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A Constructionist Approach for the Future of Learning

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Abstract

This doctoral thesis investigates the impact of the "maker movement" on education, exploring how making, tinkering, coding, and play contribute to the development of 21st-century skills such as creativity, problem-solving, and computational thinking. Grounded in the constructionist approach, it emphasizes the intrinsic value of the learning process and interdisciplinary connections across STEAM (Science, Technology, Engineering, Arts, and Mathematics) domains. Starting from a robust exploration of the literature and an empirical study into youth perceptions, this research outlines an expansive educational framework that transcends traditional STEAM boundaries.

The thesis illustrates the transformative journey, highlighting the formation of communities of practice and the launch of innovative outreach initiatives. It argues against offering a singular conclusion, instead presenting an integrated approach that weaves together theoretical insights with practical outcomes. The work supports pedagogical principles and demonstrates the benefits of innovative educational activities, advocating for a model of cross-disciplinary contamination and inclusivity.

By bridging the gap between various fields of research and between academia and the broader community, this dissertation suggests a paradigm capable of producing impactful educational advancements. It presents a journey through educational models and methodologies, the expansion of university missions, and the measurement of the impact of university FabLabs, thus contributing significantly to both academic discourse and practical applications in educational settings.

1 Introduction

Contemporary research findings provide substantial support for the notion that engaging in making and tinkering activities contributes significantly to the development of crucial skills such as creativity, innovation, problem-solving, and computational thinking — all of which constitute the essential skill set for the 21st-century [22, 157, 106, 123]. Unlike conventional teaching methods that often emphasize a definitive solution to a problem or a predetermined process for reaching a solution, approaches centred around making, tinkering, coding, and play accentuate the intrinsic value of the process itself over the outcome. Moreover, this approach encourages interdisciplinary connections within the **STEAM** domains (**S**cience, **T**echnology, **E**ngineering, **A**rts, and **M**athematics), an aspect that has been underscored by scholars in the field [120].

The surge of interest in the “maker movement” in recent years has propelled an active process involving building, designing, and innovating tools and materials to craft shareable artifacts. Referred to as “making”, this learner-driven educational practice promotes learning, active engagement, and comprehension [229]. Making denotes the act of generating tangible artifacts [113], or creating physical entities [193]. It also encompasses the strategic utilization of software and/or physical materials to construct artifacts [168].

Tinkering, an integral facet of making [229], is a problem-solving technique and learning strategy characterized by a culture of improvement, experimentation, and iterative trial-and-error methods [133]. Advocates like Martinez and Stage [145] contend that making and tinkering embody a playful approach to problem-solving, driven by direct experiences, experimentation, and discovery. The acts of programming, coding, and physical computing are regarded as inherent to making activities [113], allowing students to construct and reconstruct artifacts, design programs, and debug errors.

In the context of programming, making, and tinkering, the dynamic and active nature of play is inherently intertwined. The playful essence of these activities significantly enhances learners’ interest [117, 229]. Scholars like Martin [143] assert that learning environments rooted in making and tinkering settings are inherently motivational, fostering engagement, persistence, and identity development. While the practice of making, tinkering, coding, and play is relatively new in educational contexts, its theoretical foundations can be traced back to Papert’s constructionism [121], linked to Piaget’s constructivism. The essence of Papert’s theory is that knowledge is constructed through interactions between learners and the world, people, and objects [3], mirroring the experiential nature of making. Similarly, Papert’s constructionism posits that individuals build internal knowledge when they design and fabricate meaningful artifacts [169]. This approach is also aligned with Vygotsky's social constructivism, which underscores the role of interaction and knowledge sharing in children's cognitive development [163].Education and scientific dissemination have long been the cornerstone for shaping the minds and thoughts of generations.

This doctoral thesis is a multifaceted exploration of our constructionist approach to education, grounding our perspectives in the dynamic and interdisciplinary realm of STEAM. As one navigates through this comprehensive study, numerous examples emerge, illustrating our relentless efforts in forging this pedagogical approach within an interdisciplinary framework.

1.1 Goal

This thesis embarks on a comprehensive exploration of the multifaceted challenges in STEAM education, addressing them by placing a primary emphasis on pedagogy over tools, and emphasizing an interdisciplinary approach and adaptable assessment frameworks. By integrating various disciplines, we recognize that understanding the computational aspects alone is insufficient; instead, a broader perspective is essential for effective education. In pursuit of this, we adopt a "generalist" approach, drawing on diverse disciplines to uncover novel insights. We acknowledge the importance of scientific and academic processes but also value knowledge from informal sources like books, policy documents, practitioner articles, and oral traditions.

Our research delves into foundational literature, ranging from 21st-century skills to the integration of maker and tinkering cultures in education (Chapter 2). Beginning with an explorative study (Chapter 3), we have designed and developed an integrated and innovative architecture for our learning lab through an iterative process (Chapter 4). Concurrently, we have implemented concrete educational interventions for our university students (Chapter 5), for schools in our geographical area (Chapter 6), and for our local community (Chapter 7), culminating in the development of "TheLaaab", a platform to reach a wider audience (Chapter 8). In summary, we have developed a holistic framework that extends beyond traditional STEAM boundaries, aiming for a comprehensive pedagogical outlook. Over three transformative years, our team has expanded its scope, engaging with various communities and fostering interdisciplinary discussions within the education sector, both inside and outside the university. Given that our extensive investigation renders a singular conclusion limiting, we have woven together our research threads in the final chapter. Our work not only confirms but also enhances established concepts in the literature, reinforcing pedagogical principles and underscoring the benefits of innovative educational activities.

This dissertation stands out for its "integrated" approach, which merges academic research with third-mission insights. It leverages the strengths of both domains, uniting areas that typically remain separate. By encouraging cross-disciplinary collaboration and narrowing the divide between academia and the public, this work proposes an inclusive model that engages all citizens, holding the promise of significant advancements in education. Our journey has traversed three interconnected areas: educational models and methodologies, extending university missions beyond conventional scopes, and measuring impacts. Each addresses a crucial aspect of the evolution and effectiveness of university FabLabs, contributing to the overarching goal of advancing STEAM education.

1.2 A few words about the author(s)

In the realm of education, where innovation and multidisciplinary thinking intersect, this doctoral thesis emerges as a unique journey. This atypical work not only explores the rich tapestry of constructionist pedagogy within the STEAM framework but also reflects the diverse and evolving background of the author, whose own path of growth has significantly influenced the development of these ideas. For this reason I have decided to briefly introduce myself.

Francesca Fiore is a Ph.D. candidate in the Social Informatics Research Group at the University of Trento, in Italy. With a background in sociology, her research focuses on the intersection between learning, creativity, crafting, and technology and attempts to design ways to diversify participation and practice in scientific dissemination and teaching. She coordinates the activities of the Fablab UniTrento, a laboratory of digital prototyping that she helped to create in 2020. Within the University of Trento, Francesca Fiore teaches courses in Participatory Design, Information Systems, and ICT Innovation; she is also a mentor to some activities promoted by the School of Innovation. Her experience inspired her to establish the GLOW association. Through this entity, she organizes events and courses on scientific dissemination related to these topics. Currently, she coordinates almost 20 trainers and facilitators..

She is deeply fascinated by the multifaceted domain of play. This includes multiple activities, contexts, social engagements, and tools, and the abundance of ideas and innovations they produce. Grounded in constructionist ideology, she champions the active and public creation of artifacts and ideas of personal resonance. Such endeavors not only empower individuals but serve as formidable instruments for cognitive development and refinement. With learners at the center of her ethos, she advocates for a learning paradigm driven by their intrinsic values and aspirations. This approach transcends prescribed curricula and the predispositions of educators.

Beyond theory, her philosophy is rooted in recognizing and celebrating the individuality of each learner's way of interacting with, and understanding of, the world. This challenges the entrenched norms and conventions that often prescribe the "right" ways of comprehension. Her unwavering commitment lies in uplifting diverse modes of knowledge acquisition. She ardently work towards devising tools and experiences that empower individuals from all walks of life, enabling them to forge their unique connections with the world.

Given this brief introduction, however, it is crucial to mention that this thesis predominantly employs a pluralistic perspective, emphasizing "We". Such an approach underscores that this work, rich in depth and breadth, is a collective endeavor. With a tapestry of skills, mindsets, and backgrounds, our team brings forth fresh perspectives, inspirations, and ideas. Our strength is derived from our collective diversity. Together, we epitomize the idea that we are indeed, greater than the sum of our individual components.

1.2.1 Methodological note

In the vast tapestry of academic inquiry, this thesis does not anchor itself solely to a single theoretical strand. Much like its author, the text is an amalgamation of varied influences and philosophical currents. Owing to a robust methodological grounding rooted in her sociological education, the author ventured into the realm of social informatics and later adopted a more comprehensive approach, specifically the methodology of constructionism.

While we strive to be “bridges”, connecting disparate pieces of knowledge, we do not claim expertise in every realm. Our strength often lies not in possessing all the answers but in identifying those who can guide us through the maze of challenges.

The rigorousness of our findings may occasionally come under scrutiny, given the inherent complexities of conducting longitudinal studies or the brief span of some projects, which may elude conventional metrics. Furthermore, when delving into transversal competencies and skills, immediate assessment may be elusive. Yet, the palpable enthusiasm of participants and educators, the heartwarming instances of students we once met in middle schools now walking our university corridors expressing gratitude, often compensate for the arduous journey.

Situating itself uniquely, this thesis stands at the intersection of diverse disciplines, a phenomenon seldom witnessed in the realms of science and engineering. Our aspiration is to stimulate actionable contemplation on the “underrepresented challenges” we spotlight. While we acknowledge the importance of significance and reproducibility, we postulate that their attainment might necessitate a deviation from traditional methods. Our ultimate goal is not merely to provide a roadmap for replicating results; we endeavor to furnish readers with a profound comprehension of the foundational processes that underpin our work.

1.3 Thesis structure

Chapter 2 delves deep into the scholarly realm, presenting an exhaustive state-of-the-art literature review. Beginning with the globally recognized 21^{st}-century competencies, the chapter meticulously investigates how the maker culture and the art of tinkering can be instrumental in revitalizing the Italian education system.

In Chapter 3, our focus shifts to an exploratory field study. This research examines the perceptions surrounding STEAM and academic orientation in the Trentino region, offering insights garnered from students of our university.

Chapter 4 lays the foundational stone of this thesis, outlining the architecture of our methodologies and underlying philosophies. It further elucidates our research queries and critical focal points that guide our investigative journey.

Chapter 6 through 8 present applied case studies, showcasing the practical application of our constructionism framework. This section offers a panoramic view of its implementation among our university students of the University of Trento, collaborations with schools, its outreach to the wider community, and its digital adaptations for online audiences.

Lastly, Chapter 9 aims to weave together the diverse threads explored throughout the thesis, offering a comprehensive conclusion that encapsulates our findings.

Figure 1.1 provides an overview of the thesis structure, detailing its division into chapters and showing which articles from the publication list can be found in each of them.

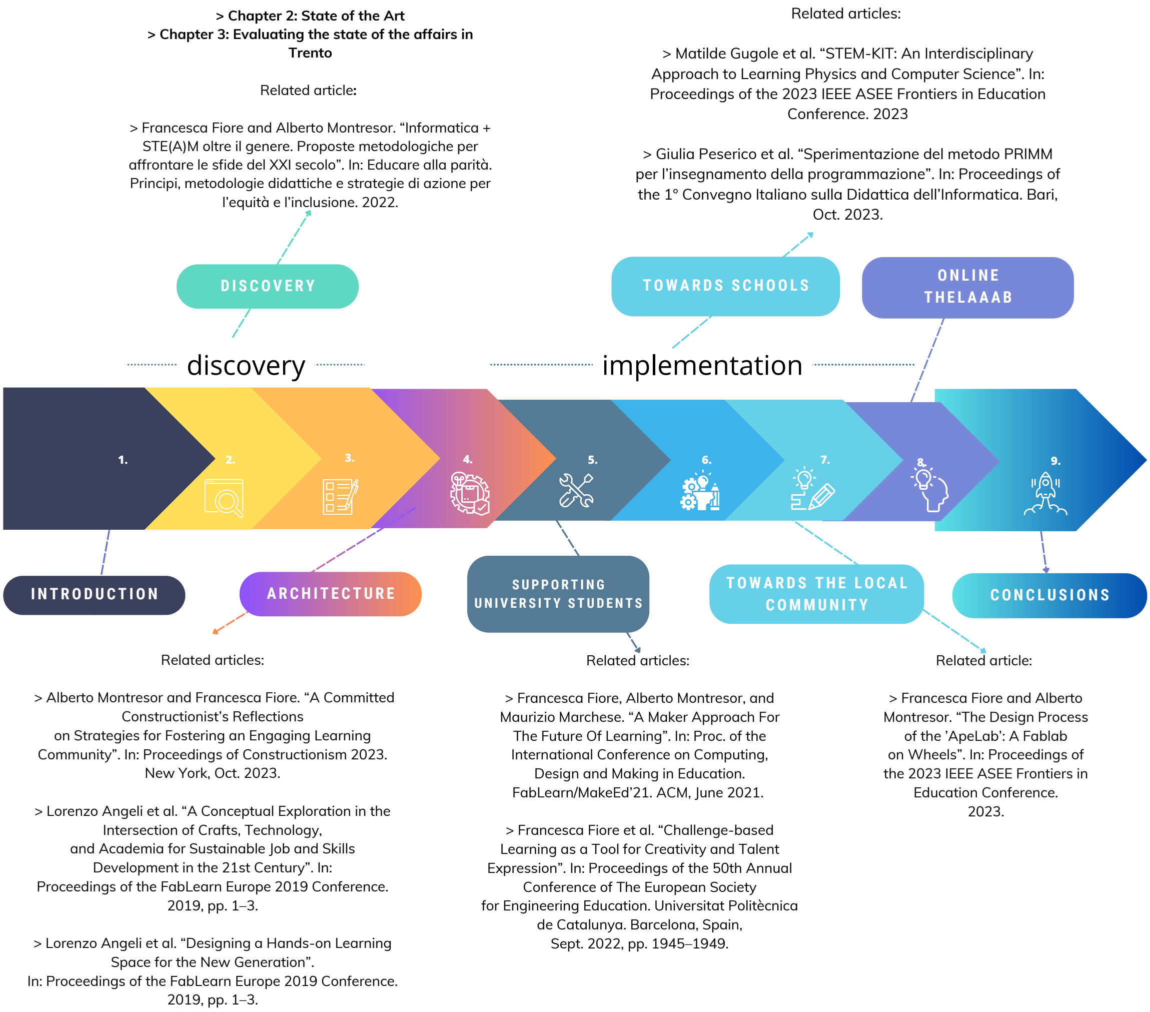

Figure 1.1. Thesis Structure

List of contributions The following publications have been authored during the PhD programme and reported in the following chapters.

