities) are integrated into larger PNRR-funded projects, often within Innovation Eco-systems like iNEST for Northeast Italy, which includes the University of Udine's CLab (Consorzio iNEST, 2025) or other national centres. This ensures continuity of funding and greater integration with national development strategies.
2. European Structural Funds (ERDF, ESF); European structural funds, programmed at regional or national levels, also continue to support innovation, research, and skills development projects, in which CLabs or similar models can be included; for example, the "Digital Contamination Lab 2025" by Lazio Innova is supported by the PR FESR Lazio 2021-2027 (Lazio Innova, 2025).
3. Self-funding and Local Collaborations; many universities, after receiving initial funding from MUR (such as from the 2016-2017 call), have developed greater autonomy in managing and raising resources. This occurs through:
    - Involvement of Private Companies; businesses actively participate in CLabs by proposing challenges, providing mentors, or offering sponsor-ships, recognizing the value of training and access to young talents and innovative ideas.
    - University Funds; universities themselves allocate part of their budgets to these

    - initiatives, as they are considered strategic for their "third mission" (knowledge transfer and interaction with society).
    - Regional or Local Calls; there are often specific regional or chamber of commerce calls that support youth entrepreneurship and innovation.

As a consequence, the key aspects of the current situation can be delineated as follows:

- *Widespread Adoption*; most large Italian universities, and many medium-sized ones, now have their own Contamination Lab or an equivalent initiative (often rebranded, such as the Innovators Community Lab in Trieste (Università degli Studi di Trieste, 2025)), testifying to the model's validity.
- *Specialization*; while initially CLabs had a more general scope, today there is a tendency to specialize in strategic sectors (e.g., agro-forestry, digital, health, energy, tourism), often in line with territorial vocations and funding priorities (like the PNRR).
- *Ecosystem Integration*; CLabs are increasingly seen as fundamental nodes of a broader innovation ecosystem, which includes incubators, accelerators, science and technology parks, and startups.
- *Academic Recognition*: Many CLabs still offer the students university ECTS credits (European Commission: Directorate-General for Education, Youth, Sport and Culture, 2015), in Italy referred to as “CFU”, integrating the extracurricular training pathway with the traditional academic curriculum.

1.5 Other examples of Contamination Labs in Italy/world; characteristics and differences with the current case

Several Italian universities have adopted and adapted the C-Lab model (Fig. 3; Tab. 1). It is important to note that, despite a ministerial imprint, each university retains the freedom to adapt its Contamination Lab to its specific characteristics and local context, while maintaining the core principles of "contamination" and entrepreneurial orientation. Among the most consolidated, there are: the “Contamination Lab Cagliari”, one of the earliest and most influential, with strong links to ICT and entrepreneurship (Università degli Studi di Cagliari, 2025a); the “Contamination Lab San Giovanni a Teduccio” at the University of Naples Federico II (Università degli Studi di Napoli “Federico II,” 2015), focusing on smart cities, sustainability, and agri-food technologies (Università degli Studi di Napoli “Parthenope,” 2022); and the “C-Lab Sapienza” (Sapienza Università di Roma, 2021, 2026), which links engineering, architecture, and social sciences through open innovation processes. These labs differ in their governance models, thematic focus, and degree of integration into formal curricula.

In general, Italian Contamination Labs range from ICT- and start-up-oriented (Cagliari, Bologna, Pisa) to sector-specialized hubs, such as the CLab of Faenza, having an agriculture/food focus (EmiliaRomagnaStartup, 2025). Some (e.g., Pisa) awards academic credits and formal integration (Università degli Studi di Pisa, 2025).

Figure 3. Universities belonging to the Italian CLAB network (figure taken from (CLab@Salento, 2026)).

Table 1. Examples of Contamination Labs in Italy & Abroad (Università degli Studi di Cagliari, 2025b)

Lab	Location	Key Features / Focus	Notes
C-Lab Cagliari	University of Cagliari, Italy	ICT, entrepreneurship, startup acceleration; follows projects beyond launch	One of the earliest Italian C-Labs
C-Lab Pisa	University of Pisa, Italy	Graduate/PhD level; design thinking, business modelling	Offers PhD+ and CyB+ programs with academic credits
C-Lab Naples	University of Napoli, Italy	Smart cities, sustainability, agri-food tech	Collaborates with local companies and public bodies
C-Lab Faenza	Faenza (Ravenna), Italy	Open space + digital; idea-stage entrepreneurship	Agriculture and food sector focus
d.school Stanford	Stanford University, USA	Design thinking, innovation, cross-faculty education	Emphasis on entrepreneurial mindset and systemic design
Design Factory	Aalto University & global, Finland	Product development, multidisciplinary innovation	Part of a global engineering-design innovation network
EPFL Changemakers	EPFL, Switzerland	Entrepreneurial, social & tech innovation	Living Lab hybrid focused on sustainability

Contamination Labs have generated several significant experiences since their inception, contributing substantially to promoting entrepreneurship and innovation in the university context. While it's challenging to compile an exhaustive ranking of the "most relevant," as success can be measured in various ways (number of start-ups generated, territorial impact, project quality, etc.), we can identify some experiences that have stood out for their visibility, innovation, or impact on the territory:

1. CLab Torino (Politecnico di Torino and University of Turin) (Fiore et al., 2019; Politecnico di Torino, Università di Torino, 2026):
    - Relevance: It was the first inter-university Contamination Lab in Italy, resulting from the collaboration between two major universities in a city with a strong industrial and innovative vocation.
    - Impact: It offered a unique environment for students and PhD candidates from diverse disciplines, promoting the experimentation of new learning models and the development of projects with entrepreneurial and social aims, closely linked to the challenges of the Turin area.
2. Contamination Lab of the University of Pisa:
    - Relevance: The Pisa CLab is an example of continuity and adaptation, having evolved its focus on spreading entrepreneurial education and promoting a culture of innovation with a strong emphasis on sustainability as a key element of value creation.
    - International Visibility: Recently, Professor A. Cavicchi, scientific director of the Pisa CLab, was invited by the European Commission to present the "case of the Pisa Contamination Lab" at an international event on entrepreneurship ("Entrepreneurial Skills and Competences Throughout Life"), demonstrating its European recognition.
    - Collaborations: It organized workshops in collaboration with European alliances (such as the "Start For Future Alliance") to support research teams and start-ups, facilitating the creation of innovative enterprises.
3. Contamination Lab Trento (University of Trento and HIT - Hub Innovazione Trentino) (Università degli Studi di Trento, 2026):
    - Relevance: It has distinguished itself by its strong integration with the highly developed Trentino innovation ecosystem. The partnership with HIT has enabled the creation of an environment where innovation and entrepreneurial culture are taught both to complete students' traditional education and to promote new successful activities based on real cases and industrial needs.
    - Internationalization: It has a strong focus on international "contamination," allowing participants to work with international teams and mentors.
4. Digital Contamination Lab (Lazio Innova in collaboration with several Lazio universities):
    - Relevance: While not strictly university-led in its organization like others, Lazio Innova's "Digital Contamination Lab" is a significant example of how the CLab methodology has been adopted by regional development agencies, in collaboration with multiple universities (e.g., University of Tuscia, Cassino, Sapienza).
    - Strategic Sectors: It focuses on high-potential sectors such as Environment and Energy, Digital, Culture and Tourism, Health and Social Well-being, and has awarded innovative projects with a concrete impact on the Lazio territory.
5. Contamination Lab of the University of Padua (CLab Unipd) (Università degli Studi di Padova, 2026b, 2026a):
    - Relevance: It has a consolidated history and has seen the participation of important industrial entities like Stevanato Group and Irinox, demonstrating how CLabs can be fertile ground for innovative relationships between academia and industry, leading to the birth of successful entrepreneurial initiatives. It has a strong focus on spreading entrepreneurial culture and developing projects with market appeal.