- Lorenzo Angeli, Milena Stoycheva, Francesca Fiore, Alberto Montresor, and Maurizio Marchese. "A Conceptual Exploration in the Intersection of Crafts, Technology, and Academia for Sustainable Job and Skills Development in the 21st Century". In: *Proceedings of the FabLearn Europe 2019 Conference*. 2019, pp. 1–3
- Lorenzo Angeli, Francesca Fiore, Alberto Montresor, and Maurizio Marchese. "Designing a Hands-on Learning Space for the New Generation". In: *Proceedings of the FabLearn Europe 2019 Conference*. 2019, pp. 1–3

- Francesca Fiore and Alberto Montresor. "Informatica + STE(A)M oltre il genere. Proposte metodologiche per affrontare le sfide del XXI secolo". In: *Educare alla parità. Principi, metodologie didattiche e strategie di azione per l'equità e l'inclusione.* 2022
- Francesca Fiore and Alberto Montresor. "The Design Process of the 'ApeLab': A Fablab on Wheels". In: *Proceedings of the 2023 IEEE ASEE Frontiers in Education Conference.* 2023
- Francesca Fiore, Alberto Montresor, and Maurizio Marchese. "A Maker Approach For The Future Of Learning". In: *Proc. of the International Conference on Computing, Design and Making in Education.* FabLearn/MakeEd'21. ACM, June 2021, 11:1–11:4. DOI: 10.1145/1122445.1122456
- Francesca Fiore, Alessandra Scroccaro, Arianna Conci, and Alberto Montresor. "Challenge-based Learning as a Tool for Creativity and Talent Expression". In: *Proceedings of the 50th Annual Conference of The European Society for Engineering Education.* Universitat Politècnica de Catalunya. Barcelona, Spain, Sept. 2022, pp. 1945–1949. ISBN: 978-84-123222-6-2. DOI: 10.5821/conference-9788412322262.1259. URL: https://sefi2022.eu/
- Matilde Gugole, Francesca Fiore, Tommaso Rosi, Giuliano Zendri, and Alberto Montresor. "STEM-KIT: An Interdisciplinary Approach to Learning Physics and Computer Science". In: *Proceedings of the 2023 IEEE ASEE Frontiers in Education Conference.* 2023
- Alberto Montresor and Francesca Fiore. "A Committed Constructionist's Reflections on Strategies for Fostering an Engaging Learning Community". In: *Proceedings of Constructionism 2023.* New York, Oct. 2023
- Francesca Fiore and Chiara Gulino. "Designing an Inclusive Activity Mediated By Technology and Performative Arts". In: *Proceedings of the 9th World Congress on Electrical Engineering and Computer Systems and Sciences (EECSS'23).* Brunel University, London, United Kingdom. DOI: 10.11159/mhci23.104
- Giulia Peserico, Francesca Voltolini, Maria Serafini, Federica Picasso, Daniele Agostini, Francesca Fiore, Anna Serbati, and Alberto Montresor. "Sperimentazione del metodo PRIMM per l'insegnamento della programmazione". In: *Proceedings of the 1° Convegno Italiano sulla Didattica dell'Informatica.* Bari, Oct. 2023

2 State of the art

Where did we start from

The digital revolution has brought a profound transformation of the job market and of business in general, a transformation that is still ongoing [203]. This shift requires policymakers and businesses to respond immediately and far-sighted to avoid missing the wave of the fourth industrial revolution. Technology and automation are already destroying or changing millions of jobs, and several estimates show that many more are at risk of automation over the next decade; particularly vulnerable are administrative and routine functions. Up to half of global work activities could be automated [149], and by 2030 between 400 and 800 million people could see their work transformed by automation. In addition, up to 375 million workers (or 14% of the global workforce) may have to switch job categories [150]. Moreover, the fact that the jobs most likely to be replaced by automation are those with low pay raises further concern [195]. However, work automation is only one side of the coin. In fact, the digital revolution is also creating new jobs, and today's jobs, in most cases, are not really 'destroyed', but rather transformed, while requiring new skills and knowledge.

In particular, we are seeing a sharp decrease in activities based on routine cognitive skills and manual skills, while the share of tasks requiring analytical and interpersonal skills continues to increase. On the one hand, this change could appear positive and encouraging, as it would allow workers to focus on cognitive activities considered more stimulating. On the other hand, however, not everyone has adequate knowledge, skills and characters to adapt to a world of work that requires less manual and routine activities; this generates a sense of vulnerability and insecurity — not only from a strictly occupational point of view, but also from a socio-relational point of view — in those who cannot count on professional requalification and reintegration tools, absolutely necessary in a constantly changing world [72].

Adapting to this new reality will not be easy, especially taking into account the fact that employment growth should come mainly from new and highly skilled jobs, which may not be able to absorb those lost in other economic sectors [220]. According to some estimates [220], 65% of children who enroll in primary school in 2019 will be employed, at the end of their studies, in jobs that do not yet exist. Preparing young people for this change requires the support and modernization of education at all levels, from primary school to university, in order to provide students with the skills they need to work in the digital age. Only with the right public education and training policies will the next generation of young Italians be able to leverage the digital revolution to create new businesses, generate jobs in innovative technology sectors and solve local problems in an alternative and innovative way.

Failing in this challenge, ignoring the opportunities offered by technology, would not only be a missed opportunity for growth and wealth creation in our country, but it could also exacerbate the inequalities between Italy and the other countries that are already responding to the digital revolution. Italy has not yet adapted to this change and is confirmed as one of the tail lights on a European scale for investment in training, which means fewer specialized profiles attractive to companies, especially in the technological field and in the STEAM disciplines.

The low number of graduates in STEAM disciplines is a problem of fundamental importance, which must be addressed in a constructive way to make our country more competitive to allow young people to find employment quickly and with good salary levels. The failure of the modernization of education in Italy is reflected in the data on youth employment immediately after graduation. Only 56.5% of young people between 20 and 34 find work immediately as soon as they finish their studies, a percentage in Europe that is higher than only Greece [75].

It is also emphasized that young people with economic or social disadvantages tend to have weaker digital skills than their more fortunate peers, thus risking further accentuating inequalities within the country [52]. If you look at the data from the Organization for Economic Co-operation and Development (OECD), workers with the highest digital skills already earn on average 27% more than those with basic skills [211] and, in OECD member countries, 42% of people with no digital skills are unemployed [211, 221]. Of particular concern is the already significantly low share of women in the area where most of the jobs will be created in the future.

In OECD countries, fewer than 5% of women plan to pursue a career in engineering and computer science [211, 210]; this figure is even lower in the European Union (16%). 58% of ICT specialists employed are female. However, in Italy, the percentage is even lower with merely 15 out of 100 women working in the digital sector [75]. The policies implemented to prepare the country for the digital revolution, especially those in the educational sector, will play a crucial role in determining its impact on our society.

2.1 The skills of the 21st century

As our society evolves, the school risks falling behind, continuing to propose a fragmentation of skills and disciplines that reflects a work model that is now on the verge of extinction. There is a general transformation of industrial economies into knowledge-based economies, which becomes of central importance and requires to be continuously regenerated and updated through learning [68, 232].

While companies are looking for transversal professional profiles, characterized by a ductile intelligence — i.e. professional figures who have skills aimed at social interaction, collaboration, creativity and other areas that cannot be replaced by machines — students should be trained in jobs that do not yet exist, technologies not yet invented and problems not yet recognized as such [68].

Some argue that we are transitioning from an industrial society to an information society; however, as posited by Mitchel Resnick [189], a more apt description of our evolving society might be a "knowledge society," with creativity at its core. Some argue that we are transitioning from an industrial society to an information society; however, as posited by Mitchel Resnick [189], a more apt description of our evolving society might be a “knowledge society”, where creativity is at the core. In this emerging paradigm, it is imperative for individuals to develop the ability to be flexible and adapt to new scenarios and contexts.

With regard to ICT skills, it is evident that it is not enough to equip students with a specific set of theoretical and specialist knowledge, as these would risk becoming obsolete soon. In fact, currently almost 50% of the disciplinary knowledge acquired during the first year of a four-year technical degree is already obsolete at the time of graduation [220].

What matters is to prepare young people to be creative, to adapt to an ever-changing environment, to learn to learn, to take initiative and to be resourceful. In short, to be protagonists of the digital revolution and active users of digital tools to innovate and generate wealth. In this sense, technology and digital skills should not be seen by students as an end, but rather as a tool for learning, creating, expressing themselves and offering innovative solutions to economic and social problems.

In 1996, the Delors Report [65], crafted by the International Commission on Education for the Twenty-first Century, deliberated on the competencies essential for addressing impending challenges. The discussion identified four foundational elements: knowledge, understanding, competencies for life, and competencies for action. These elements were subsequently organized into four main categories, recognized as the Four Pillars of Education: Learning to Know, Learning to Do, Learning to Be and Learning to Live Together [203].

Wagner [231] and the Change Leadership Group at Harvard University identified another set of competencies and skills. They argued that the skills needed to be ready for twenty-first century life, work and citizenship are:

- critical thinking and problem solving;
- collaboration and leadership;
- agility and adaptability;
- initiative and entrepreneurialism;
- effective oral and written communication;
- accessing and analysing information;
- curiosity and imagination [203].

Lastly, in 2015, in the report “New Vision For Education” [162], the World Economic Forum (WEF) has identified sixteen competencies that should be prioritized in 21st century societies.

The WEF groups them into three pillars (Figure 2.1). The first is foundational literacies. This category includes literacy — which consists of the ability to read, understand and use written language — and numeracy — which consists of the ability to use numbers and symbols to

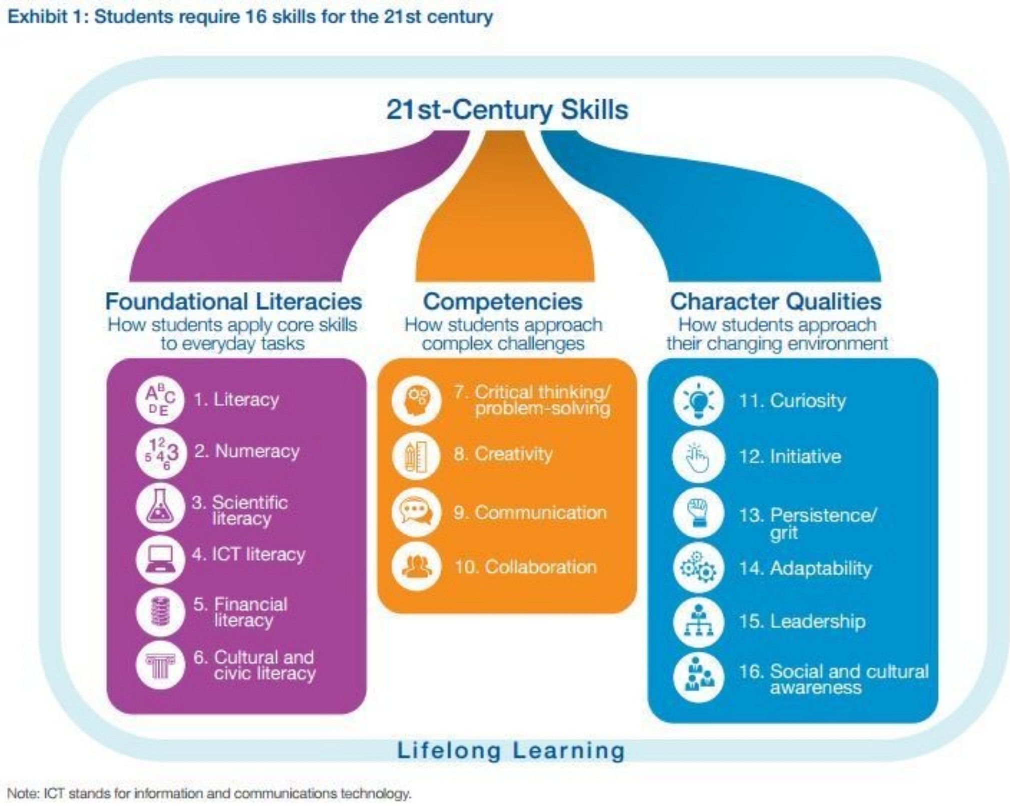

Figure 2.1. The skills of the 21st century.

express quantitative relationships. Both remain extremely relevant in contemporary society as a prerequisite for allowing students to learn new skills, including digital ones, and to train independently throughout their life. Other basic knowledge for the 21st century are: scientific literacy, that is, the ability to use scientific knowledge and principles to understand the environment of an individual and formulate hypotheses; ICT literacy, that is, the ability to use and create content for technology, to find and share information, answer questions and interact with other people and with computer programs; financial literacy, which is the ability to understand and apply conceptual financial aspects in practice; cultural and civic education [1]. Basic knowledge, however, may not be sufficient in the digital age. Therefore, the second pillar proposed by the WEF includes competences. These describe how students face complex challenges and critically evaluate and pass on knowledge, as well as the ability to work efficiently in a team. For this, critical thinking and problem solving are fundamental. Specifically: the ability to identify, analyze and evaluate situations, ideas and information to work out solutions to complex problems. A prerequisite for critical thinking is creativity, that is, the ability to imagine and devise innovative ways to deal with complexities. Communication and collaboration involve the ability to listen, understand and contextualize information as well as the ability to work as a team to achieve a common goal, together with the ability to prevent and manage conflicts.

Finally, the third pillar includes character qualities, which describe how students cope with an ever-changing environment. Perseverance and adaptability guarantee better chances of resilience and success in facing obstacles. In particular young people, who will have to use ever recent technologies and face unfamiliar problems, will be asked to be very adaptable. Curiosity and initiative are the base for discovering new concepts and ideas. Finally, leadership skills and social and cultural awareness enable constructive interactions with others in socially, ethically and culturally appropriate ways. The second and third pillars of 21st century competencies presented by the WEF relate more generally to social and emotional learning (SEL).

The WEF [161] discovered that students who enjoy social and emotional learning tend to score higher compared to their peers. Over the long term, this engagement is mirrored in enhanced educational outcomes and elevated employment rates. The OECD also identifies basic knowledge, technical skills, social skills and emotional intelligence as essential to enable effective use of digital technologies and to quickly adapt to new situations and new jobs [72, 220]. In particular, the OECD recognizes the importance of three groups of skills: technical and professional knowledge (including specialized ICT skills to program, develop applications and manage networks); generic ICT skills to use these technologies for professional purposes; complementary skills (leadership, communication, teamwork and the ability to deal with complex problems).

The European Commission, in the Framework for Digital Skills 2.0 [52], has highlighted five key areas: literacy on data and information — which includes the ability to critically analyze information and therefore to search, evaluate and interpret the data and their sources; communication and collaboration — which consist in the ability to communicate and collaborate in various forms through digital means, as well as to exercise active citizenship through digital services; the ability to create, modify and improve digital content; the ability to protect devices, content, data and online privacy; and, finally, the ability to solve problems through digital means and to innovate processes and products through technology. There now seems to be a widespread consensus on the need to promote the skills of the future highlighted in this section, but the debate on how these skills can be promoted in education is still open.

2.2 Makers and the school of the future

Even though the need to promote new skills at school appears as a clear goal, only few countries have developed strategies to promote their acquisition in formal education [210]. In Italy, the curriculum of most schools has not undergone radical changes in recent decades (1990–2020), despite the profound changes in the economic and social fabric; all of which means that we are still educating our students for the past rather than the future.

Furthermore, teaching methodologies have remained traditional, although many of the skills taught in schools are — with rare exceptions — the easiest to digitize, automate and outsource. A particularly promising application regarding 21st-century skills is the integration of the maker approach into the school curriculum. The makers are the “digital artisans”, those inventors, authors and artists who for passion design and self-produce in their laboratories (called makerspaces or FabLabs) mechanical, electronic equipment, open-source software, robotic creations and everything that stimulates their desire for innovation.

The movement of makers is based on the democratization of the process of creating innovative solutions through the use of digital manufacturing tools such as three-dimensional (3D) printers, laser cutting machines and electronic components such Arduino electronic boards equipped with sensors and actuators. The maker approach at school allows students to be active users and digital creators, rather than mere passive consumers of digital services.

Technical skills are not an end in themselves, but rather become a lever to build new business solutions, improve their surroundings and respond to the complex problems of our times. For example, during science classes, students can build a digital microscope to observe bacteria, and thus learn about the technology by 'putting their hands in the pie' and making original digital solutions as part of their learning path [79]. At the didactic level, the object of study and the process of creating the object itself become a pretext for implementing paths of analysis and self-analysis and the implementation of knowledge and skills [140].

This digital creation process is based on learning-by-doing, a concept that is not new in the pedagogical field. Indeed, experiential education, constructivism, and critical pedagogy are theoretical pillars that have been established for over three decades. [27, 198]. Seymour Papert's theory of constructivism places experiences based on production at the center of learning: it proposes an idea of "*learning by building knowledge through the creation of something that can be shared*" [145] and underlines the role that students can assume in their own learning process through direct physical engagement with the phenomena and problems of the world [23]. Students in this vision are no longer passive recipients but active builders of knowledge [189] that in this way can develop their own voice, their thinking and their identity.

In the digital age, however, this concept of learning-by-doing or learning-through-making is enriched with new important applications, thanks to digital manufacturing and the maker approach. The idea of bringing digital manufacturing to support learning was born in 2002 at the Massachusetts Institute of Technology (MIT), when Professor Neil Gershenfeld created the concept of a digital manufacturing laboratory (FabLab) to promote creativity in learning of students of different subjects, from architecture to engineering. Gershenfeld described this digitalization of fabrication as the process during which not only the design, but also the materials and the manufacturing method are digitized, so digital fabrication means bringing programmability into the real world [67].