Other universities in Italy in which a Contamination Lab took place are: University of Basilicata (Università degli Studi della Basilicata, 2026), University of Brescia (Università degli Studi di Brescia, 2026), University Carlo Cattaneo (Università Carlo Cattaneo – LIUC, 2026), University of Catania (Università degli Studi di Catania, 2026), University of Genova (Università degli Studi di Genova, 2026), Online University Mercatorum (Università Telematica Universitas Mercatorum, 2026), University of Modena and Reggio Emilia, (Università degli Studi di Modena e Reggio Emilia, 2026), University of Molise (Università del Molise, 2026), University of Palermo (Università degli Studi di Palermo, 2026), Polytechnical University of Marche (Università Politecnica delle Marche, 2018), University of Salento (CLab@Salento, 2026), University of Teramo (Università degli Studi di Teramo, 2025), University of Venezia (Università Ca' Foscari, 2026), University of Verona (Università degli Studi di Verona, 2026).

These experiences demonstrate how Contamination Labs have become a pillar for innovation in Italian universities, not only by training new generations of entrepreneurs but also by acting as catalysts for technology transfer and value creation in their respective territories.
Internationally, initiatives akin to the C-Lab format include the "Design Factory Global Network" (originated at Aalto University, Finland), the "d.school at Stanford University" (Hasso Plattner Institute of Design at Stanford University, 2025), and the "EPFL Changemakers" program in Switzerland (École Polytechnique Fédérale de Lausanne - APLF, 2023) —each promoting cross-disciplinary, project-based innovation embedded within higher education (Jussila et al., 2020), with a systemic impact—principles that align well with Africa/ Agricultural Engineering applications. Many labs currently lean towards general innovation or ICT; a domain-specific lab in Agricultural and Biosystems Engineering—embedded in agronomy + engineering faculties and focused on agri-tech, mechanization, post-harvest processing, forest systems—would be a strategic innovation, combining lessons from both national and international models.

2. Methods

2.1 The University of Udine's Contamination Lab: A Different Approach to Raising Awareness of Agricultural Engineering and Engage Companies

The Agroforestry Engineering C-Lab of the University of Udine (Università degli Studi di Udine, 2025) has a strong focus on applied research and the resolution of specific problems proposed by companies, just as the sector to which it is referred. This perspective, while not excluding entrepreneurship as a potential ultimate outcome (e.g. possible creation of start-ups after this experience), emphasizes co-creation of solutions and technology transfer more strongly. We can say that this C-Lab stands out for its strong emphasis on "Corporate Problem Solving and Collaborative Research" as the main driver of innovation, while still retaining elements that can lead to entrepreneurship. Furthermore, one of the crucial points in pursuing "third mission" activities by university professors is always to come in contact with potentially interested companies. The former, indeed, does not have adequate resources to actively carry out real and effective scouting or advertising activities, as it is also (rightly) engaged in other areas related to teaching and basic research. (i.e., the first and second missions) The latter, on the other hand, may not be aware of all the expertise and people they could find at the university and end up contacting only those they already know. Although mainly aimed at students, a C-Lab focused on Agroforestry Engineering is also an excellent opportunity to bring these two subjects together. Indeed, it filters companies to only those that are genuinely interested in the sector (or that already define themselves as part of it) and shifts the burden of engagement onto them through an advertising campaign on institutional channels (therefore having a lower effort than one aimed at a specific target).
More into detail, the Agroforestry Engineering C-Lab of the University of Udine unfolded through the following steps:

1. Collection of adhesions from companies and request for a definition of challenges by them: companies presented real problems, problematic points, or opportunities for improvement/ innovation that required a research and development approach; this was at the heart of the "research collaboration"; specifically, in the 2025 edition, solutions were requested for these themes (see following paragraphs for a higher detail):
    - Optimization of water resource management in agriculture.
    - Development of smart sensors for crop monitoring.

    - Solutions for phytoremediation.
    - Market analysis of liquid food mixing products.
2. Formation of multidisciplinary teams; participating students (mainly from engineering, computer science, agricultural sciences) were organized into teams, trying to enhance multidisciplinarity, as it is crucial for tackling complex problems from various angles.
3. Problem analysis and understanding phase; the teams applied methodologies like Design Thinking, hence, they dedicated time to:
    - thoroughly understanding the needs and perspectives of the company and the end-users of the problem (empathy);
    - clearly outlining the problem to be solved (Statement Definition);
    - generating a wide range of ideas for solutions (Ideation);
4. Solution development and prototyping phase; the teams worked on devbeloping concepts, prototypes (even just conceptual, virtual or low-fidelity), and/or feasibility studies for the proposed solutions; the focus was on the technical validity and innovation of the solution to the corporate problem rather than on the "business model"
5. Specialized mentoring; participants received support from:
    - University professors and researchers, specifically for the scientific and technical validity of the solutions;
    - Company experts, to ensure the applicability and relevance of the solutions in the industrial context.
    - Innovation experts, to guide the problem-solving process.
6. Presentation and feedback: at the end of the C-Lab, the teams presented their solutions to the proposing companies and a jury of experts. Feedback was crucial for refining ideas and evaluating their future applicability.
7. Analytical evaluation of proposals, ranking of groups and award ceremony.