Since 2002, the concept of FabLab has spread all over the world, not only within universities, but also as private or public spaces intended for entrepreneurs or, more generally, for anyone interested in creating something innovative with digital tools. The spread of FabLabs was triggered by a drastic drop in the costs of digital manufacturing tools after 2000. In 2009, the expiry of patents on Fused Deposition Modeling (FDM) 3D printing in plastic, has led to a further drop in the price of desktop printers, which have come to cost as little as a few hundred euros. And open-source software has made such technologies even more popular. In these workshops, anyone can use digital manufacturing tools to create anything they deem useful, important or just plain fun, and FabLab projects range from jewelry to furniture to entire homes.

According to the Italian National Institute of Documentation, Innovation and Educational Research (INDIRE), there are three characteristics referable to this type of activity that are particularly interesting in the educational field [79].

The first is the **tinkering methodology**, represented by the *think-make-improve* design cycle. It involves a first phase of conception, a second phase of realization and a final verification and improvement phase, which leads to the redefinition of the initial project and of the ideas assumed at the outset. For example, students can create a prototype of their creation simply by drawing a three-dimensional image and printing it in 3D. Once the prototype is tested, the changes can easily be implemented by working on the three-dimensional image and cheaply reprinting a further prototype in a short time.

The second characteristic is the **philosophy of sharing**, which espouses openness to collaboration and knowledge sharing. According to this philosophy, copying or drawing inspiration from the work already accomplished by others does not equate to 'cheating', but rather, serves to enhance the existing work through integration. 'Copying' becomes, in this sense, an activity to be encouraged because it supports and facilitates dialogue and growth among students, who are thus pushed not to be afraid of making mistakes, trusting that their own companions will correct them.

The third characteristic is the **hacking approach**, which involves analyzing the functioning of certain objects, breaking them down and reassembling them, and using the knowledge gained to create new things. For example, the DIY digital microscope, designed (and shared) by the Dutch makerspace Waag society for its BioHack academy (BHA), uses the lens removed from a webcam to create a digital magnifying glass [25].

Most FabLab projects, however, remained within the domain of prototyping and higher education. It was not until 2008 that Stanford University introduced `FabLab@school`, the first conceptualization of a project that leverages digital manufacturing with an explicit emphasis on primary and secondary education. Since then, especially in a selected group of countries, we have seen a growing interest among primary and secondary school educators on how to integrate making in the classroom. In Italy, the `hacker@Scuola` project has been active for some years now. It involved modern technologies for teaching, with the aim of monitoring, even beyond national borders, the most interesting experiences in the educational field linked to the maker movement, but activities in this area are still limited to projects and workshops that are often extra-curricular.

The making approach in primary and secondary school is relatively recent, but this teaching methodology has already been shown to support the development of a range of 21^{st} century skills among younger students, including resourcefulness, creativity, teamwork and adaptability [21, 174, 175, 179, 192]. Indeed, the idea of "playful experimentation" with tools and materials is powerful in the context of learning, and when children create something with their hands they are engaged in active learning and at the same time have fun [196].

Recent studies on introducing a maker culture into schools through laboratories and updating the academic curriculum suggest that students develop skills, as well as interest, in STEM subjects [20, 122], as well as critical thinking and the ability to solve complex problems [142]. Furthermore, the realization of projects through digital manufacturing also often implies an interdisciplinary approach, another crucial element in the training of future workers and citizens, who will face increasingly complex and transversal challenges compared to the most various branches of the known.

Making can be applied not only to teaching STEM-based activities, but to virtually any subject taught in 21st-century schools. It promotes learning in an innovative and fun way: "by reserving time for play, free exploration, iteration, reflection and sharing, [...] young people will have more opportunities to develop self-awareness, collaboration and decision-making capacity" [196]. This concept is underlined also by the "Lifelong Kindergarten" team, who support the idea that "play" also cultivates the attitude of taking risks, experimenting and assessing the boundaries [189].

By learning to learn and exploit the iterative creation process, students also acquire the power to learn from mistakes and perfect their skills through experience and perseverance. By cultivating an agile perspective on problem solving, developing curiosity and learning to be comfortable with 'not knowing', students develop a maker mindset that will be extremely valuable in an ever-changing job market.

Through the digital design and fabrication process, students experience "new levels of collaboration" [27] and, often, students directly ask for help or offer it to others, inspire or are inspired by other ideas or problem-solving strategies, and build or link their work to experiments already started by peers [188].

More generally, there is a growing number of experiences demonstrating how making can motivate and support students' activities by leveraging their interests and the experiences they draw from the reality in which they are immersed every day with the aim to deepen engagement and learning [21].

Making in education can therefore be a tool to prepare our students with fundamental skills, abilities and character qualities in the 21st-century. However, the application of making in schools is still very recent and most makers' activities are still carried out in private schools, museums and higher education institutions [21, 101].

Bringing these activities to all Italian schools as a tool to support learning can be a starting point for preparing the next generation of young Italians to see technology as a tool for creation, change and training in order to acquire the skills needed to enter the world of work [29].

2.3 A as STEAM

The emphasis on citizen empowerment has been a significant tool for enhancing community involvement and decision-making. Concurrently, STEAM, as the integration of science, technology, engineering, arts, and mathematics, has become a pivotal medium to boost innovation and creativity. There is an inherent interlink between empowering citizens and STEAM disciplines, as STEAM education can pave the way for societal transformation and sustainable growth. By enveloping all these disciplines, STEAM provides a holistic view of the world, nurturing creativity, innovation, and problem-solving abilities. This forward-looking approach can recalibrate future generations' values, turning them into catalysts for change.

Magone & Mazali's [139] observation underlines the mutable nature of digital content and its many potential iterations. Such insights urge a contemplative approach towards the skills modern creative thinkers should possess to effectively navigate today's technological milieu. The emphasis is gradually transitioning from 'design for Industry 4.0' to 'education for Industry 4.0' [167]. This stresses the importance of foundational knowledge, especially through hands-on experience in design education. There is a noticeable discrepancy when transitioning from academic learning to confronting real-world challenges. Educators and researchers have advocated for incorporating 21st-century skills such as creativity, innovation, and entrepreneurship into curricula [42]. The debate intensifies as many propose including the "Arts" in the STEM curriculum, transforming STEM to STEAM [102, 138].

However, not without concerns: The British Educational Research Association, among others, has reported inconsistencies in STEAM education, from its terminology to its pedagogy [51, 6]. A recurring ambiguity revolves around defining the "Arts" in STEAM [176].

This ambiguity extends to STEM education itself, with interpretations differing based on context, geographical differences, and absence of a theoretical foundation[32, 191, 37]. Despite its ethos, STEM's real-world applications often vary[144]. For STEAM education to genuinely serve its purpose, research must unpack its real-world implications [176]. While STEAM is believed to cultivate creativity and critical thinking, supporting evidence remains sparse.

Although arts education has shown cognitive and academic benefits, translating these benefits to STEAM remains an uncharted territory. Bridging this gap requires focusing on the core outcomes synonymous with arts education, such as creativity and critical thinking. The activities described from Chapter 5 to Chapter 8 and future studies in this direction will hopefully help craft effective STEAM education models. This study delves into various STEAM pedagogical approaches, utilizing computational thinking and computer science methodologies to equip students with technical skills for modern technological tools. For the above reasons, from now on we will refer to STEAM disciplines.

2.4 Focusing on coding

As mentioned above, the 21st-century requires a significant transformation, both on a personal and social level, in the ways we work, learn, communicate, and develop [47]. This process is inherent in the term "learning society" or knowledge society: it refers to a change that has occurred in recent decades in the way we conceive education and its relationship with the labour market, but also, more generally, to an increase in the ease of access to knowledge for segments of the population [77]. Competences and abilities are increasingly connected to self-entrepreneurship, the necessity of "learning to learn", and acquiring a lifelong learning attitude. It represents a paradigm shift that profoundly affects education, training, guidance, and employment systems: there is a growing demand for designing pathways dedicated to competences [185].

Internationally, today, competency-based education is considered the most suitable response to a new need for training directed towards individuals who will be required to utilize acquired knowledge to solve personal and work-related problems. Among these, this research focuses on coding, understood as a skill that enables the development of mental flexibility, problem-solving abilities and goal orientation. Furthermore, coding represents the most effective and enjoyable tool for developing computational thinking, a skill applicable in various aspects of life and beneficial to everyone, both students and non-students.

Computational thinking can be defined as "*a process of formulating problems and solutions in a way that can be executed by an agent processing information*" [236]. It goes beyond mere programming; it involves thinking at various levels of abstraction, thus becoming a genuine fourth basic skill alongside "reading, writing, and arithmetic" [93]. In other words, it helps develop logical and creative problem-solving skills, improving thinking abilities that contribute to learning and understanding. It provides the necessary ability to devise concrete and effective procedures leading to the achievement of a goal [153].

The first to use the term "computational thinking" in 1996 was Seymour Papert, in reference to Logo, the language he developed to teach programming to children. Papert's aspiration in creating Logo was not to train generations of computer programmers [207]: "My main goal is not about the machine but about the mind [...] and the role I give to the computer is that of a bearer of cultural 'germs' or 'seeds' [...]." "*A mind cannot grow much if it only accumulates knowledge but must also invent ways to make the best use of the knowledge already possessed*" [172].

Regarding coding, Mitchel Resnick, the developer of the programming language called Scratch, has also spoken about it in the following terms: "*when you become fluent in reading and writing, you don't do it just to become a professional writer. But learning to read and write is useful for everyone. And the same goes for programming. Most people won't become computer experts or programmers, but the ability to think creatively, think systematically, work collaboratively with others* [...] *are things that people can use, regardless of the job they do*" [189].

Over the years, interest in learning coding has significantly grown internationally, leading to an increase in available resources for acquiring the basics of computational thinking. The British Royal Society's report in 2012 marked a milestone as it made coding a mandatory part of education for every student in the United Kingdom, starting from primary school [212]. A few years later, in January 2016, then-US President Barack Obama urged young people not to spend their resources on buying video games but to instead concentrate their efforts on creating them. He launched a plan to promote coding in all schools [151]. More recently, in December 2021, the Italian Government decided to prioritize digital skills, especially coding, as part of the National Recovery and Resilience Plan (PNRR). These skills will be fully integrated into the educational program of all Italian schools at every level by the 2024–25 academic year [181].

2.4.1 With a gender lens – STEAM, Computer Science and Women: Some Numbers

Whether in the roles of educators, teachers, or family members, it is a familiar experience to witness how young individuals exhibit varied responses when confronted with situations involving "science" or "numbers", whether in formal or informal settings. This spectrum of reactions, ranging from aversion to genuine enthusiasm, prompts an intriguing inquiry: Why do these distinct reactions emerge even before a precise understanding of the situation at hand? What factors contribute to the divergence in comfort levels when engaging with scientific-technological challenges? Moreover, why does this discrepancy often correlate with gender?

To comprehend this phenomenon, the concept of "positioning" within the scientific-technological or STEM or STEAM realm proves valuable. Thus, STEAM positioning is defined as an individual's cognitive, emotional, communicative, evaluative, and behavioural orientation concerning the STEAM domain. This encompasses their stance on topics, agents, and activities linked to the scientific-technological sphere [219]. Consequently, positioning regarding the STEAM field reflects how each person perceives their role within this domain. At the educational level, this encapsulates their viewpoint on the significance of the scientific-technological world in their lives and their beliefs about their role within that world [57].

While the realm of STEAM education has recently begun to delve into the affective dimension of this educational paradigm, research has explored the variables influencing students' positions in these areas, often from the vantage point of identity. From psychological and sociological standpoints, an individual's positioning toward the STEAM field is an intricate interplay of psychological variables, including interests, aspirations, self-efficacy perceptions, and competencies in science, engineering, technology, and/or mathematics [219]. This positioning is further shaped by the societal image attached to individuals associated with STEAM, as well as by one's general self-perception and self-conception within this field. In essence, STEM positioning both shapes and is shaped by an individual's identity.

Despite extensive efforts, research has consistently highlighted the persisting underrepresentation of girls and women in STEM fields at the post-compulsory educational level. Statistical data reveals that globally, women comprise merely 35% of students enrolled in STEM-related disciplines, indicating a stark gender imbalance [59]. While Western Europe and the United States have achieved near gender parity in overall university-level STEM education participation between women and men [76, 160], disparities still manifest within specific STEM fields. Notably, gender-based differences emerge, with girls showing a higher propensity for careers in healthcare and biology, while boys are more inclined toward computer science, engineering, and physics [182].

Gender disparities also permeate various constructs linked to students' identities, including their interests and self-efficacy, beginning at an early educational stage. Empirical investigations have demonstrated that girls' interest in science wanes considerably more than that of boys during the transition from primary to secondary education [15]. Given the significant implications of these disparities in the educational landscape, the development of gender-sensitive curricula, such as the work by [16], has gained prominence. This underscores that concerns surrounding STEM education extend beyond content and instructional strategies; incorporating a gender-equity perspective into STEM education is imperative and cannot be disregarded.

A promising approach for examining students' engagement with diverse STEM domains lies in adopting an identity-focused lens. This lens offers a conceptual framework for comprehending how students perceive their alignment with various STEM activities, leading some students to identify STEM as a domain "for them", while others may not share this sentiment [61]. Existing research has predominantly characterized students' STEM identity as a composite of their relationships with distinct STEM fields. For instance,Ward Hoffer [233] defines STEM identity as the way individuals conceive of themselves as scientists, technology users, engineers, or mathematicians. Similarly, [126] conceptualize STEM identity as a socially-rooted construct contingent on the extent to which individuals view themselves and are acknowledged as part of a STEM community or field.

In certain instances, the term "STEM identity" has been used interchangeably with "science identity" [209]. However, we find this practice problematic for two reasons. Firstly, it obfuscates the nuances of distinct disciplinary identities, potentially hindering a comprehensive understanding of their unique attributes and implications. Secondly, this practice inadvertently implies that STEM identity might exist purely as a theoretical concept, devoid of empirical substantiation. Consequently, it becomes crucial to probe into how students' identity development is characterized, particularly within the context of integrated STEM educational activities or during the formative years when the demarcations between science, technology, engineering, and mathematics remain less distinct.

This becomes particularly true and significant in the field of computer science.

Computer science, along with other so-called "hard" sciences such as mathematics, physics, and engineering, is still considered a subject unsuitable for the female gender [30].

It has not always been this way: many women have contributed to the development of this discipline [180, 202]. In the United States, female participation reached its peak in 1980, with a significant 44% of female students among the total computer science graduates, but then declined dramatically to 13% after the dot-com bubble of 2000, finally stabilizing around the current 18%. Optimistically, it was thought that the growth of the so-called knowledge economy associated with the spread of innovative technologies would be able to destabilize the social categories of traditional allocation of male vs. female jobs, favoring women's access and advancement in the job market [58, 74].

Unfortunately, it did not turn out that way. In 2018, female students constituted only 19.8% of the graduates in ICT across the 28 countries of the European Community. This is in stark contrast to other STEM disciplines, where the gender gap has progressively decreased: in 2018, female students accounted for 54.8% of the graduates in sciences, mathematics, and physics [76].

The situation in Italy is even less promising: in 2018, the female presence in computer science degrees stood at 14.5%, with fluctuations between 14% and 15% over the last 10 years. Again, the contrast with other STEM areas is evident: in 2018, in Italy, female students constituted 46.6% of the graduates in sciences, mathematics, and physics. Interestingly, the European situation is quite varied, and some countries show a higher female participation in computer science degree programs than the average, with rates around 33% in Romania, Bulgaria, and Estonia [154].

2.4.2 The necessity of epistemological pluralism

The female disaffection towards computer science begins very early, during childhood, due to the different use of games and video games, often directed at a predominantly male audience and based on symbolic dimensions traditionally associated with masculinity, such as violence, competition, and dominance [43]. The gap widens during subsequent educational paths, reinforced by the expectations and often unconscious prejudices of teachers and counsellors, which contribute to the progressive thinning of the proportion of women entering ICT work contexts [58]. In this context, we will not delve further into the reasons behind the sources of exclusion.

In particular, we will consider the perspective [180, 225] that such exclusion is determined not so much by rules that keep women away but by a context that makes them reluctant to participate. Our central thesis is that achieving equal access even to the most basic processes of computation requires epistemological pluralism that accepts the validity of multiple ways of knowing and thinking. In "The Second Self",Sherry Turkle [225] argues that schools, especially in science and mathematics classes, generally propose only one type of learning and problem-solving: the traditional step-by-step analytical model. Different approaches based on more active and collaborative teaching are often dismissed as "messy" or "intuitive", implying that they are not reliable. Gender studies [58], on the other hand, show that girls often tend to adopt different problem-solving styles compared to boys. This does not mean that all girls or all boys solve problems in a single style, but rather that there is a wide range of styles. However, girls tend to use more collaborative techniques, such as building consensus and adapting rules, compared to boys, who more often see a problem as a personal challenge [145]. Both of these characteristics are useful and worthy of monitoring and inclusion.

There is a clear implication of gender roles in these different propensities: while transversal skills are more often attributed to women, "hard" mastery skills are more frequently attributed to men. When we reward a certain aptitude over another in the school model, we implicitly ask some boys and girls to ignore their best instincts. We figuratively tie their hands behind their backs.

The point is not that active teaching is suitable for one type of student and not for others. Adopting a less formal and standardized mentality in the classroom allows all students, both male and female, to learn in their own style, thus finding their way. Allowing everyone, boys and girls, to confront concrete and real challenges will enable them to build a sort of “toolbox” that will be useful in all the challenges they will encounter in the future. The goal of the activities presented in this short chapter is not to steer boys and girls towards specific disciplines; rather, we believe that free exploration can lead to more informed educational and career choices, experiencing activities firsthand, and critically evaluating one activity over another, thus discovering their talents and passions, regardless of gender social conditioning.

2.5 Preliminary questions – where did we start from

When we started this research, we were inexperienced, and our main focus was on innovation within education and how to make schools more “modern”. Only later did we realize that our scope of action could be much broader. But let us proceed step by step.

FabLabs, are often referred to “places where people have access to low-cost digital production tools and come together face to face to create anything” [86, 97, 87, 92]. This definition often leads people to focus primarily on the social aspects of FabLabs and the prototype and artifacts that come out as outputs.

When talking about university FabLabs, indeed, there are differences and critical aspects that should not be overlooked:

1. the educational processes incorporated and generated during the design and development process in student projects;
2. the ability of university FabLabs or those located in educational contexts as potential platforms to train and prepare true “creative thinkers”, i.e. students and citizens who are cognitively adaptable and flexible, ready to meet the needs of the future job market, thus acquiring the 21-century skills necessary for the new generations;
3. the ability to include local communities in the proposed activities.

Recently, there has been a lot of discussion about the “Third Mission” of the academy, to emphasize that universities must take on a new fundamental objective alongside the traditional ones of higher education and scientific research: dialogue with society. The term "Third Mission" refers to a suite of activities that universities can undertake to interact directly with society, in addition to their traditional teaching (first mission, centered around interaction with students) and research (second mission, primarily involving interaction with scientific communities or peers) endeavors [14]. As a result, universities come into direct contact with subjects and social groups other than the consolidated ones and therefore make themselves available to modalities of interaction with variable content and form dependent on the context. A distinction that is considered useful to introduce is between:

- third mission from the point of view of economic exploitation of knowledge;
- third mission from the point of view of culture and society [14].

In the latter case, public goods are produced that increase the welfare of society. These assets can have cultural content (events and cultural assets, management of museum centers, archaeological excavations, scientific dissemination), social (public health, activities for the benefit of the community, technical / professional advice provided in teams), educational (education of adults, lifelong learning, continuous training) or civil awareness (debates and public disputes, scientific expertise). Thus, a critical aspect is: How can we transfer outside the formal and institutional barrier the educational model and knowledge produced in our university labs? How can we make the public aware? How can we transfer the knowledge we produce among citizens?

In the previous section, we argued that FabLabs are more than the sum of their parts. They have real potential to shape individuals lives and to create a shift in how we produce and consume everyday tools and artefacts. FabLab impact includes social impact (such as forming and connecting local communities, social capital formation, intergenerational learning, sharing and wellbeing), economic impact (such as helping to create and support entrepreneurship, assisting local and international businesses and informing non-governmental agencies and policymakers) and environmental impact (such as sustainability, food security, recycling materials, retro-engineering and shifts in where things are produced). The impact on education, as part of the social side, will be our focus.

The aim of this research project is thus to develop a methodology for teaching and learning with digital fabrication and design – a method with principles that facilitate learning of 21^{st}-century competencies. As argued above, we know that academic makerspaces can create meaningful experiences for students, yet how do we measure their impact? What kind of learning outcomes can everyone involved have? How were learning outcomes assessed during and after the process? To what extent are students developing skills and competences related to the design process (e.g. exploration, language, judgement, reflection, etc.)?

2.5.1 Preliminary research goals

For the purpose of this research, the researcher at the beginning of this exploration started from three main aspects:

1. educational models and methodologies;
2. "taking outside": third mission in place;
3. how to measure impact.

Research questions

The principal aim of part one is to design and investigate the issue related with the educational process of a university FabLab.

The key questions that guided our research team were:

> **RQ1**: *What are the types of educational processes embedded in the design of a university FabLabs and its activities?*

The creation of FabLabs in universities must not only be functional to carry out normal curricular courses, but can serve as a support platform to provide the users with the aforementioned

21st-century skills, as students but also as citizens. The goal is to create "creative thinkers", thus incubating proactive minds that can be adaptable to the needs of the labor market of the future. Design processes in places like FabLabs involve these design processes and critical thinking. Supported by the new technologies for digital prototyping [92] the FabLab can be one of the promising platforms for providing citizens with 21st century skills. Blikstein listed three advantages of integrating FabLabs into schools being that FabLabs:

1. improve and enhance existing practices, skills and expertise;
2. accelerate the cycles of invention and design;
3. improve long-term projects and peer collaboration [27].

Posch [183] supported Blikstein's claim by stating that FabLabs play an key role in scientific and engineering training and practical learning of STEAM-related disciplines, as well as for artistic design and artefacts. These claims justify research like this to help identify the capabilities of university-established FabLabs.

"Taking outside": third mission in place

In the second aspect,in order to fully embrace the third mission of the university, the aim was to activate formal and informal learning processes, creative and innovative co-planning among citizens usually non-involved in the formal learning spaces.

The key questions leading this part, thus, were:

> **RQ2a**: *How can we transfer outside the formal and institutional barrier the educational model and knowledge produced in our university labs?*
>
> **RQ2b**: *What are the educational methodologies and approaches that are best suited for integrating activities inside and outside a university?*

Third Mission means that "propensity of structures to open up to the socio-economic context, exercised through the enhancement and transfer of knowledge" [14]. Therefore, our goal was to transfer our knowledge even outside the university setting. The objective was to inform and to disclose but also to intrigue. Science is often overlooked and taken as something distant and boring, something for the few. Our task was supposed to be creating new educational models, which do not make science spectacular, but which could push people, especially the younger ones, to have the desire to deepen and explore more their knowledge.

How to measure impact

In the third part, the goal was to understand the real value of what we try to design and develop. The key question then was:

> **RQ3**: *How do we measure the impact of our activities?*

So far, there are no well-established methodologies to measure the impact [79], so a further aspect was selecting the appropriate tools and methods. Our goal was to find and highlight the best metrics that can be measured over a short period of time, without neglecting the long term and longitudinal. To this extent, qualitative and quantitative methods would be applied to measure single events' impact but also, in the long run, in understanding if our activities could affect academic performance and future academic choices.

Evolution of research Questions: A Dynamic Process in Scholarly Inquiry

The art and science of research often begin with guiding questions, seminal inquiries that provide an initial roadmap to the research terrain. These initial questions, though fundamental in setting the course, are seldom rigid constructs. Instead, they are susceptible to evolution and refinement as research progresses, a phenomenon that our study too has borne witness to.

The preliminary questions presented at the outset of our study were invaluable. They established a firm foundation, acting as guiding beacons in the otherwise daunting expanse of academic exploration. However, akin to many scholarly pursuits, our research journey was not linear. As we delved deeper into our subject and as our understanding matured, we found the need to slightly modify and recalibrate our questions to better align with emerging insights.

The dynamic nature of research is, in essence, a testament to its authenticity and depth. As researchers, we strive not for a predetermined outcome but for the pursuit of knowledge and understanding. It is only natural, then, that as we encounter new data, experience unanticipated challenges, or gain novel insights, our guiding questions evolve to mirror our enhanced perspective.

Chapter 4 of our study is a proof to this evolutionary process. In it, we lay out the architecture of our model and, importantly, trace the metamorphosis of our guiding questions. As readers journey through this chapter, they will witness not just the blueprint of our analytical construct but also the nuanced shifts and refinements in our inquiries. This dual presentation serves not just to provide transparency in our methods but also to celebrate the organic and dynamic nature of academic exploration.

Research is a journey, marked by continuous learning and adaptability. Our guiding questions, though they started as firm anchors, evolved as our knowledge deepened, ensuring that our study remained responsive, relevant, and rigorous.

2.6 Theoretical framework: Constructionism

In conducting this research, we started from Papert's **constructionist theory**, which is grounded in the elaborations of Jean Piaget's constructivism. In this framework, learning is depicted as the cognitive process of adaptation encountered during new experiences. The learning process for students unfolds as they construct this knowledge independently. This construction is facilitated through a process termed adaptation, defined as the ability to adjust to the surrounding environment and circumstances [3].

Jean Piaget postulated that the four pillars for the construction of knowledge are Assimilation, Accommodation, Equilibrium, and Schemes. The adaptation process is derived from the interplay of assimilation and accommodation. Piaget contended that within the human mind, there are structures capable of adapting to changes in the surroundings, and therefore capable of adjusting to the external environment when new conditions emerge. To achieve this, it is necessary to attain a state of equilibrium between the external world and internal mental structures, referred to as Schemas or Schemes.

In our context, when students are tasked with new activities, they are propelled to interpret, make improvements, or alter their beliefs [24]. The four pillars hold significance in this research as they could serve as a lens for interpreting the processes unfolding while users are engaged in crafting projects within the FabLabs. This principle extends to scenarios where an individual utilizes the provided tools and applies newly acquired skills in a unique and personal manner. This notion is bolstered by the theories of Lev Vygotsky, who emphasized the process of internalization. Appropriation is another term closely aligned with the internalization process [230].

In this perspective, Philip defined constructivism as the knowledge created by people influenced by their values and their culture [171]. This knowledge is also built based on their social and intellectual development, grown during the performance of other cognitive activities, especially if carried out in collaboration with others. Martinez and Stager [145] further elaborated this definition by stating that "knowledge does not result from receiving information transmitted by someone else without the student undergoing an internal process of making sense".

Papert, building on Piaget's theories, added to the view of constructivism the idea that this occurs especially in a context in which the students are consciously engaged in the construction of a public artefact [230]. The constructionist approach helps to understand how ideas are obtained when expressed through different media, when actualized in particular contexts, when elaborated by individual minds. The emphasis shifts from universals to students' individual conversations with their favourite representations, artifacts, or objects to think with.

For Papert, projecting our feelings and passions is a key to learning. Papert, as pedagogical reformers, believed that "learning results from experience and that understanding is built within a student's head, often in a social context" [145]. While learning occurs within a person's mind, it happens in a more structured and contextualized way when the person is engaged in a personally meaningful activity, often associated with a tangible product that can be shown, discussed, and shared with others.

The term "personally meaningful" also implies the freedom to act driven by the learner's impulse rather than imposed from the outside. The tangible product can be a software, a computer drawing, the design of a three-dimensional object, a video game. As early as the 1960s, Papert was the first to assert that boys and girls must "appropriate" the computer, not to train themselves in the use of pre-existing applications, not to do exercises or solve problems assigned by someone else, but to use it as a creative tool. Finally, at the core of constructionism, there is also the idea of socially constructed learning, where the creation of new knowledge and skills occurs through speaking and working with others, sharing the fruits of one's creation.

In 1999, Seymour Papert initiated his final ambitious institutional research endeavour by establishing the Constructionist Learning Laboratory. This technology-rich, project-based, multi-aged laboratory was situated within Maine's troubled prison for teens, known as The Maine Youth Center.

The remarkable journey of the Constructionist Learning Laboratory is extensively documented in Gary Stager's doctoral dissertation titled "An Investigation of Constructionism in the Maine Youth Center", completed at the University of Melbourne in 2006 [214].

In his book "Invent to Learn: Making, Tinkering, and Engineering in the Classroom" [145], Gary Stager shares that shortly after the commencement of this three-year project, Seymour Papert outlined the Eight Big Ideas Behind the Constructionist Learning Laboratory. While not exhaustive, this list effectively elucidates the principles of constructionism to a broader audience.

Eight big ideas behind a constructionist learning lab

1. **Learning by doing**: we all learn better when learning is part of doing something we find really interesting; we learn best of all when we use what we learn to make something we really want;
2. **Technology as building material**: if you can use technology to make things you can make a lot more interesting things; and you can learn a lot more by making them. This is especially true of digital technology: computers of all sorts including the computer-controlled Lego in our Lab;
3. **Hard fun**: we learn best and we work best if we enjoy what we are doing. But fun and enjoying does not mean "easy". The best fun is hard fun. Our sports heroes work extremely hard at getting better at their sports. The most successful carpenter enjoys doing carpentry. The successful businessperson enjoys working hard at making deals;
4. **Learning to learn**: many students get the idea that "the only way to learn is by being taught". This is what makes them fail in school and in life. Nobody can teach you everything you need to know. You must take charge of your own learning.
5. **Taking time – the proper time for the job**: many students at school get used to being told every five minutes or every hour: do this, then do that, now do the next thing. If someone is not telling them what to do, they get bored. Life is not like that. To do anything important you have to learn to manage time for yourself. This is the hardest lesson for many of our students.
6. **You cannot get it right without getting it wrong**: nothing important works the first time. The only way to get it right is to look carefully at what happened when it went wrong. To succeed you need the freedom to goof on the way.
7. **Do unto ourselves what we do unto our students**: we are learning all the time. We have a lot of experience of other similar projects but each one is different. We do not have a pre-conceived idea of exactly how this will work out. We enjoy what we are doing but we expect it to be hard. We expect to take the time we need to get this right.

Every difficulty we run into is an opportunity to learn. The best lesson we can give our students is to let them see us struggle to learn.

8. **We are entering a digital world where knowing about digital technology is as important as reading and writing**: so learning about computers is essential for our students' futures but the most important purpose is using them *now* to learn about everything else.

3 Evaluating the state of the affairs in Trento

A sociological analysis on the knowledge and importance of coding

Considering the acknowledged significance of coding for new generations, particularly within the context of the knowledge society, an exploratory sociological research study was conducted in 2021. This study aims to complement the bibliographic research conducted and to enrich itself with a perspective of the local fabric. This chapter indeed seeks to provide an additional overview of the context in which we find ourselves and the target audience we typically address.This initiative involved a group of students from the Qualitative Research courses led by Professor Bassetti, and the Information Systems Laboratory directed by Professor D'Andrea, where the author served as a teaching assistant for five years. The objective of the research was to analyze the extent to which the theoretical premises identified in the literature were mirrored in reality.

Particularly, we focused on whether young people are familiar with coding and aware of its significance for their education, in terms of hard skills and, above all, transversal competencies. In particular, the target chosen for data collection involved young people aged between 16 and 24 years, enrolled in a secondary school or a university course located in the city of Trento. Following a criterion of diversity in educational backgrounds and gender, the research involved students who were computer science experts, students who were not computer science experts, as well as teachers and trainers engaged in raising awareness and teaching coding. In this way, it was possible to obtain a more realistic overview of the actual knowledge and consideration of coding among adolescents and young adults currently engaged in educational paths, and to gather opinions from professionals in the field regarding the importance of embracing computational thinking.

From a structural point of view, the following chapter is organized into two main sections, each further divided into two or more subsections, in order to adequately frame and deepen each aspect of the research. Specifically, Section 3.1 concerns the methodology adopted for sampling, data collection, and analysis. In this section, particular attention is given to the reasons why our research team chose to delve into the topic of coding, the criteria used to define the participating subjects, and the issues encountered during data collection. Section 3.2 presents the research results, organized into four core themes: coding among young people, benefits of coding, limited effectiveness of school teaching, and coding awareness through gamification. Each of the identified dimensions addresses a specific research question, analytically examining the outcomes of the coding of interviews and focus groups.

3.1 Research methodology

3.1.1 Methodology and planning

Our choice to investigate the knowledge of coding and its importance attributed to it by young people was derived from observing a phenomenon of particular interest to us and from the literature that can be found in the previous chapter. The age of knowledge has made coding an increasingly demanded and sought-after skill, to the point of being recently included in education as a compulsory activity in all schools at every level [12]. The growing role of coding is also evident from the literature for children specifically designed to introduce the basics of computational thinking, as well as the increase in associations, workshops, training days, academic articles, and newspaper articles dedicated to coding.