What distinguishes it and why it is an effective model:

- *Strengthening the third mission*: this approach maximally emphasizes the university's "third mission": technology transfer and territorial impact. It's not just about producing knowledge, but directly applying it to solve concrete problems for businesses.
- *Developing highly demanded skills*: students acquire not only entrepreneurial skills but also applied research, incremental/disruptive innovation for industry, collaborative problem-solving, and project management with external stakeholders. These are highly sought-after skills in the job market, both in established corporate settings and in start-ups.
- *Pipeline for Corporate Innovation*: For companies, participation means gaining access to new ideas, fresh talent, and an innovative approach to solving problems that they might not be able to address internally with the same speed or perspective. It could lead to the adoption of new technologies or the initiation of joint internal R&D projects.
- *Indirect Entrepreneurial Potential*: Even if the primary orientation is not immediate start-up creation, the most promising solutions could still evolve into:
    - Broader joint research projects.
    - Hiring of participants by the companies.
    - Spin-offs or start-ups if the solution has sufficient market potential to justify an independent entrepreneurial path (e.g., the developed solution can be a product/service saleable to other companies).
- Role of PNRR and iNEST: Being part of the PNRR and iNEST context means that this CLab is part of a broader strategy for strengthening innovation and competitiveness in Northeast Italy, with a clear mandate to facilitate collaboration between research and industry.

Ultimately, the Udine CLab, with this specific focus, not only distinguishes itself by a more applied collaborative research approach but also represents a virtuous model of how the university can become a strategic partner for corporate innovation, generating mutual value and training professionals with highly specialized and in-demand skills.

2.2 Communication media that enabled recruitment

The selection of participating students was conducted through a multichannel communication campaign:

- Social Channels: advertising on the University's profiles on the main social networks (Facebook, Instagram, LinkedIn).
- Direct Communication: sending an email to all the university students (15269 students at that time).
- Institutional Media: dissemination of announcements on the main university media and noticeboards.
- Posters/Flyers: posters displayed in the main university locations (spec. access to classroom buildings and study rooms).

The graphics for all press releases/posts/flyers were entrusted to a professional graphic design studio and featured an image that captured the viewer's attention while also evoking the idea of a technological approach to agri-environmental issues. (Fig.4) It functions as a visual manifesto for the C-Lab in Agroforestry Engineering. Indeed, the anthropomorphic figure composed of vegetal elements symbolizes the integration of humans within agro-ecosystems, conveying a systemic and regenerative vision of engineering that overcomes the traditional nature–technology dichotomy. The presence of drones represents advanced digital technologies—such as precision agriculture and forestry—as enabling, non-invasive tools that enhance ecosystem understanding rather than dominate it. The figure's reflective posture communicates responsibility, care, and ethical agency, highlighting the role of the agroforestry engineer as a conscious manager of complex socio-ecological systems. The natural, desaturated color palette reinforces ideas of balance, sustainability, and a desirable technological future. Overall, the image visually encapsulates the concept of disciplinary contamination by merging ecology, engineering, and innovation into a coherent narrative aligned with contemporary agroforestry education.

Figure 4. Distinctive image proposed for C-lab Udine (Università degli Studi di Udine, 2025).

A subsequent survey revealed that the majority of participants enrolled after receiving the direct email. A small number participated due to word-of-mouth, and only one student responded to the social network advertising. No participants reported enrolling after seeing the posters displayed on campus.

2.3 Participating companies and proposed challenges

The Contamination Lab, named "*Agroforestry Engineering C-Lab*", took place from May 2 to May 16, 2025. Four different companies participated, proposing four distinct research topics, collected in Tab. 2.

Table 2. Research topics proposed by the four involved companies.

Title	Description
Soil Moisture Mapping	This research sought methods and tools to map soil moisture in agricultural plots at various depths (from the surface down to 50-60 cm) with a spatial resolution of 2-5 square meters. The aim was to spatialize predictive models for diseases or crop water status, which are typically based on soil moisture measurements from point sensors installed in the field, as well as other climatic or canopy data provided by a localized weather station. The request was to delve deeper into specific aspects of the proposed systems, such as: • Measurement reliability, depending on the physical mechanism involved. • Applicability limits. • Costs. • Ease of use for a farmer.
Phytoremediation and Vermicomposting	This research involved designing a compact and modular system for managing agro-food industry waste sludge through vermicomposting of the solid part and phytoremediation of the liquid part.
Thermo-Chemical and Mechanical Performance within Tanks and Mixers for the Food Industry	This research focused on the processes related to thermo-chemical and mechanical transformations occurring within tanks for liquid foodstuffs (wine, beer, tea, kombucha, fruit juices, oils and fats, vegetable pulps, beverages in general, distillates, liqueurs, concentrates, sugary solutions, brines, emulsions, etc.). The goal was to understand the dynamics of component and temperature homogenization, element dissolution, and optimal fluid agitation as container geometry and mixing system characteristics vary, ultimately identifying the salient features and performance of agitation systems.
The Future of Irrigation for Agricultural Crops	Agricultural crop irrigation faces significant challenges. Future trends indicate that more precise control, improved monitoring, and reduced water consumption will be fundamental. The objective of this project was to analyse current and future irrigation requirements and develop innovative solutions.

Each company provided a corporate tutor whose role was to present the participants the proposed research topic and explain them the expected results from the company's perspective. Eighteen students from 13 different degree programs participated in finding solutions to these research topics. They were instructed to split into four groups of 4-5 students, i.e. one group for each participating company, after the process described hereinafter.

The initial phase began with a Team Building session where the students, after listening to the presentations about each topic, were tasked with self-organizing and dividing themselves into groups; the goal was to create groups that were as balanced as possible in terms of skills, experience, and interest in the chosen topic, specifically considering the following parameters:

- Degree program of origin.
- Year and type of attended course.
- Personal preferences for a research topic.

The students successfully formed their groups independently in about half an hour, however following the organizers' suggestions. The primary goal of the academic tutors was to ensure the formation of multidisciplinary and balanced groups, paying particular attention to harmonizing the distribution of skills/academic paths and the year of enrolment at the University. Each group was then assigned a corporate tutor, based on the chosen topic, and an academic tutor. The groups then began their research work, which they were to complete over two weeks, consulting with both their corporate and academic tutors.

2.4 Proposed seminars

Within the CLab, some seminars were also held to provide students with additional tools/approaches to best develop their research topics. Specifically, the following seminars were offered:

- "*Foresight Lab to Explore Tomorrow*", Prof. C. Battistella & Dr. Eng. G. Attanasio, UniUD;
- "*Practical Creativity Workshop for Innovation*", Prof. C. Battistella & Dr. Eng. G. Attanasio, UniUD;
- "*From Wool, Flowers are Born*", Dr. C. Spigarelli, freelance
- "*Effective Management of Complex Projects*", Prof. C. Battistella & Dr. Eng. G. Attanasio, UniUD;
- "*From Idea to Enterprise*", Dr. P.P. Ganis – Vitesy.