The research design thus took shape starting from the previous chapter, confirming the importance of coding for young people, both in terms of hard skills and transversal competencies applicable to the labour market as well as other areas of life. Intrigued by the topic and the general trend of focusing specifically on coding for children and pre-adolescents, we set out to investigate whether students in Trentino region, aged between 16 and 24, are aware of what coding is and whether they consider it important for their education. This was done with the consequent goal of raising awareness on the subject if it was unfamiliar to them or, if otherwise, studying the best techniques for teaching it. In order to thoroughly address these research questions, we employed a qualitative methodology, using a series of semi-structured interviews and a focus group.

This allowed us to gather data that could comprehensively and descriptively explain the phenomenon under investigation, as opposed to relying solely on exploratory observation or limited statistical models. Specifically, through the interviews, we aimed to understand the educational and career choices of each interviewee and the motivations behind them, investigate the role and possible methods of coding instruction in secondary schools in the city of Trento, and assess students' level of interest and proficiency in the field of coding. To delve deeper into these issues, we chose to approach them in three distinct interview tracks for three types of interviewees: students between 16 and 24 years old who are not coding experts and, therefore, do not pursue educational paths related to this discipline; students between 16 and 24 years old whom we considered experts as they are enrolled in tech-IT study programs; and finally, teachers and trainers of any age involved in teaching coding either at school, or in a extracurricular way, or at the university level. On the other hand, the focus group aimed to facilitate a constructive debate specifically among university-level students, both experienced and non-experienced, with the ultimate goal of generating ideas for an awareness-raising event on the topic.

The sampling and selection of interviewees and focus group participants were done following several criteria. Firstly, we aimed to maintain gender heterogeneity as much as possible to avoid creating or perpetuating any discrimination in this regard and instead to ensure inclusivity in the research project. This approach was also applied to the age range of the interviewees, ensuring representation of various age groups within the 16 to 24-year-old range. Lastly, we made sure that Trento was the main reference city for all interviewed students and the city or one of the reference cities for the teacher trainers. Based on these criteria, we identified suitable non-expert students by utilizing personal connections with the students involved in the research. For reaching out to teachers and trainers, we collaborated with members of the Glow association and communicated with them via email. To recruit expert coding students for the research, we reached out to the Trento university community through the "Spotted Unitn" Instagram profile (https://instagram.com/spotted_unitn/), a virtual space typically used to exchange advice and information on various aspects of student life. We asked them to post an invitation for IT-savvy and expert computer science students to carry out an interview.

By doing so, we involved a total of 21 individuals in our research. Among the 15 interviewees, non-expert coding students were represented by 2 male and 4 female participants (totalling 6), expert coding students were represented by 3 male and 1 female participant (totalling 4), the teacher category consisted of 3 male trainers and 2 female trainers (totalling 5), thus reaching eight male and seven female participants overall. Similarly, among the 6 participants in the focus group, both the subgroup of expert students and non-expert students consisted of two male and one female participant, totalling 4 male and 2 female participants. Overall, therefore, we listened to 12 male voices and 9 female voices, getting close to gender parity but not actually achieving it, despite our efforts. In particular, we encountered difficulties in identifying female computer science students, which was as expected considering their actual numerical scarcity compared to their male counterparts [60].

As for the content of the three interview tracks directed towards different types of participants, a first series of preliminary questions about their background was always followed by a second series of questions more closely related to their knowledge, study, and application of coding in their everyday lives. For each category of interviewee, a basic sequence of approximately ten to twenty questions was created, ranging from purely factual inquiries such as "What did you study in high school?" to broader issues like "What do you think about the inclusion of coding in the curriculum of every educational path?" – all arranged in a logical order but easily modifiable and adaptable to the natural flow of conversation with each individual. The idea was that each interview would last approximately 20 to 60 minutes, providing us with a clear overview of the dynamics we deemed most interesting while allowing other topics to emerge at the discretion of the interviewees.

The preliminary questions not only aimed to make the conversation more relaxed and natural but also to contextualize the subsequent statements. The second set of specific questions for each category was intended to understand the motivations of expert and non-expert students in studying coding or not, and their perception of it. Additionally, it aimed to gather insights from teachers and trainers on the practical applications of coding in both work and non-work contexts.

The design of the focus group was more structured, starting with the designated number of six participants who were all strangers to each other. Besides aiming for an equal number of expert and non-expert students, we wanted to ensure that everyone felt fully involved and free to express themselves. Simultaneously, our goal was to allow the facilitator to manage the situation without significant confusion, gradually revisiting and exploring the most interesting aspects, and stimulating the conversation effectively [89].

The five phases we planned to articulate the 90–120 minutes duration of the focus group included moments of individual reflection as well as discussions in pairs and in the plenary session, thus offering different types of interactions among the participants. The hope was that each participant could feel comfortable in at least one of these modes of communication.

To start, we planned a brainstorming session in mixed expert-non-expert pairs (*Phase 1*) with the intention of finding a shared definition of coding, which would be presented and discussed with the rest of the group (*Phase 2*). Next, we wanted to incorporate an experiential component and encourage the six participants to individually tackle one or more puzzles of their choice from seven options provided by us. These puzzles consisted mainly of wooden objects representing logic problems that could be related to the playful learning of coding (*Phase 3*). Towards the end, we scheduled a plenary reflection on the just experienced activities (*Phase 4*); and we organized a vocal discussion on potential strategies to introduce young people to coding through promotional activities, with a particular focus on the immediate responses from non-expert students to the proposals put forward by the expert students (*Phase 5*).

3.1.2 Activities and problems

Once the methodological design was completed, each of the student arranged meetings with the two or three assigned interviewees. Between October 20 and November 4, 2021, all the interviews were conducted, either in study rooms provided by the Department of Sociology and Social Research, at the participants' homes, or online when necessary. The resulting average duration for each interview was approximately 33.8 minutes. On November 17, 2021, from 10:00 to approximately 11:45, the focus group took place in a study room of the Department, facilitated by one moderator with the assistance of two attendants chosen among us. The date and time of the focus group were unanimously agreed upon by all six participants, using a specially created WhatsApp group to verify everyone's availability. Both the interviews and focus group were fully recorded using mobile devices and audio recorders, with prior informed consent from the participants.

Following data collection, we proceeded with the verbatim transcription of the recorded material and the coding of the emerging content using the qualitative investigation software `Atlas.ti`, to highlight agreements and disagreements of thoughts and lived experiences among the different research participants. Each member of the research team was responsible for personally transcribing their own recorded material, to minimize the possibility of linguistic and/or semantic misunderstandings.

Afterward, we collectively coded one interview for each category of interviewees and the entire focus group. We then equally divided the remaining transcriptions among ourselves to manage time efficiently. This approach allowed us to maintain consistency in creating and assigning codes, facilitating the creation of coherent code groups, and ensuring general homogeneity in the subsequent analysis. In fact, the most recurring and prominent codes in the interviewees' discourse clearly emerged, making it straightforward to identify the major areas to analyse in response to the research questions.

On the other hand, we encountered difficulties in other areas of the research. Originally, we aimed to conduct six interviews for each category of participants to collect a sample that was as fair and homogeneous as possible. However, contacting and successfully reaching a diverse group of individuals in terms of age, gender, and educational background within a short span of weeks proved challenging. As a result, the number of interviews was reduced from the planned eighteen to fifteen, which meant we had to take out two expert students and one teacher. Similarly, the research methodology was updated during the process since we had initially planned to conduct a visual and para-documentary analysis as well. This analysis was intended to focus on blogs and social media used by young people to discuss coding and assist us in understanding if and to what extent this topic was debated and relevant to this target audience.

However, we decided to abandon this approach because, based on the data collected from interviews and the focus group, we concluded that it would not provide additional or useful information for the research we were conducting. In this regard, it is worth noting the significant discrepancy that we, unfortunately, observed in the average duration of interviews for different categories of participants. The average duration was approximately 54 minutes for teacher trainers, about 15 minutes for non-expert students, and around 25 minutes for expert students.

While not ideal, we believe that this discrepancy is understandable and constitutes a separate piece of information, which we also considered in the analysis of the collected data. On the other hand, the challenge we faced was purely logistical in determining a suitable date, time, and location that worked for all focus group participants and the research team, considering everyone's commitments.

Due to a last-minute unforeseen event, we were compelled to replace one participant at the eleventh hour. During the focus group, despite our efforts, it was also difficult to prevent certain participants from dominating the discussions and prevailing over others, albeit with good intentions.

3.2 Results analysis

In the analysis of the interviews and the focus group, we identified four main macro-areas, each represented by a Code Group, as identified through the Atlas.ti software, addressing specific research questions. The first macro theme identified is "coding among young people", corresponding to our aim of investigating whether students in Trento, aged between 16 and

24, are aware of what coding entails. The second area, "benefits of coding", addresses the question of whether young people are aware that this skill is essential for their education in terms of hard skills and transversal skills. Finally, the core themes of "ineffectiveness of school teaching" and "raising awareness of coding through playing" respond to the inquiry about the ways to sensitize young people to coding and the mechanisms for encouraging their interest in this subject.

3.2.1 Coding among young people

To understand if the Trentino students within the target age range have an idea of what coding is and what their thoughts are on the subject, we chose to approach the topic gradually by first asking them questions about their current field of study and the motivations behind their choice. Next, we examined their knowledge of both computer science in general and coding in particular, along with their emotional state in approaching these subjects. This allowed us to establish an informed reference point on which to base and contextualize the results obtained concerning the subsequent research questions, especially considering the substantial unanimity of thought among the interviewees regarding the importance of the topic. Teachers and trainers, having already made a clear career choice in this regard, are naturally harbingers of a different perspective from that of the students, but nonetheless, their input is informative regarding their knowledge and opinion of coding.

Among students in high school programs or university courses unrelated to technology, science, and informatics, there is a quickly emerging conflicting picture of the issue. For instance, H.D.M., a student of modern languages, expresses dissatisfaction as her school knowledge of computer science has never found concrete application in the real world: "*I did the ECDL course in the first years of high school* [...] *I had to do it* [...] *but if you ask me, 'Has it been useful to you so far?' Well, I don't remember that much anymore, you know* [...] *because I did it in the second year of high school, it's been so many years. So not using it anymore* [...] *I forgot everything.*" Nevertheless, the same student firmly believes that "*knowing the computer nowadays is essential*" and goes on to clarify that she does not object to teaching computer science itself, but rather to the teaching method that pushes students to study computer science "*by heart* [...] *just to pass the exam.*"

R.L., currently engaged in international studies after attending a human sciences high school, echoes similar sentiments. During his high school years, he also approached computer science mainly through the ECDL (European Computer Driving License) course. Although he "*always liked the subject,*" he believes it would be appreciated to "*maybe do something a bit more specific*" from earlier grades of education, as in Italy, there is a "*very, very basic* [...] *computer culture*". Similarly, M.Z., a law student after completing a scientific high school, points out that computer science learned during different years of study, always mandatory but superficial, was "*not exciting, in the sense that it was not all that great of an activity*" and it taught him "*very basic things*", useful on a daily basis but quite limited.

Regarding coding, non-expert students appear to be aware of its existence as a branch of computer science, but they describe it with approximate terms and clearly indicate their distance from the field. "*Everything that makes up an application*" (R.L.), "*Video games programming*" (M.Z.), "*entering a code to create a website*" (A.C.), or even "*a page, a project, all nice schematic things*" (S.F.) are some of the definitions given to coding functions, not incorrect but certainly vague and incomplete. Alongside these definitions, there are often comments that reveal the interviewee's insecurity at that moment, ranging from M.D.V.'s "*maybe it's stupid*" to H.D.M.'s "*it's a definition from an ignorant person*" along with various other shades of uncertainty. However, just as with computer science, there is a shared belief that having coding skills is "*very interesting*" (S.F.) and important "*for developing a series of skills, even mental ones,* [...] *in an* [...] *efficient way*" (M.Z.).

However, this attribution of importance does not directly correspond to a perception of coding as something close to them, on the contrary: a vast gap opens up on this juncture, between students who have never actually dealt with coding on one side and vice versa on the other side. Even among the so-called "non-expert students", there are substantial differences based on their familiarity with the actual fields of application of coding that they have had the opportunity to acquire in their educational path. For instance, R.L., despite being a self-taught learner of HTML and expressing interest in coding, feels "*very distant*" from it and doubts whether he has the necessary skills to enter that world. Similarly, A.C. believes that coding is suitable for "*intelligent and good at math*" students, but she also mentions her school year in the Netherlands and the extremely interactive and project-based approach to computer science she observed there, finding it "*cool but* [...] *impossible*".

Furthermore, M.D.V., despite studying computer science in his scientific high school, views coding as "*a very complicated and difficult thing*" distant from himself, but he has never actually participated in related activities, although he is aware of their existence. On the contrary, S.F., who attends a vocational school for graphic arts, feels the topic is "*quite close* [...] *because, for example, they ask us to present our personal website with all our projects at the exam*". Moreover S.F. had also had the opportunity, already during middle school, to take part in a national project for girls only, focusing on technology topics, "*in Milan and at the problem-solving Olympics in Cesena*", an experience that positively impacted her, also because "*it was great to see that not only males can do these things*".

The gender issue indeed proves to be particularly significant in influencing the perception of coding, and more broadly the field of computer science, as either close or distant from oneself. J.L.B., a graduate in computer science and currently a secondary school teacher, laments that "[...] *unfortunately, at that age, the idea that science, but especially computer science, is stuff for males has already formed*". In his opinion, it would be appropriate to work on eradicating this preconception starting from the language used, seeking greater inclusion of the female component, albeit with the awareness that "*the difficult thing is to do it in a way that is natural, and not that forced thing*". On the other hand, L.C. (an experienced student) confirms that in his pure computer science degree course, there may be about "10%" of girls, already "*much more than the* 1%" he expected; while I.C., in her experience as a trainer, estimates at most "15%" of female computer science students, who "*all — almost all* [...] *come from the scientific high school*".

3.2.2 Benefits of coding

A potential bait for everyone to approach coding is the proven fact that its application offers multiple advantages, both in work contexts and in terms of transversal skills associated with various daily activities. Mental flexibility and a well-established problem-solving attitude are just two of the many positive factors officially recognized as resulting from the practice of this subject. In our research, we wanted to verify whether, to what extent, and in what ways there is awareness among the young people in the Trentino region regarding the benefits of coding observed in the literature, regardless of whether they actually use this skill in their own lives. It emerged that the majority of the interviewees, both experts and non-experts, attribute positive qualities and advantageous results to coding, both in their professional and personal lives.

A.C., a non-expert student, states, for example, that "The fact that these things are taught to children [. . .] already gives them extra capabilities that can be used in life, [. . .] not only in the IT field, but also in how to approach life in general". It is significant that such importance is recognized in the dissemination of coding skills from an early age by someone not involved in the technical-informatics field. There is a strong belief in the cognitive advantages of coding both in the digital world and in everyday life. Unconsciously, the statement of this student echoes the assumption that possessing computational thinking is "an attitude and a set of universally applicable skills that everyone, not just computer scientists, would be eager to learn and use" [236]. Therefore, mastery of this additional skill proves to be fundamental universally, precisely because "*it could help anyone*" (L.C., expert student).

At the same time, it is possible to argue that this essential skill has been applied by humans long before the recent introduction of technological tools accessible to all or the dissemination of programming languages [224]. In fact, its inherent characteristic is the problem-solving elaborative process, presumably as ancient as humanity itself, whose mastery still needs to be trained, and coding serves as an excellent gym for it. Several of the interviews we conducted have confirmed this perspective, highlighting how coding allows individuals to acquire a specific method, of a structural and systematic nature, to identify one or more approaches to solving any problem they encounter.

Indeed, expert students and training instructors believe that this is one of the most effective benefits of applying computational thinking to everyday life. As stated by E.M., an expert student, "*In my opinion, it makes you learn to think in a certain way, because in the end, it's about solving problems formally, analyzing a problem, and solving it systematically, so it's useful*". A.M., a teacher and trainer, agrees with the young student, convinced that coding "*teaches you to see everything as a problem to solve, to optimize, to face* [. . .] *[to] try to improve the process, in short. You develop a logical way of thinking* [. . .] *[useful for] how I approach problems and* [. . .] *how I try to solve them* [. . .] *with a certain method*".