At the end of the two weeks, the groups prepared a summary document of their results, created a three-minute pitch to summarize their findings, and presented their research directly to a mixed jury equally composed of university professors and company professionals, who evaluated the work of the individual groups. The evaluation was conducted considering the following criteria (Tab. 3), each of them was awarded with a score spanning from 1 ("*non-sufficient*") to 5 ("*excellent*"):

Table 3. Evaluation criteria.

Criterion	Evaluation Description
1. Project Presentation	Clarity of exposition, logical structure of the presentation, effective use of visual or multimedia aids, ability to attract and maintain audience attention.
2. Communication Skills	Language proficiency, appropriate use of technical-scientific vocabulary, coherence and fluidity in a presentation, ability to respond effectively to any questions or observations.
3. Understanding of Proposed Research Topic	Demonstration of in-depth understanding of the assigned topic, contextualization of the problem, ability to synthesize sources and underlying needs.

4. Evaluation of Proposed Solution	Originality and innovativeness of the idea, technical feasibility, sustainability (environmental, economic, social), consistency with the topic's objectives.
5. Ability to Work in a Group	Quality of collaboration among team members, balanced distribution of tasks, integration of individual contributions into a unified project. Ability to address and resolve conflicts or operational difficulties.

During and in the follow-up of the laboratory, questionnaires were administered to both participants and corporate tutors to evaluate the experience, which we report in the analysis section.

2.5 Participating students

16 of the 17 participants were students from the University of Udine, while only one student came from another Italian institution. The students showed remarkable academic diversity, coming from 13 different Italian degree programs (Tab. 4). The breakdown by Department of reference for their degree programs was as follows:

- 8 students from the Department of Agri-Food, Environmental and Animal Sciences (DI4A) of UniUD (degree programs broadly related to Agriculture, Food, Environment);
- 3 students from the Department of Mathematics, Computer Science and Physics (DMIF) of UniUD (degrees broadly related to Computer Science and Informatics);
- 3 students from the Polytechnic Department of Engineering and Architecture (DPIA) of UniUD (degree programs broadly related to Engineering);
- 3 students from other departments/universities.

Regarding the level of study (Fig. 5), the majority (11) came from Bachelor's degree programs, but there were also students enrolled in Master's degree programs (5), and one student who was pursuing a Ph.D. program.

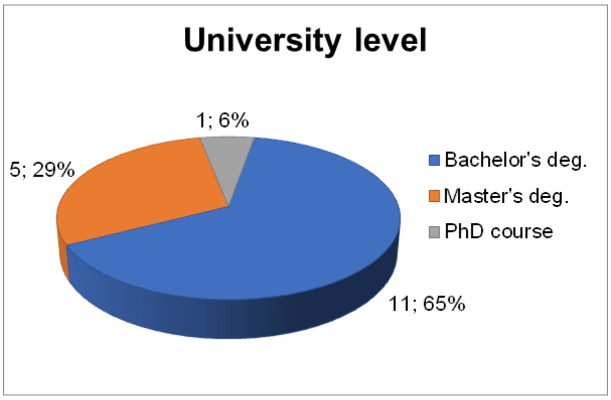

Figure 5. Distribution of Students by University Level of enrolment.

Table 4. Teams Composition: Detail of students’ degree programs (including also the degree classes (Ministero dell’Università e della Ricerca Scientifica, 2024a, 2024b)) and research topics.

Research topic / Team topic	St. ID	Official Course Denomination	Deg. Class
	1	Cultural Mediation	L-12

Thermo-Chemical and Mechanical Performance within Tanks and Mixers for the Food Industry	2	Viticulture and Oenology	L-25
	3	Viticulture and Oenology	L-25
	4	Biotechnology	L-2
Soil Moisture Mapping	5	Viticulture and Oenology	PhD
	6	Internet of Things, Big Data, Machine Learning	L-31
	7	Computer Science / Informatics	L-31
	8	Mechanical Engineering	LM-33
Phytoremediation and Vermicomposting	9	Industrial Engineering for Sustainable Manufacturing	LM-31
	10	Food Science and Technology	LM-70
	11	Biotechnology	L-2
	12	Biotechnology	L-2
	13	Artificial Intelligence & Cybersecurity	LM-18
The Future of Irrigation for Agricultural Crops	14	Electronic Engineering	L-8
	15	Agricultural Sciences	L-25
	16	Public relations	L-20
	17	Territorial and Urban Planning	LM-48

The distribution of average exam marks at the date of participation to the C-Lab (Fig. 6) suggests a high (spontaneous) selection standard for the Contamination Lab, evidenced by the dominant presence of students with high academic performance (peaks at 25 and 30 over 30) and the absence of marks below 21 upon 30, indicating a sample composed of highly motivated participants with a solid theoretical foundation.

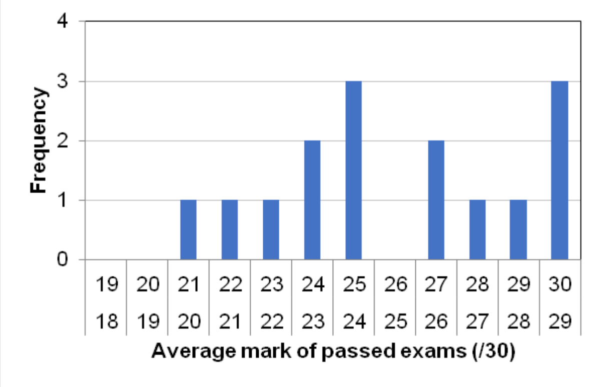

Figure 6. Distribution of students based on the average mark of passed exams.

The distribution by percentage of completed exams (Fig. 7) reveals a heterogeneous sample composition, characterized by two distinct prevailing groups. There is indeed a large segment at mid-course (50 % of completed exams), which guarantees energy and updated knowledge, and another significant group of senior students (90 % of completed exams), which contributes maturity and result-orientation.

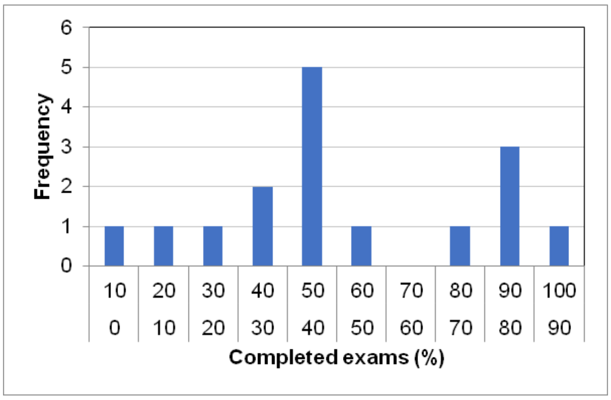

Figure 7. Distribution of students based on the percentage of completed exams.

The distribution by enrolment year (Fig. 8) reveals a strong presence of recently enrolled students (2024, i.e. students with only one year of university study), ensuring fresh perspectives within the Contamination Lab, complemented by a balanced mix of students from various other academic cohorts (e.g., 2018, 2020, and 2022), which guarantees a crucial combination of academic experience and novelty.

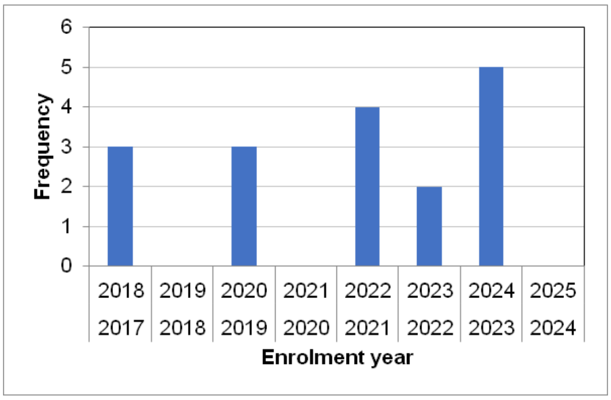

Figure 8. Distribution of students by university enrolment year.

The analysis by completed years of university (Fig. 9) reveals a strongly bimodal and polarized composition, with dominant groups at the 1st year and the 5th year, ensuring maximum intergenerational contamination between students with fresh perspectives and those with high academic maturity and deep theoretical knowledge.

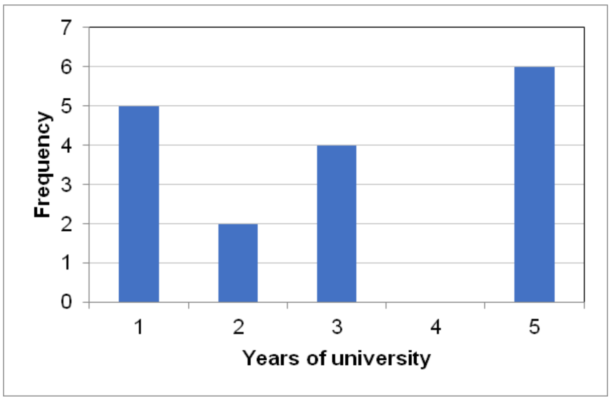

Figure 9. Distribution of students by completed years of university.

3. Results

3.1 Feedback from companies on students' outcomes

Company tutors were asked to provide specific feedback, by completing a questionnaire, on three main areas:

- the research outcomes,
- the relationship established with the student group,
- the overall collaboration between the company and the University.

The data collected yielded the following results:

- Research Outcomes; all company tutors agreed that the groups failed to present ideas that were truly innovative or immediately interesting for concrete application; despite this, three out of four tutors expressed an overall positive evaluation of the work carried out by their research group; only one tutor gave a strongly negative assessment.
- Relationship with the Research Group; the relationship between the company tutors and their respective research groups was reported to be generally good; however, in the majority of cases, a lack of initiative in interaction on the part of the groups was highlighted; one tutor was particularly critical of their group, while another expressed great satisfaction with the established relationship.
- Company-University Collaboration; all company tutors expressed a very positive evaluation regarding the collaboration with the University and indicated their willingness to repeat the experience.

3.2 Feedback from participating students

Students were asked to provide feedback by completing a questionnaire. The evaluation specifically covered:

- The level of interest shown towards the assigned research topic.
- The quality of the relationship between the group and the company tutor.
- The internal dynamics and relationships among group members.
- A general assessment of the overall experience within the CLab.

The analysis of the questionnaires revealed the following results:

- Interest in the Topic; one group expressed a critical evaluation of the research topic, describing it as uninteresting because it focused on market research rather than the development of a product or service; all other participants stated they were satisfied with the assigned topic.
- Relationship with Company Tutor;: only one group gave an unsatisfactory rating regarding the relationship with their company tutor; all other participants evaluated this relationship positively.
- Group Dynamics; a critical issue regarding the ability to work as a team was found in two out of four groups; in one case, the problem was attributed to the individual conduct of one member; in the other, to a lack of harmonious cooperation among participants.
- Overall CLab Assessment; almost all participants and all groups expressed a broadly positive opinion of the initiative promoted by the University and stated they would be willing to repeat the experience; only one participant expressed a critical view of the initiative, indicating they would not be willing to repeat it.

3.3 Feedback from academic tutor

The feedback received from academic tutors, the students and company tutors were all agreeing, while providing further information.

Specifically, the following critical points emerged:

- In two groups, a lack of internal cohesion was observed, which negatively affected the final outcome of the research work.
- In all groups, communication with the company tutor was insufficient, preventing an optimal alignment between the group's work and the company's expectations.
- In one case, a lack of proactive attitude was also noted on the part of a participating company, whose evaluation was found to be in disagreement with the final judgment expressed by the jury.

4. Discussion

4.1 Academic Background and Performance Correlation of Participants

The analysis of the participants' academic data revealed several interesting correlations with the final project ranking, evidenced by the determination coefficients of the regression lines plotted on the data.

The first graph presented here (Fig. 10) highlights a negative correlation between final ranking and years of attendance demonstrating that the groups achieving the best final ranking are, on average, those composed of students with the highest number of years of university attendance (and, presumably, the widest and riches competencies).

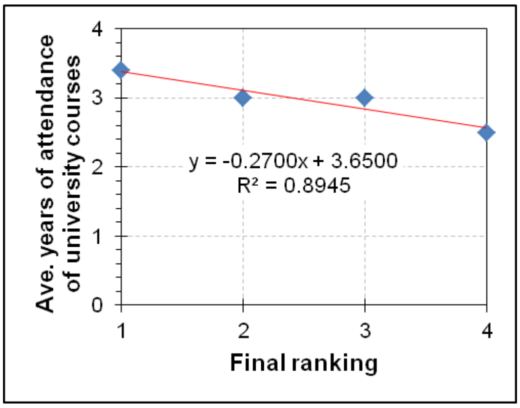

Figure 10. Average years of attendance of university courses vs final ranking

The graph of Fig. 11 demonstrates a strong, positive, and apparently counter-intuitive correlation, indicating that the Contamination Lab groups with the highest percentage of academic path completion tend to achieve the worst final ranking. However, this piece of information should be related to the previous figure, considering that the higher the number of attended academic years, the higher the possibility for students not to have completed their academic grades.