Consequently, coding can be seen as a discipline that, in parallel with the development of logical thinking, leads to the ability to solve problems through structured methods. According to Wing, who builds on Papert's ideas, this systematic nature of coding arises from the fact that programming involves step-by-step formulation of a solution to a specific question, which must then be translated into a form that can be processed by a computer, regardless of its human or technological nature [236]. In other words, coding is not characterized by the mere execution of a program by a computer, but it also involves understanding and formulating problems and solutions, encoded and translated into shared languages. Thus, if we move away from the view that sees computational thinking as firmly anchored and limited to the IT field, it becomes evident how it can be "*applied to a little bit of everything*" (F.M.B., expert student).

Closely related to the universal utility of skills developed through coding, such as problem-solving, is the versatility of this field, which provides "*a broader idea of how certain things work*" (F.M.B., expert student). While some state that they do not consider coding as "*an essential basic skill, if that's not what you want to do*" (M.Z., non-expert student), there is an awareness that "*the further you go, the more important it will be even in the working environment*" (F.C., expert student). The interviewed teachers and trainers confirm this view, considering coding useful in "*any job*", as well summarized by J.L.B., a teacher, who exemplifies it in the professional figure of a garbage collector or a courier. When faced with a map of the city indicating the stops to reach to complete their task, this person must organize themselves logically to select the most optimal route in terms of time and safety. For example, they would prefer a route with right turns rather than left turns, as the latter are more dangerous.

"[...] *it sounds like nonsense, right?*" J.L.B. continues, "*But then you look at the data, and couriers have half the accidents compared to regular people,* [...] *there's a substantial difference. So if everyone could think in terms of analysis, evaluation, and finite reasoning, in my opinion, there would be a lot to gain*". It then becomes evident that, contrary to common belief, computational thinking does not only concern areas related to computer science or engineering but potentially any task. It represents a transversal skill that, like others, can be applied to topics of different nature and origin, and it enhances the worker in any work context.

As such, it is also multifaceted and capable of addressing the needs and situation of each individual, so that A.C., a non-expert student, defines it as particularly useful "*because it allows you to be much more independent*", while L.C., an expert student, mentions how it facilitates the approach to "*anything of a technological nature*", including the use of digital identity or SPID. Benefiting both professionals and non-professionals, the autonomy provided by coding is proven to derive, once again, from its fundamental principle of devising solutions. Specifically, the constant hands-on experimentation and the continuous trial and error are necessary difficulties in relation to the advantages they bring [41]: "*No matter how much you think and prepare, there will always be a problem* [...] *[so] another transversal aspect is that [coding] teaches you to be very patient*" (L.C., expert student).

The ideal process of learning coding indeed takes place through distinct and not at all obvious methods. D.L., a teacher involved in the volunteer movement "Coderdojo", notes that while working in various educational settings, he has realized the importance of students mastering the concept of "learning to learn" before delving into programming practices per se. This formula for knowledge transmission is actually recognized as a key skill in learning in general, and as such, it is incorporated into the current education system as stipulated by the European Parliament and the European Council through Recommendation of 2006/962/EC [41]. In teaching coding, this perspective can find particularly fertile ground as a more suitable approach for disseminating computational thinking within school curricula. Additionally, the ability to learn autonomously and consistently can be seen as a result of continuous practice of computational thinking, which, as seen before, comprises various mental skills related to organizing thoughts, processing information, and consequently, one's own education.

"*Coding, specifically, really teaches you to take each step, look at it, and think... do forward thinking*" (L.C., experienced student); it essentially trains you to visualize the different steps that lead to a result, in a systematic and organized way, and to orient your thinking forward. This ability is intuitively connected to that of planning the next steps in one's life, with a view to achieving desired professional and personal outcomes in the near or distant future. In addition to individual impact, it can also have a social effect. In the words of the training manager for Veneto and Trentino-Alto Adige of Informatici Senza Frontiere, "*If our boys and girls know how to use it [technology] from an early age, but use it actively, we have given them an extra chance to be active and incisive citizens* [...] *in their daily lives and in society*" (I.C., teacher and trainer).

In light of these considerations, we can conclude that the benefits of coding are indeed evident to the young people in the Trentino area, whether they have already been exposed to coding concepts or have no prior specific knowledge. Despite the very small number of subjects we interviewed, they are essentially in agreement in defining coding as a skill that, once acquired, expands their cultural baggage in a transversal manner. Young people, in particular, are seen to benefit from learning coding in terms of both skills and mental capabilities, which will support them in complex decision-making and organizational situations as they transition into adulthood. The spread of correct and purposeful use of technology among them also appears to contribute to making them increasingly aware protagonists of the society they live in, designating coding as a beneficial and fundamental skill for the future, in computer science and every other field.

3.2.3 Poor effectiveness of school teaching

What has emerged so far demonstrates that young people are aware of the importance that coding holds in their education, primarily in terms of employment prospects but also from the perspective of transversal skills. In general, computer science is considered an essential component not only by the experienced students, among whom some define it as "*the vanguard of sciences*" (L.C.), but also by the non-experienced students, who acknowledge that "*everyone knows it's important*" (A.C.) and even refer to it as "*fundamental*" (H.D.M). The interviewees widely agree on the usefulness of deepening their knowledge in this field, as "*whatever* [...] *you study, it could come in handy*" (L.C., experienced student), and "*these disciplines should be expanded* [...] *because currently, we see them in every aspect of daily life*" (R.L., non-experienced student). However, the recognized benefits of coding, as discussed in detail, are in contrast with a widespread perception of overall inadequacy in the school's computer science education. This critique is not only voiced by non-experienced students but also by teachers and trainers. These considerations, spontaneously emerged during the interviews, appeared noteworthy to the extent that we deemed it appropriate to allocate ample space to them in the data analysis. In our view, their relevance stems from the fact that the adequacy of computer science education in schools and universities was not initially identified as a central theme of the research project, but rather emerged as a topic felt by the interviewees, who they reported with notes of criticism, irony and discouragement. Specifically, as partly seen before, most non-experienced students highlight not only a clear sense of inadequacy but also a weak connection between the computer science taught at school and its actual usefulness. The criticisms mainly focus on the teaching methodology, described as "boring" because it heavily revolves around passively copying steps demonstrated by the teacher on the computer, without "*ever having the opportunity to take notes, do our own things, or effectively study them*" (A.C., non-experienced student).

The same A.C., enrolled in a scientific high school in the Province of Trento, also emphasizes: "*I didn't like it [computer science] much because the teacher didn't involve us much* [...] *It was boring because we spent the whole period copying from the board*". And she admits: "*I deleted everything, except for the things I already knew how to do*". This is a thesis also supported by H.D.M., a university student, who directly refers to the teaching method: "*Explaining computer science in such a frontal and non-interactive way* [...] *I mean, okay, but for me, it's more difficult*". The inadequacy of adopting a teaching and learning method often focused solely on passing a specific exam or completing the school year is evident. The solution adopted by students in response to this type of teaching is to "learn things by heart", with an overall discouraged attitude: "*No one understood the reasoning, so we said, well, it's like this now, that's enough... So from my point of view, I never really studied computer science* [...] *I don't even know what the exams were about, if you ask me today*" (H.D.M., non-experienced student).

The school teaching in coding and computer science is reported to be of little effectiveness due to a frontal and passive teaching method. This aspect also emerges in the research of Papert [170], according to whom using the computer as a tool for assimilating knowledge means aiming for active learning: the student must know how to program and not let the computer program them. In other words, students should not be seen as vessels to be filled with notions but rather instructed based on the goal to be achieved, which is to program the machines. A very similar concept is presented by I.C., a trainer, who highlights that "*machines must be used and guided by us if we want to make them our assistant*". Referring to young people, she adds that "*if we adults help them by providing methods, giving them guidance, [the computer] becomes an ally and a tool they use, they become more and more protagonists of it*".

To further summarize this view with a provocation, "the importance of play and thinking takes precedence over the learned notions" [170]. Coding, in fact, is based on Papert's constructionist learning theory, as it promotes the construction of mental models, the development of critical abilities, and the realization of concrete and operational thought processes. It is also capable of correcting the flaws of traditional schooling, where the student is often a passive object of educational systems that make them less participative [91]. However, this cannot happen if the teaching of coding is also subjected to the aforementioned flaws, as unfortunately confirmed by the professional experience of the trainers and teachers we interviewed in the context of the research.

These ones contribute to the overall assessment of inadequacy in the teaching with particular bitterness, strongly criticizing various aspects. A heavy burden of bureaucratic work, the lack of adequate computer laboratories, and the presence of teachers who are highly unprepared in the subject are just some of their reasons supporting the criticism of the Italian computer science curricula: "*From the perspective of well-organized structural commitment, there is nothing. You can even go through the entire school path without even catching a glimpse of a computer.* [...] *I think that in the guidelines of the Ministry, it is indicated that coding should be done, but it is not mandatory, and many schools do not do it*" (D.L., volunteer CoderDojo trainer).

On this front, it is very recent, compared to the date of writing of this research report, the decision of art. 24 bis of D.L. 152/2021 to introduce computers in all schools, including kindergarten. Starting from the academic year 2022–2023, the National Training Plan for teachers at schools of all levels "identifies, among the national priorities, the approach to learning computer programming (coding) and digital teaching". The aim is to promote and improve digital learning and skills as provided for in Law 107/2015, following the indications of the National Recovery and Resilience Plan (PNRR) that identify coding as a central theme to be adopted in the educational program of Italian schools. Therefore, starting from the academic year 2023–2024, all teachers will attend refresher courses in order to adapt to the redefinition of educational goals; starting from the academic year 2025-26, "*the development of digital skills will be pursued, also promoting computer programming learning (coding), within the framework of existing teachings*" (art. 24 bis D.L 152/2021). Even though at the current state, we must admit, it is far from achieving the hoped-for objectives.

Being able to stimulate the curiosity of the class and encourage active learning requires appropriate preparation. For this reason, even from volunteer movements like Coderdojo, initiatives targeting primary and secondary school teachers are increasing to raise awareness and bring them closer to a relatively new world in the Italian educational landscape. In the context of the emerging knowledge society, the importance of promoting the development of skills necessary to engage with new knowledge is becoming increasingly evident within educational systems. Crucial, for example, will be the ability to establish connections and synergies between the different learnings pursued within the school system, and to leverage technology as an amplifier of human potential and a tool to enhance the effectiveness of traditional learning processes [165].

On the other hand, the current lack of effectiveness in Italian education is connected to a series of structural rigidity in the curriculum, evaluation methods, schedules, physical spaces, and more, which are discordant with the dynamic, diverse, and complex characteristics of modern society. Consequently, it becomes challenging to capture students' attention and interest and to engage them in the learning process [165]. Notably, the theme of motivation for learning recurs several times throughout the conducted interviews, from which it becomes clear that to engage and inspire young people in coding, it is necessary to adequately motivate them at the school level. Besides being an essential element in raising awareness among young individuals about the subject, motivation appears to be a key ingredient in breaking down any prejudice and convincing boys and girls that "*anyone can do coding*" (I.C., trainer). The first step to spur students' interest would be to accommodate their inclinations and personal interests: "*there's the issue of motivation, if you tell them to only copy what you, as a teacher, like, that's what they'll learn; the best thing is to say 'create your own website, think of a topic you like, and develop it using the technology I explain to you'. That usually makes them take a step forward*" (D.L., trainer).

The difficulty in motivating students to study is the reason why, according to the interviewed teachers and trainers, most coding initiatives directed at students target primary school children or, at most, lower secondary school students. An example of this is the workshops organized by Coderdojo itself, which has long been engaged in educational activities specifically aimed at the age group of 6 to 12 years old. The trainers explain this choice by observing that children are typically very curious and easily engaged, making it easier to stimulate their participation and ignite their passion for an activity. They also learn more quickly than teenagers and are more malleable. As explained by J.L.B., a computer science teacher in primary and secondary schools in Trento, "*Children are extremely motivated, even with something trivial* [...] *if you set it right the boys get excited, and of course, the girls as well*". On the other hand, high school students seem to be a less sought-after target because motivating them appears more complex and challenging: "*[In the] first and second years of high school, you have some problems* [...] *with motivation. Apart from those two or three students who already know they will become computer scientists, engaging the others is the most difficult thing*" (J.L.B., trainer).

I.C.'s experience as the training manager of Informatici Senza Frontiere (ISF) confirms this gap between different age groups and the consequent focus on children when it comes to teaching coding. However, she also adds that, in the age group above 14 years old, "*it has been proven, I would say there is a global consensus now, that if we intervene and teach in a playful, fun way, we can engage girls and boys in using the computer*". Thus, a paradox emerges that we deemed worthy of attention: if coding is a mental exercise that everyone can benefit from when taught in the right way, why do coding activities mainly target children and sometimes teachers, while overlooking high school students? Accepting the assumption that motivation is the key to answering this question, our research therefore aimed to delve into the issue of how to best engage older students in coding learning, starting with the use of playful activities.

3.2.4 Coding awareness through play

Through the interviews with non-expert students, we have understood how coding, for those who have only a vague notion of it, tends to be labeled as something distant, complex, far from everyday life, and related only to certain educational paths. A.C., a non-expert student, summarizes the sequentiality of this type of thinking well: "*I think it doesn't concern me much because I don't believe I am capable, I mean I don't believe I would be able to learn it... to know how to use it in the best way*". Even though these "non-experts" do not actually exclude the possibility of being interested in initiatives related to the spread of coding, there is a persistent general demotivation or lack of confidence regarding the learning of this skill. On the other hand, the testimony of expert students, teachers, and trainers serves as a counterpoint, as they highlight its transversal benefits from various perspectives. Bringing the circle to a close, with unanimous agreement, there is an insufficient evaluation of education on coding and the development of computational thinking at the school level, where the few initiatives present are also rarely conducted in an appropriate manner and/or targeted to the age group investigated.

Based on these results, we wanted to delve deeper into the issue of approaching and motivating young people to learn coding, especially those who perceive it as a distant world. As already analyzed, the concept that coding can be learned by anyone and be useful to anyone seems to be effectively conveyed only by actively motivating students, for example, through playful tools. The expert students and trainers interviewed support this assumption, sharing their experiences and opinions on the matter. For instance, computer science student L.C. approached coding as a child through a "little game" composed of blocks, where "*depending on how you put the blocks together, you could make things happen, make them repeat certain actions, particular actions*". Similarly, F.C., a student of communication and meta-electronics engineering, suggests that to teach coding, it is useful to "*start with concepts and foundations, perhaps starting with a game to then make* [...] *them understand what is underneath it all*".

The importance of play in learning has been extensively analysed by various scholars and educators between the 19th and 20th centuries, including Maria Montessori, Rosa Agazzi, John Dewey, and Friedrich Froebel. Their studies highlight the child's ability, through playful activity, to develop creativity and strengthen acquisitions, while also promoting the learning of "emotional, relational, and cognitive skills" [208]. Even earlier, Jean-Jacques Rousseau introduced play into children's education, as it represents "one of the main ways in which children learn" [73]. According to the pedagogue Jean Piaget, playful activity also guides a complete development of the individual as it facilitates socialization and the development of intelligence [73].

Among the interviewees, there is a certain knowledge of different games that can serve precisely this purpose in the field of coding. D.L., a trainer, reports that "*There are games for the general public that have programming elements in them*". Three trainers and one experienced student specifically mention the free programming environment of Scratch, characterized by a graphical programming language, as a game to successfully engage and sensitize young people to the world of coding. Scratch is, in fact, "both a programming language and an online community where kids can program and share with others [...] their interactive multimedia creations like stories, games, and animations" [204]. The teacher and trainer A.M. endorses its highly educational qualities, allowing for quickly achieving visible and concrete results with strong motivational capacity: "*I know that from a certain point of view, it's for kids... but it is also used by adults, and I really like it* [...] *And you learn a lot, you learn geometry, logic, the Cartesian plane, etc. You do a lot of things, and you get results*". The possibility of obtaining real results through Scratch is also observed by the experienced student D.F. during the focus group, who describes it as "*a language, more like a puzzle, where you combine basic components* [...] *and* [...] *you manage to get something real, like making the little character move or things like that*".