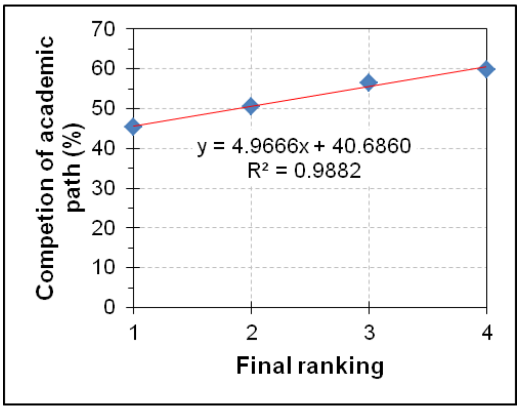

Figure 11 Completion of academic path vs final ranking.

The graph of Fig. 12 reveals a strong negative correlation indicating that the Contamination Lab groups with the highest average mark of passed exams are the ones that unequivocally have achieved the best final ranking.

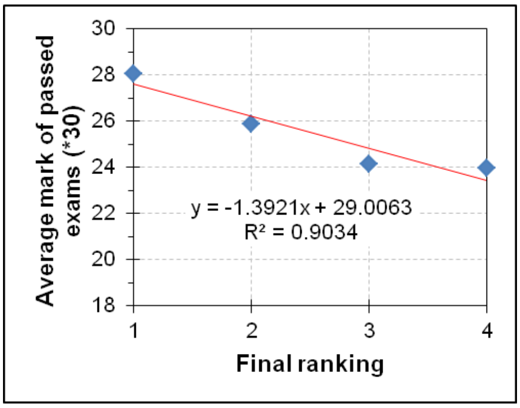

Figure 12. Average mark of passed exams vs. final ranking at the CLab.

Summarizing the data, the groups that achieve the best final ranking are, on average, those composed of students with the highest average mark of passed exams (strong negative correlation) and the highest number of years of university attendance (negative correlation). This suggests that fundamental cognitive capacity and academic maturity—developed through both successful study performance and long-term exposure to the university environment—are critical success factors in the C-Lab. These attributes translate into greater discipline, better problem-solving skills, and superior ability to synthesize complex though different information, which are essential for addressing the corporate challenges.

A strong, positive, and, at the first sight, counter-intuitive correlation was also observed: the groups with the highest percentage of academic path completion tend to achieve the worst final ranking. This potential divergence between the skills valued in a conventional curriculum (focused on quick exam completion) and those required by the C-Lab (creative exploration, risk-taking, and open-ended innovation) warrants further investigation even if it can be explained at first instance considering that the higher possibility for students not to have completed their academic grades if their academic path is longer, as for students with more attended academic years. This is in accordance with the first result. However, it is essential to note that the validity and generalizability of this counter-intuitive correlation must be evaluated with caution, given the limited sample size of C-Lab participants, which may not guarantee sufficient statistical power and representativeness to exclude the risk of a sampling error.

4.2 Why Companies Should Participate in a Contamination Lab (C-Lab) Instead of Seeking Traditional Academic Consultancy

Engaging in a Contamination Lab offers companies operating in the development of engineering systems for agri-food, forestry, and environmental sectors a fundamentally different—and often more strategic—form of collaboration with the university compared to simply requesting technical advice or consultancy. While conventional university–industry interactions are typically vertical, involving a direct and expert response to a narrowly defined technical problem, the C-Lab model promotes horizontal co-creation, where innovation emerges from an open, multidisciplinary dialogue between students, researchers, and company representatives.

In a C-Lab, companies propose real-world challenges not to be solved through a predefined method, but to be explored creatively by interdisciplinary student teams using design thinking, rapid prototyping, and agile innovation methodologies. This approach allows firms to tap into cognitive diversity and uncover ideas that are not constrained by existing technical paradigms—often producing unexpected, unconventional yet applicable solutions. In this regard, a C-Lab in Agricultural Engineering provides an ideal environment for the application of advanced systemic methodologies for functional analysis, problem-solving and creativity guidance, such as the TRIZ, i.e. the 'Theory of Inventive Problem Solving' (Wikipedia, 2026), developed by Genrich Altshuller and his colleagues since 1946 and formalized in 1984 (Altshuller, 1984).

Moreover, C-Labs serve as powerful platforms to promote corporate visibility and foster talent scouting. By participating, companies position themselves as dynamic and innovation-oriented actors within the academic ecosystem, gaining access, at the same time, to a pool of motivated students who may become future collaborators, interns, or employees whose competencies and attitudes are already tested in applied, team-based contexts. Unlike in traditional consultancy relationships, the C-Lab enables ongoing, informal interaction between companies and students throughout the challenge development process, creating deeper mutual understanding and long-term recruitment opportunities.

Another key advantage lies in the risk–benefit profile of these initiatives: the participation in a C-Lab is low-cost and low-risk for companies, but potentially high-reward, especially for SMEs and start-ups lacking internal R&D capabilities. Companies are actively involved in defining challenge briefs, mentoring, and evaluating project outcomes. Beyond immediate outputs, this engagement is not limited to a passive sponsorship: it also fosters alignment with the university's third mission by contributing to knowledge transfer, entrepreneurship, and innovation ecosystems, enhancing the reputation of participating companies among emerging professionals and within the university networks. Hence, it is possible to state that a Contamination Lab is not merely a support service—it is a collaborative innovation environment where companies are active stakeholders in shaping both educational and technological outcomes (Graham, 2018; Ministero dell'Istruzione dell'Università e della Ricerca (MIUR), 2016).

4.3 Strategic Advantages for a University in Hosting a Recurring Contamination Lab on Agricultural Engineering

For universities that host both Engineering and Agricultural Sciences departments, establishing and continuously supporting a Contamination Lab (C-Lab) dedicated to Agricultural Engineering offers strategic, didactic, and institutional advantages that extend far beyond the timeframe of individual editions. Agricultural Engineering, by its very nature, operates at the intersection of technical and biological systems, addressing complex challenges in agri-food, forestry, and environmental domains through an inherently multidisciplinary and a technical, application-oriented approach (Fig. 13). As such, a recurring C-Lab focused on this field can enhance the university's capacity to act as an integrated innovation hub—making, at the same time, the Agricultural Engineering group (and subject) more visible both internally and externally. This visibility is particularly valuable in positioning the university as a reference point for companies developing machinery, automation or digital solutions for bio-based systems, offering them a clear gateway to a coherent and well-coordinated academic interlocutor.

Moreover, the Agricultural Engineering research group/subject, due to its hybrid nature and systems-level vision, is uniquely suited to coordinate and synthesize contributions from vertical research groups in both Engineering (e.g., control systems, materials, electronics) and Agricultural Sciences (e.g., agronomy, animal science, food technology). A C-Lab can become a catalyst for such interdisciplinary collaboration, reinforcing internal synergies and enabling the creation of truly transdisciplinary project teams. This bridging function—akin to the role played by Management Engineering between technical and economical disciplines—makes Agricultural Engineering a strategic driver of cross-sectoral innovation and policy-relevant research.

From a governance and investment perspective, supporting a C-Lab in Agricultural Engineering also ensures high return on educational and institutional investment: the relevance of the field spans multiple sectors, including mechanization, food processing, forestry, water and soil management, and sustainability transitions. This breadth means that each iteration of the C-Lab contributes to multiple strategic priorities simultaneously—regional development, innovation ecosystems, green transition, and industrial partnerships. For these reasons, the continued investment in such a format not only strengthens the role of Agricultural Engineering within the university but also maximizes the institutional impact per unit of resource deployed, aligning perfectly with third-mission objectives and long-term research valorisation, in a win-win strategy.

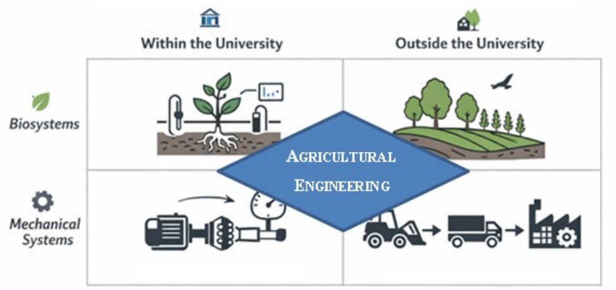

Figure 13. Possible role of Agricultural Engineering in relation to the Domains of Application/Interest (bio- or mechanical systems) and the Areas of Influence (within or outside the university); within this matrix, "horizontal" relations (i.e. between cells in an horizontal direction in this matrix) are interlocutions, "vertical" relations are collaborations.

5. Conclusions

5.1 Synthesis of Results and Model Validation

The results emerged from this case-study empirically confirm that the Contamination Lab (C-Lab) represents a necessary and scalable "hybrid response" to the difficult positioning of Agricultural Engineering in Italy. The marginalization of this sector has historically created a communication gap with engineering and technological disciplines and a lack of visibility toward companies manufacturing agri-tech, food machinery, and forestry equipment; the C-Lab has demonstrated its ability to bridge this gap by acting as a platform for institutional mediation. The validation of the model rests on three fundamental pillars:

- *Effectiveness of the so-called "Technological Triad" (Agriculture, Engineering, Computer Science)*: the platform facilitated a transdisciplinary collaboration that conventional departmental systems tend to inhibit. The success of the groups depended on the ability to integrate biological and agronomic sensitivity (Agriculture) with the rigor of mechanical design (Engineering) and the power of digital systems (Computer Science). This technical synergy validates the C-Lab as the natural environment for the evolution towards Biosystems Engineering, allowing diverse knowledge to converge on real-world problems that none of the three disciplines could solve in isolation.

- *Relational Value Beyond the Product*: despite some reservations expressed by company tutors regarding the immediate "innovation readiness" of the results (perceived as not yet mature for industrial application), all companies rated the quality of the process and the collaboration with the University extremely positively. This data demonstrates that the value of the C-Lab for the agri-tech industry lies in co-creation and talent scouting: companies seek direct contact with future designers and managers of agricultural technology.
- *Coordinating Role of Agricultural Engineering*: the students' willingness to repeat the experience confirms that the model meets a latent demand for hybrid skills. In this context, Agricultural Engineering assumes the role of a strategic "glue," proving to be the only discipline capable of translating IT and engineering innovations within the constraints and needs of the agricultural world.

5.2 Determinants of Success and Group Dynamics

The analysis of performance and interactions within the teams revealed crucial evidence for the future design of challenge-based learning initiatives. The data collected suggests that the effectiveness of groups in solving complex industrial challenges is not accidental but is influenced by academic and attitudinal factors that deserve in-depth analysis:

- *The Value of "Academic Maturity" as a Prerequisite*: the positive correlation between C-Lab performance and indicators, such as average grade and years of attendance, highlights that soft skills do not operate in a vacuum but are more effectively grafted onto solid disciplinary foundations. Academic maturity seems to provide students with the resilience and synthesis skills necessary to manage the ambiguity typical of open-innovation projects. This suggests that, in team composition, the presence of "senior" profiles acts as a stabilizer for group dynamics.
- *The Paradox of Study Completion*: the negative correlation emerged between the exam completion rate and the final project ranking is of extreme interest. This counter-intuitive data suggests a divergence between the success metrics of the traditional academic curriculum—often focused on mnemonic learning speed and conformity to predefined schemes—and the skills required by the C-Lab. In unstructured industrial contexts, risk propensity, cognitive flexibility, and divergent thinking are necessary; those are qualities that, paradoxically, risk being "eroded" by an excessively rigid study path focused solely on quantitative performance.
- *Conflict Management and Team Coordination*: Although multi-disciplinarity is the lifeblood of innovation, the results show that it can generate communicative friction and coordination difficulties, if not mediated. The tendency of teams to encounter obstacles in communication with company tutors highlights a linguistic gap between university and industry. This underlines the need to systematically integrate specific training modules on teamwork management and creative problem-solving methodologies, especially within Agricultural Engineering curricula.

5.3 Implications for Agricultural Engineering and Academic Policy Recommendations

To reverse the marginalization of Agricultural Engineering and recover the necessary dialogue with Engineering and Computer Science departments, the Contamination Lab model must not be interpreted as an isolated or one-off event. On the contrary, it must evolve into a permanent and structured institutional tool. Based on the evidence collected, it is recommended that universities hosting both agricultural and engineering-technological departments formally adopt this model, focusing on three strategic directions:

- *Synchronization of Languages and "Disciplinary Diplomacy"*: the C-Lab serves as a training ground for future Biosystems Engineering graduates, allowing them to perform the necessary synthesis between the metrological and technical rigour, typical of engineers, and the biological and environmental complexity, inherent to agronomists. This "synchronization" is the only way to heal the historical Italian academic misalignment: the C-Lab forces different areas to converge on a common object (the machine, the sensor, the process), transforming the bureaucratic barriers of SSDs into permeable boundaries for intellectual exchange.