As stated by A.M., it is, moreover, a flexible tool that can be adapted to the learning needs of children and adults alike, making it accessible to all ages, proving that "*anyone can do coding*". Equally committed to the cross-cutting expansion of computer science learning through gaming methods, albeit specifically in the school environment, are organizations like Code.org, which aims to provide every student in every school with access to computer science education. The organization's website offers various digital gaming activities focused on programming, designed for young people of all ages. Additionally, there is a section explicitly dedicated to high school students "and beyond" [50], a target that, as seen previously, is rarely taken into consideration in coding education. In addition to increasingly advanced online courses provided by well-known institutions like Harvard University and LinkedIn, here, older students can explore careers related to computer science and opportunities for mentoring, internships, and scholarships [50].

Similarly, the aforementioned Coderdojo movement is mentioned by three trainers and two expert students for its specific goal of introducing children and young people to the world of coding through playful activities. This "*international network of computer clubs where children and teenagers can meet and freely learn to write computer programs, develop websites, applications, games, and much more*" (Coderdojo Verona, n.d.) provides further evidence of the importance and effectiveness of learning coding in an active, enjoyable, and proactive way, quite different from what is typically offered in Italian schools. In the words of trainer D.L., in fact, "*Coderdojo does not have a school-based approach* [...] *Participants come, and they are children from 7 years old and up* [...]*[and] they try to build a little program... usually, the ideal is to create something fun, we teach them to create a video game*".

Another playful dimension that, according to four of the expert interviewees, would raise awareness of coding is the game of Lego bricks. I.C., a trainer, connects them to programming, saying that "*for example, Lego Mindstorms can be programmed with Scratch and similar tools. And then, it always refers to the concept of blocks* [...] *and being able to construct a sequence of bricks to achieve something that is at an exponentially higher level of difficulty compared to the individual brick you have*". The teacher and trainer A.M. takes the correlation even further, stating that "*those who created Lego Mindstorms* [...] *are people who have been dealing with computational thinking for a lifetime. In a way, the idea is that it gives you a mental openness that is associated with a creative game, so to speak*". As previously mentioned, computational thinking and coding are inherently linked, as the latter can develop the former and, in relation to it, the problem-solving activity that falls among its primary benefits.

Role-playing games are also mentioned as playful activities that can be related to these three areas. This is primarily because they are characterized by "*many rules [that] represent a formal system of execution* [...] *that somehow resembles* [...] *that of informatics*", as explained by A.M. "*And then [for] the fact that within this system, however, you have ways to solve problems and, in some way, this is associated with the ability to act in a complex manner, and therefore to find a different solution to a problem of some kind*". The ability to playfully develop coding skills, computational thinking, and problem-solving is similarly recognized in board games, such as Risiko (F.B., expert student) and Scrabble (F.C., expert student). Their affinity with the world of coding, more or less apparent depending on the type of game, once again lies in the presence of precise rules, the need to adopt a personal strategy and planning, and the strong connection to problem-solving [69].

Playful activities, therefore, seem to represent an optimal dimension for raising awareness among young people of all ages about learning coding elements. Through fun and stimulating activities offered by various physical and digital games, designed more or less specifically to lay the foundations of this skill, even those who do not consider themselves endowed with the necessary characteristics to approach the subject can be more easily motivated and passionate about it. This will reduce the perceived distance from this reality, hopefully leading to a greater general awareness of the transversal scope of skills associated with coding.

3.3 The local context

By entering the terms "coding" and "Trento" in any search engine, it will take less than a second for various results related to teaching and initiation to computational thinking in the Trentino capital to appear. At the top of the page, for example, you will find the local section of CoderDojo, (`https://www.coderdojotrento.it/`). Following this, you will see a small series of laboratory events organized in recent years by individual schools, the University of Trento, and local associations and museums such as Informatici Senza Frontiere, an Italian association that works to bridge the digital divide, and MUSE, the Museum of Science in Trento. These initiatives are often framed within the broader "Hour of Code" movement, also known as "Code Week" (`https://hourofcode.com/it;http://www.codeweek.it/`). Finally, there are some online training opportunities on "Coding and Computational Thinking" accredited by the Italian Ministry of Education, University and Research (MIUR), intended for teachers of all levels of public education.

By further researching and expanding the search, we can add Voxel and Delta Informatica to the list: the former is a transqueer-inclusive community in Trento for all women who want to become coders and software developers or improve in these fields (`https://www.voxel.community/it`); the latter is a company that provides various types of training in the field of business informatics. In June 2017, Delta Informatica received the Family Audit certification issued by the provincial agency for family, birth rate, and youth policies of the Autonomous Province of Trento (`https://www.deltainformatica.eu/formazione/`). After that, the relevant results will conclude, unless there are any updates from individual schools, the university, or local associations and museums, sometimes in collaboration with each other through funding opportunities, competitions, or similar initiatives.

On one hand, the Trentino region does not have a complete lack of opportunities for approaching coding; however, it cannot be said that such opportunities are abundant or structured in a way that reaches the population in a widespread and universal manner. In the case of school-age children and teenagers it becomes evident that there is a divergence between those who happen to find themselves in an environment sensitive to the topic, perhaps due to the personal interest of a family member or a teacher at their school, and those who do not. Therefore, it is not surprising that even among young peers from the same medium-sized city, there is a strong disparity in awareness of coding and its benefits, as indicated by the results of our research.

At the same time, the analysis of data collected in 2021 presents a concerning picture. The knowledge of coding is recognized as advantageous in various fields by all those who have approached it, both young and old; and the growing academic studies on the subject validate these personal testimonies. However, the school education system is slow to update itself on the topic, especially in higher grades, and is commonly described as inefficient, insufficient, and inadequate in teaching even the basics of programming. Above all, the lack of use of a highly potential educational approach, that of the ludic dimension, is evident in higher education institutions. Through this approach, even students who feel "distant" from the world of coding could more easily find themselves curious and interested in the field.

As seen before, the conducted interviews also confirm the presence of a generalized gap in providing training and introduction to coding for young adolescents, with a preference for children in the age group of 6-12 years, considered more suitable for achieving effective long-term results. Trainers and teachers interviewed report that, unlike adolescents, children are more easily stimulated to learn, engaged in the activities proposed by teachers, and inclined to understand computational thinking. Similarly, they observe a clear gender gap during adolescence that is absent in earlier stages: in their experience, it is during this phase of growth that boys and girls begin to define their interests, and too often, they do so by following stereotypes that associate technical-scientific subjects as predominantly male and humanities as predominantly female. Female students over the age of thirteen are thus considered "lost" by trainers in the field of computer science, and they, in turn, start to perceive computer science as distant from them, regardless of whether they have experienced it or not.

Also, from the identification of these age and gender-related issues, therefore, the following research stems. The primary objective is to spread awareness that "*it is never too late*" to learn the basics of computational thinking (I.C., trainer), and that it "*helps you a lot*" (J.L.B., teacher), and should be known by everyone regardless. It is indeed important to advance an initiative aimed at students, regardless of gender and the educational path they have chosen, avoiding prejudices that women may not be suited for computer science or that programming would be inaccessible to those studying in certain fields. Additionally, this study and the proposed and implemented initiatives aim to raise awareness that coding is not necessarily an activity exclusively related to pure computer programming. It will promote transversal skills and competencies that can be applied in all fields.

In this sense, we aim to show that teaching coding to young people over the age of ten, specifically in secondary schools, is particularly crucial. Whether they are already predisposed towards certain paths or believe that they are not related to computer science and coding, it is precisely in this age group that boys and girls begin to try to give a name to their interests and direct their educational and career choices in one field or another. Often, they rely on partial or even misleading information, influenced by stereotypes or trends. In those last three years of school, they find themselves having to make significant life decisions, usually with only the guidance of adults around them.

The backbone of the entire proposal and litmus test of its success will necessarily be inclusivity: to ensure that the initiative remains consistent with the context analysis conducted and the data collected, we find essential that it does not perpetuate any form of discrimination and is aimed at all categories of boys and girls, without distinctions. Despite the undeniable challenges inherent in designing an activity that caters equally to students with varying levels of coding experience, it would seem like a mistake to focus solely on the participation of those who have had fewer opportunities to explore the world of coding before or who statistically might have fewer opportunities in the future. We believe that such a choice would risk highlighting the gap instead of bridging it and would be counterproductive in demonstrating the true cross-disciplinary nature of coding.

The widespread belief, found among the students we have referred to as "non-experts", that coding is something unattainable, complex, and distant from their lives, is instead the myth that we aim to debunk with what we are proposing. Our hope is to intrigue and engage the participants in the topics we promote, so that if they wish, they can then independently explore them as they see fit. Therefore, the activities we will present from chapter 5 are not motivated as a direct response to an explicit need, but rather as a desire to fruitfully stimulate young people to learn a skill that, for the most part, they have not yet had the opportunity to appreciate its multifaceted relevance. We believe that practices of coding awareness and digital prototyping through play deserve more attention at the institutional as well as extracurricular level, especially in high schools. We will aim to seize the opportunities offered by innovative and playful learning approaches, encouraging creative, logical, and computational thinking.

3.4 A key takeway from this preliminary study

The transition from the era of knowledge to the era of skills is happening ever more rapidly [40]. Proficiency in transversal, basic, or specialized technical skills is fundamental for the positioning of workers at different levels of organizations within the complex and articulated reality known as the "learning society" [48]. In the context of a liquid society, where "flexibility is the slogan" [18], knowledge is continuously transforming, and the ability to perform professionally has been replaced by the ability to act professionally, where competence assumes a generative capacity for ever-new performances [190]. This is evidenced by the relevance attributed, in professional action, to tacit knowledge and competencies, such that today work is no longer reducible to the exercise of skills considered necessary for its performance but examines the protagonism of the individual with their cognitive-behavioral resources [40].

The preliminary research presented has considered coding precisely as a skill deemed fundamental for the education of new generations, to the extent that it has been defined as a "national priority" by the recent PNRR (art. 24 bis D.L. 152/2021). Considering this theoretical framework, the sociological analysis carried out demonstrates that young people from Trentino are indeed aware of the recognition coding receives in contemporary society, both in terms of hard skills and transversal competencies. However, paradoxically, the benefits associated with coding collide with a prejudice concerning their perception of themselves as ignorant and the impression of coding being excessively difficult. Moreover, especially from the words of teachers and trainers, the issue of the gender gap emerges, a relevant topic in sociological tradition, made evident in this case by the under-representation of women in the study of informatics and STEM disciplines in general. The gender issue poses itself as one of the most interesting themes, also in the perspective of possible future research lines, particularly with the purpose of focusing attention on the opinions, feelings, prejudices, and plans of boys and girls regarding coding and the gender gap in this field. The collected data then pointed to a widespread perception of inefficacy of the Italian education system regarding the teaching of computer science, a sentiment confirmed primarily but not exclusively by non-expert high school students as well as university students. This issue, although initially not identified as the focus of the research and not considered in the construction of the interview script, turned out to be central to defining the activities of the focus group and the subsequent development of the project proposal. To overcome a teaching methodology that often discourages those who should instead be encouraged and sensitized to the study of computational thinking, the data suggested addressing students' motivation, primarily through the use of playful activities. To experiment with what was learned in this regard, a moment of play dedicated to solving puzzles and logical enigmas was included during the focus group. The enthusiastic and interested response of all participants to the planned activity and the subsequent discussion confirmed the results of the analysis regarding sensitization to coding through playful activities and strengthened our belief in the validity and reasonableness of the activities and projects we will present in the next chapters.

In fact, based on the preliminary research on the state of the art of the previous chapter and these results, the following research took shape.

4 Architecture

Embracing the challenge

When I was younger, at a Christmas dinner, an uncle told me that I was conducting my explorations "sporadically, like a leopard's spots", and that soon I would understand how to connect the dots. Similarly, a few years later at a conference, I heard about the Marco Polo research, of which I could not find any references afterward, but understood it as a way of venturing into the unexplored and embracing all the new discoveries, bringing them back with oneself. Thus, with these two approaches intertwined, somewhat connected by serendipitous aspects and enriched by the knowledge accumulated from academic readings and field studies, our little ecosystem was born, with the UniTrento FabLab serving as its pulsating core.

In this chapter there are adaptation with minor modifications of our previous work published as "A Committed Constructionist's Reflections on Strategies for Fostering an Engaging Learning Community", "Designing a Hands-on Learning Space for the New Generation" and "A Conceptual Exploration in the Intersection of Crafts, Technology and Academia for Sustainable Job and Skills Development in the 21st Century" (see publication list at Section 1.3). These works offer a glimpse into the embryonic version of our laboratory, almost in a historical key. The aim is also to demonstrate how transformative this journey has been. Following this initial historical perspective, an adaptation of "A Committed Constructionist's Reflections on Strategies for Fostering an Engaging Learning Community" (see publication list at Section 1.3) will provide a more updated vision of our organizational design.

4.1 The context and a brief history

In Italy, university FabLabs are typically established within design, architecture, and art faculties. They provide students with access to digital fabrication tools that enhance their technical skills and stimulate their creativity [26]. Alternatively, they can be found within civil and industrial engineering departments, giving technical students the opportunity to rapidly prototype their designs before moving them to production [143]. These FabLabs promote the maker approach, which is based on hands-on and project-based learning methodologies, within the universities. The FabLab at the University of Trento, on the other hand, has a unique story.

The UniTrento FabLab was created within the Department of Computer Science and Engineering. Over the last four years, a distinct aspiration has emerged: to serve as the "educational hub" for a broader constructionist community, connecting all university departments and potentially reaching all the educational stakeholders in the local area, such as schools, cultural associations, and museums. Although some may find it surprising that an initiative like this originates from a computer science department, it is, in fact, a natural fit [169].

The University of Trento is a medium-sized, generalist university with 16,000 students located in the alpine region of Italy. Trento is an autonomous province, enjoying a certain degree of political and administrative autonomy from the central government of Italy. This autonomy allows the province to manage its own affairs in areas such as education, healthcare, transportation, and local administration. It also enables the province to make decisions and policies that cater more effectively to the specific needs and interests of its citizens while preserving and promoting its unique cultural and linguistic heritage. As a result, a strong sense of community is present in the region.

The University of Trento is the sole academic institution in the area, fostering strong ties between the university and the local community. The University offers a variety of degrees in numerous fields, including science, engineering, humanities, law, business, social sciences, psychology, and more recently, medicine. Arts and design programs are absent, except for a blended engineering and architecture degree with strong roots in the Department of Civil Engineering. Very recently, the university established a Teaching and Learning Center, trying to innovate its pedagogy, and started to participate into European networks where challenge-based learning is studied and encouraged. In 2019, the Department of Computer Science and Engineering established a FabLab, which, after a period of reduced activity due to the pandemic, became fully operational in 2021.

4.1.1 Fablab 1.0

Guided by the insights garnered from the preceding chapters, we embarked on the task of materializing these conceptual notions. This section is poised to adopt a historical lens, denoting it as Fablab 1.0, as it retraces the evolutionary trajectory that culminated in the establishment of the University of Trento's Fablab, detailing its inaugural steps.

Normally, when asked about how the FabLab was initiated, the story is almost always the same: it was just an idea in 2018. Then we began with the first activities in 2019, in a room full of students but with no digital prototyping machines. Subsequently, with the onset of the COVID-19 pandemic, the machines arrived, but the students were absent. It was only from the latter half of 2021 that we were able to operate with machines and students present in the same location simultaneously.

However, here is the story of FabLab UniTrento step by step.

During the initial months of 2018, a cohort of colleagues from the Social Informatics group dedicated efforts to enhance the integration of the Innovation and Entrepreneurship (I&E) curriculum with our technical courses. Swiftly, a pressing need emerged-to forge a space akin to a makerspace. The preliminary conceptualization revolved around two interlinked courses. The first envisaged adapting an existing program concentrated on product design and development, to be conducted within an environment reminiscent of a makerspace. The second course aimed to empower students to collectively evolve, shape, and sustain the lab employed in the inaugural course, thereby establishing a legacy shared among successive student cohorts.

The notion of fostering a legacy initiated by students and the concept of tapping into collective knowledge and solutions eventually became foundational to several interventions within the realm of technical education, as delineated in Chapter 2. This framework also underpinned the formulation of the intervention discussed in Chapter 4.

Amid this phase of brainstorming, a pivotal concept took root: the notion of peer-to-peer sharing of skills and expertise. This concept emerged as a fundamental bridge across the gaps in students' technical education. It retained its significance as we laid the initial groundwork for designing the fablab at the University of Trento.