- *Evolution of the Corporate Role: From Client to Co-creator*: critical feedback received from tutors highlights a fundamental policy lesson: the success of hybridization depends not only on the university but also on the maturity of the industrial partner. It is necessary to train corporate mentors so they move beyond the logic of "request for a supply/advice" and embrace that of a "collaborative research." Universities should promote the C-Lab as an Open Innovation environment where the company does not limit itself to evaluating a result, but actively participates in the training of the very hybrid profiles it claims to need.
- *Formalization in Study Paths*: to maximize impact, it is suggested to integrate the C-Lab not as an extracurricular activity, but as an accredited optional module (with ECTS/CFU) or as a preparatory phase for the degree thesis (related to a compulsory qualification). This would give academic dignity to the "contamination" activities and encourage the brightest students to invest time in projects that, while risky and unstructured, represent the true frontier of employability in agri-tech 4.0.

5.4 Study Limitations and Possible Future Evolution

Despite the interesting evidences from the obtained results, this study has some methodological limits that pave the way for necessary future investigations, and evidences some possible refinements of the proposed model:

- *Large-scale Validation*: future research developments should include monitoring multiple editions of the C-Lab and comparing different universities. This will confirm whether the "study completion paradox" and the correlation with academic maturity are structural phenomena of the Italian university system or linked to the specific local context.
- *Transition to the Thematic Model*: the natural evolution of the proposed format involves moving from an "open" approach to vertical Thematic C-Labs. Although this new format is not free from potential problems (Tab. 5), pre-defining priority technological areas—such as the development of agricultural robotics, the integration of new materials for agri-tech, or the application of AI and Big Data in crop monitoring—would allow for the attraction of industrial partners with more homogeneous technical challenges. This approach would foster deeper scientific convergence between Agriculture, Engineering, and Computer Science departments, bringing the solutions designed by students closer to the industrial prototyping phase.

Table 5. Pros and Cons of a thematic model for the future C-Lab.

Aspect	Pros	Cons
Strategic Thematic Framing	Creates coherence across activities; aligns with long-term research themes	Reduces flexibility; may exclude emerging or interdisciplinary topics
Company Engagement	Facilitates deeper, more strategic partnerships with companies in relevant sectors	Limits involvement of companies from outside the thematic area
Academic Involvement	Enables targeted involvement of experts; easier coordination across departments	May side-line researchers not directly aligned with the selected topic
Student Orientation	Helps students understand expectations and relevance of their participation	May discourage students with unrelated backgrounds from applying
Employment Matching	Improves alignment between student skills and labour market opportunities	Risk of narrowing exposure to only a segment of the agri-tech sector
Participation Diversity	Enhances clarity of the lab's objectives and attracts students with strong motivation	Potential reduction in interdisciplinary richness and spontaneity

5.5 Final remarks

The Udine experience validates the C-Lab as a general organizational model capable of transforming a structural limit into a strategic advantage, creating an ecosystem where, the hybridization of more than a subject (in this case: agricultural, engineering, and IT skills) produces a value greater than the sum of the individual disciplines. In comparison to traditional capstone courses or internships, C-Labs offer greater flexibility, transdisciplinarity, and autonomy for students, while also delivering tangible value to external stakeholders. From a pedagogical point of view, after this experience, it is also possible to formulate the following reflection: to prevent the progress of an academic career from reducing students' mental flexibility, it is essential to introduce also contamination experiences early on. A contamination lab is thus confirmed as an essential tool for "training" the ability to apply technical rigor to fluid problems, preparing future graduates for the real challenges, in particular in the agri-tech sector. As such, C-Labs represent a powerful tool to revitalize the teaching and perception of Agricultural Engineering in Italy, helping to attract diverse student profiles, stimulate entrepreneurial initiatives in agri-tech, and align academic training with the innovation dynamics of real-world agri-food systems. Therefore, the C-Lab Udine offers Agricultural Engineering the opportunity to reclaim its centrality: no longer a "niche" sector between two distant areas, but the centre of gravity around which technological innovation for sustainability and food security revolves. It can be seen as a concrete response to the need for a new paradigm for Agricultural Engineering in Italy. The evolution towards a more structured, thematic, and institutionalized format will allow this discipline to emerge from its academic "shadow zone" to assume a strategic coordinating role. By transforming the current difficult positioning into a competitive advantage, Agricultural Engineering can become the true catalyst for Italian agro-industrial innovation, capable of governing the complexity of the ecological and digital transition through the skillful synthesis of diverse knowledge.

Author Contributions

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Conflicts of Interest

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Abbreviations

The following abbreviations are used in this manuscript:

ABET	Accrediting Board for Engineering and Technology
AIIA	Italian Association of Agricultural Engineering (it. Associazione Italiana di Ingegneria Agraria)
ASABE	American Society of Agricultural and Biological Engineers
BSc	Bachelor of Science
CAP	Common Agricultural Policy
CFU	University learning credits (it. Crediti Formativi Universitari)
CLab	Contamination Lab
CREA	(Italian) Council for Agricultural Research and Economics (it. Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria)
CUP	Univocal Project Code (it. Codice unico di progetto)
DI4A	Department of Agri-Food, Environmental and Animal Sciences of UniUD
DMIF	Department of Mathematics, Computer Science and Physics of UniUD
DPIA	Polytechnic Department of Engineering and Architecture of UniUD
ECTS	
ECTS	European Credit Transfer System
EPFL	(Swiss) Polytechnic Federal School of Lausanne (fr. École Polytechnique Fédérale de Lausanne)
ERDF	European Regional Development Fund
ESF	European Structural Funds
EU	European Union
FabLab	Fabrication Laboratory
FSC	(Italian) Development and Cohesion Fund (it. Fondo Sociale di Coesione)
HIT	Innovation hub of Trentino (it. Hub Innovazione Trentino)
ICT	
INEST	interconnected North East
LM-XX	Italian codification for Master's degree curses
L-XX	Italian codification for Bachelor's degree courses
MIUR	(Italian) Education, University and Research Ministry (it. Ministero dell'Istruzione dell'Università e della Ricerca)
MSc	Master of Science
MUR	(Italian) University and Research Ministry (it. Ministero dell'Università e della Ricerca)
PhD	Philosophiæ Doctor
PNRR	(Italian) National Recovery and Resilience Plan (it. Piano Nazionale di
PoliMI	Polytechnic of Milan
PoliTO	Polytechnic of Turin

- PR FESR Projects on the European Regional Development Fund (it. Fondo europeo di sviluppo regionale)
- R&D Research and Development
- SMEs Small and Medium Enterprise
- SSD Scientific-Disciplinary Sector
- TRIZ Theory of Inventive Problem Solving (ru. Teorija Rešenija Izobretatel’skich Zadač)
- UniMAP Universiti Malaysia Perlis
- UniUD University of Udine

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