As 2018 neared its close, the project gained momentum, with the formal objective of establishing a dedicated fablab within the University.

The first six months of 2019 witnessed the establishment of the initial iteration of the fablab, featuring the active engagement of a broader cohort of colleagues. Following this, in the latter part of the same year, the lab underwent a temporary hiatus due to renovations undertaken by the university. The lab's construction advanced steadily across 2020 and the opening months of 2021, predominantly influenced by the disruptions stemming from the COVID-19 pandemic. The pandemic necessitated the curtailment of in-person activities at the university, thereby contributing to the measured progression of the lab's development.

Yet, the initial phase of 2019 already witnessed some activities. We encapsulate several key interventions and contributions stemming from our research endeavours.

From a theoretical and conceptual standpoint, we delved into the potential positioning of the laboratory within both our university and the local community, as elaborated in this chapter and Chapter 7. On a pragmatic note, the lab commenced operations by delving into a niche that surfaced during our research — an intersection encompassing traditional crafts, scientific pursuits, and artistic expressions.

This initial experiment unfolded through a sequence of workshops, all revolving around the art of photography. The workshops commenced with an invited expert discussing photography's role as a conduit for communication, followed by a hands-on session delving into post-production techniques. Although additional workshops centered on crafting 3D printed pinhole cameras and developing photographic film were conceived, logistical constraints stemming from the lab's relocation prevented their execution.

Our reference to this initial experiment does not solely stem from its profound content impact, but rather as an embodiment of the type of experiential learning fostered within a makerspace ecosystem — characterized by peer-based interactions, informality, engagement with local community members, and an ethos of openness.

4.1.2 The very first design of the UniTrento Fablab

In this section, we present our first sketch of the principles that are at the basis of our fablab, with a specific emphasis on how fablab education should be adapted given the change in audience between "millennials" and "Generation Z". This is an adaptation with minor modifications of our previous work published as "Designing a Hands-on Learning Space for the New Generation" (see publication list at Section 1.3).

Abstract In this poster paper, we presented a "design document" for a fablab which is being developed at the University of Trento, in Italy. We discuss why and how the space of the fablab can be rethought for the generation of students currently in higher education, which, we argue, has different features than the one originally targeted by these structures. We discuss the three main design elements that we will use — combining high-tech with low-tech; constructivist education; and interdisciplinarity. Finally, we outline the relevant stakeholders for this type of initiative and how they can be empowered and integrated in the lab's architecture.

Introduction Since their inception in 2001, fablabs have undergone many radical evolutions, one among many being the introduction of easy-to-use electronics prototyping platforms such as Arduino. The increased accessibility of technologies such as 3D printing, laser cutting, the aforementioned Arduino etc. has proven in this sense to be a critical asset for the success of the fablab. This success particularly helped in accomplishing one of the fablab's implicit missions: building awareness ("evangelisation") in its users of the opportunities that these technologies represent. Additionally, many studies testify to the validity of fablabs as test beds for pedagogical experimentation and innovation, promoting a culture of hands-on learning and practice, especially in schools [118]. A subtle but substantial change happened in their user-base (i.e., the students), however. In universities, current cohorts are part of a completely different generation than the one that fablabs were originally designed for [119]. In 2001, MIT undergraduate students would on average be born between 1979 and 1983. Currently, those students would be born between 1996 and 2000. This second group has grown up and lived with digital technologies being a pervasive reality in their lives. Therefore, — we argue — those might not be interested in this "evangelisation" dimension but might be looking for a different educational gain from the fablab setting than the original group. This paper represents a "design document" for a fablab that the authors are developing at the University of Trento, Italy. We describe how we aspire at contributing to bridge the skills and generational gap between the current "high-tech" fabrication and traditional "low-tech" fabrication. We will describe how, for this model to be successful, students/users need to be strongly empowered. We then have a brief overview of who are the stakeholders that need to be involved for this educational mission to be achieved and draw some possible conclusions on what are the opportunities stemming from this view.

Framework We root our model on three pillars. These are not novel to the digital fabrication context. Instead, we believe that the space in the intersection between these three elements and the Higher Education context can be explored further. These are:

1. matching high-tech with low-tech fabrication;
2. constructivist Education;
3. interdisciplinary Education.

The first element stems from a reflection on the role of technology in the lives of the current cohort of students. As discussed before, students currently enrolled in university programs were born in the late 1990s and grew up accompanied daily by pervasive technologies. This, combined with the devastating effects of the 2008 economic crisis, lead to a generation of students that does not need to be convinced about the applicability and impact of technology. The aim, instead, is to create a lab that brings "low-tech fabrication" skills in the Higher Education context. Examples of such skills might be handicrafts, professional crafts, and spatial reasoning. These competences are fundamental for many economic activities that were once dominant in our cities (and in Northern Italy in particular).

These nowadays, however, are hardly represented in educational activities of universities. This is particularly true in ICT departments and curricula, which instead are the breeding ground for the affirmation of "high-tech" fabrication. From a practical point of view, a better integration of "low-tech" fabrication in the fablab would allow students to move from conceptualization to prototyping with a lower technological barrier, while also broadening their skillset. Filling this educational gap requires the deployment of pedagogical methods that allow for a free exploration of these subject-matters. Our design relies on a constructionist approach [44], which implies the need to challenge traditional trainer-student roles [38]. This can be seen as a source of extra complexity, but we deem this necessary because of two key factors.

On the one hand, students (and especially those in ICT-related fields) are possibly more up to date with technological trends than their trainers, leading to a need to empower them more radically in order to deliver a relevant technology-based education. On the other hand, to deliver on low-tech fabrication, we will need to rely on experts which are likely not to be teachers. Both these challenges become less complex in a constructivist learning space, which unties the involved actors from their traditional roles (i.e., trainers as the only providers of knowledge; students as receivers of knowledge) [31]. Interdisciplinarity becomes a natural — and desirable — consequence of these first two elements. Fablabs are by their nature facilitators of idea generation and cross-pollination [216]. We think that this needs to be brought at the forefront of the learning mission of the fablab, using the "making" as a field equalizer for students and experts, since nobody from a single discipline can possibly have the competences to take ownership of all processes that happen in this unique learning space.

The implementation of this framework requires the identification of all possible involved actors, and the establishment of an organizational structure flexible and resilient enough to guarantee a balanced representation of all the diverse expertise that contribute to the lab. What this means concretely, and who are the actors that we plan to involve is the subject of the next section.

Stakeholders The plan to implement the framework elements outlined above requires an involvement of multiple stakeholders at different levels, from within and outside the university.

We will briefly discuss their roles, starting from the internal ones. First of all, for daily operations, we plan to rely on a solid backbone of volunteers (in our case mostly students). Beyond operations, however, volunteers are also seen as the main content providers, and are encouraged to use staff as providers of solutions to make their ideas for prototypes, events, and workshops real.

As we are operating in a university context, we need to be aware of the fact that individual students are likely not to remain in the university in the long term. This can be a problem — as it makes harder for individuals to contribute to the long-term growth of the lab — but also a resource. A fast rotation of volunteers helps keeping a steady flow of fresh ideas, and mitigates the risk of burnout, especially when students are under high load for other academic reasons. We argue that coordinators and staff do not need to be subject to the same speed of rotation, and indeed might benefit from being more stable positions. Most crucially, the complexity of understanding procedures in the public administration means that, if staff were to rotate quickly, substantial effort would be spent in recovering procedural know-how.

Additionally, however, long-term retention of staff establishes clear figure heads and responsibility for external stakeholders that wish to support our initiative and allows to incrementally expand the lab's network rather than lose parts of it with departing staff. It should be stressed, however, that staff and coordinators are not the owners of the lab, and their main role is empowering the volunteers. The final internal stakeholder are university departments. As we discussed in the previous section, one of our goals is to promote interdisciplinarity. This translates concretely in the need to involve as many departments as possible to participate in the creation of this learning space. Sharing this project not only ensures diversity, but also makes it more resilient, diversifying funding sources and catalysing internal synergies. External stakeholders are more heterogeneous, so they will only be given a cursory look. In this sense, the most important class is that of practitioners, both from the "high-" and the "low-tech" fields.

Startups, innovation hubs, accelerators and foundations from the "high-tech" world that can support and benefit from the activity of the lab, gaining visibility, providing cases and challenges, and obtaining a more informal access to the talent pool of the university. Craftsmen, associations and groups of citizens on the other hand also benefit from the increased visibility, and act as gateways to those "low-tech" contexts that are less explored in their interactions with technology. Finally, local governments can act as network multipliers to broaden the reach of the lab.

Conclusions At the turn of this decade, the model of the fablab appears to be established and eradicated, and many universities adopted it as a one of their facilities. However, we believe a strong focus should be placed on a reflection and revision of what their role is, especially as an educational space that should complement and enhance the teaching offer of higher education. We argue that, as a side-effect of this reflection, some of the functions that fablabs perform might be put aside, to bring at the front one of the original goals of these spaces: providing students with a safe space for hands-on learning centered on skills and expertise that are not taught in their regular curricula. We argue that, in these times, this is particularly relevant for “low-tech” ideas and elements, to be explored in their combination with the “high-tech” fixtures of fablabs. As the technologies featured in fablabs have matured, the opportunity rises to refine the value proposition of these spaces. They no longer are a privileged space in which 3D printers or laser cutters can be found, neither they are the cheapest or fastest prototyping facilities. Instead, they remain, especially in their university incarnation, a rare context in which all these technologies and many others can be freely experimented with, without fear of heavy repercussions for failure. By this perspective, the fablab becomes not a space for “service” in the way that we commonly understood in the latest years (i.e., prototyping/electronics/cutting service), but a real “service” for the whole community that hosts them: from students, to universities, to enterprises. The opportunities stemming from this view are broad and powerful. As our societies face broadening skill gaps, increasingly difficult inter-generational dialogue and a culture of education which tends to work in silos, these laboratories can become a versatile link in the complex chain of human activities.

Poster We include the paper's poster that was presented at the conference (Figure 4.1).

Figure 4.1. Poster presented at the FabLearn Europe 2021 conference.

4.1.3 The "MILE Lab"

In this section, we present a slightly more mature view of the Fab Lab model that we presented in Section 4.1.2. We call this the "**MILE** Lab", focused on **M**aking, **I**nnovating, and **LE**arning.

Abstract Since the beginning of the new millennium, the rise of the maker movement has sparked again interest in crafts in academia and high-tech industry. Some attempts at establishing collaborations have been tried but have not solved the overarching problem of how our economy and society can find ways to cope with the perspective of technological unemployment. In this position paper, we propose a reflection, that leads to a model for a university laboratory that operates at the intersection of the three sectors of crafts, high-tech industry, and academia. We outline a vision where each of these sectors contributes with its main strengths to the creation of a laboratory that lies at the intersection between Making, Innovating, and LEarning, that we call the MILE Lab, that can aim to address the challenge at stake.

Keywords: skills development, interdisciplinary education, hands-on learning, technological unemployment.

Introduction With Artificial Intelligence widening its fields of application at an increasing speed, a similarly increasing number of jobs appears to be threatened by the perspective of the so-called technological unemployment [217]. This view is currently strongly debated [178], but one aspect remains factual: some jobs are rotating out of the market or have been otherwise significantly resized by the impact of automation. One such class of jobs is that of crafts [223].

The decline of crafts, it could be argued, started with industrialization almost two centuries ago. One of the side effects of digitalization, however, has been that of increasing economic inequality [131], which also contributed to this trend. The parallel increase in scholarization in the West [70, 36], also reduced generational turnover in the field of crafts, since the newer generation saw those jobs as less attractive. The final tally leads to a situation where crafts are hardly at the center of the political, academic and economical discourse, and products of these activities have been by and large replaced by industrially manufactured goods.

In this landscape, however, the arise of the maker movement can be seen as going against the trend. The vision of enabling rapid, accessible technology-powered crafting at small scale has gained substantial traction in the crafts, higher education, and industrial sectors alike. The movement impacted all these sectors, and has recently also started to produce significant results in the education field, especially at the school level [109],

In this section, we want to propose a reflection and a model for a university laboratory that operates at the intersection of the three sectors of crafts, high-tech industry, and academia by leveraging the defining aspects of those areas. We will outline a vision whereby each sector contributes to a common vision, leading on their core area of expertise and supporting those of the other sectors. Mirroring the expansion of STEM to STEAM [134], the key advancement proposed in our model is that of enhancing university makerspaces by actively including craftsmen as co-designers and co-leaders of the process.

We approached this task by first defining what are the problems of each of these sectors, focusing on how their job market operates and what skills they might need to remain sustainable in the digital era. For each sector, we also looked at what solutions have been attempted both on a per-sector basis and by grouping them in pairs and draw, making some critical considerations and highlighting where they could be improved. We will then briefly outline our model, and finally look at the limitations and potential impacts of our vision.

Problem definition and partial solutions In pre-industrial contexts, a large majority of the workforce was employed in farming, and crafts represented the more highly skilled segment of the labour market. Socially, this set them as a middle point between those that had to work to produce basic subsistence (*farmers*) and those that — in a form or another — employed workers (*aristocrats*). With the rise of industrialization, market demand for crafted goods decreased, making these jobs less attractive as a venue to economic stability.

Nonetheless, crafts kept developing well into the 1900s thanks, in greatest part, to the model through which skills used in the craft are transmitted, namely the master/apprentice relationship. Even this institution, however, has been disrupted by two key factors: first, as mentioned before, crafts became in general less lucrative and attractive as jobs; second, the rise of a competitive job market made the choice of working an unpaid apprenticeship position at a workshop usually a less interesting proposition than taking a job in the industrial sector. Despite this, crafts have grown to be part of our human and social heritage, to the point where they have been ascribed as a category to be part of the UNESCO Intangible Heritages. Some of them, however, have also been flagged as "endangered" [223], due to the shrinking number of people able to perform these crafts and low generational turnover despite many efforts undertaken to consortiate and consolidate crafts at local or national level (for example, see [186]).

Since the 2000s, the maker movement has revitalized the interest in crafts for the younger generation through the use of technology. The idea of combining the latest technologies with creativity and handcraft to create physical artifacts gained substantial traction. Crafts, however, have been mostly seen as something to be optimized through the use of technology, rather than a skillset with its own dignity. In other words, we could say that the maker movement has a tendency to "tech-wash" the crafts.

The same high-tech industry enabling the maker movement, however, isn't immune from the changes of the last years. Currently, industry employs a substantial amount of workers in lines such as clerical work and programming. These jobs have been recently framed as the most threatened by the perspective of technological unemployment [90]. Indeed, industry and academia alike recognize the need for engineers to develop a skillset which goes beyond technical skills [2]. Interestingly enough, some of these skills are integral parts of crafts, such as creativity and communication skills. To solve this, a great number of training programmes for young professionals have recently sprung as a way to complement academic education, offered by many heterogeneous organizations.

In parallel, academia has been facing the issue of making their educational offer more relevant to the jobs market and increase its mobility to industry and back [116]. In trying to fill industry demands, it focused its efforts on delivering technical skills, but the need of expanding academic education beyond such skills has been documented since the early 2000s in, for example, the EU's University Modernization Agenda [63]. In the European Union, substantial effort has been devoted to strengthening the ties between academia and industry to bridge the so-called innovation gap [166] through programmes such as the EIT, but there is no consensus yet as to the degree of their effectiveness. It should be noted that these collaborations have often seen innovation as the product of the cross-pollination between academia and industry, but have not involved crafts. Crafts are often involved as local stakeholders in lower level of educations (i.e., schools), but rarely they are involved in Higher Education. The general attitude toward crafts has seen the sector as one which is not academic enough, and especially not belonging to the much-sought STEM area.

The inclusion of Arts in STEM, however, creates a natural fit to deliver on the teaching of skills such as creativity by collaborating with those professionals that have historically pushed the boundaries of "applied creativity" in our societies. This trend also matches well with the pedagogical reflections of the last decade that have disrupted the traditional teacher/student roles in the classroom. Examples of these are methods based on experiential, project-based, hands-on learning. Indeed, as the speed of knowledge generation and obsolescence increases, all these methods have shown that changing the fundamental relationship of the classroom can be a powerful tool to provide more effective education. These settings also provide a scientifically validated playground in which craftsmen can attempt to disrupt the aforementioned master/apprentice relationship in novel ways.

If disruptions, and therefore innovations, are born in the boundaries between disciplines [215], the three-way boundary between these three sectors is one in which we can search for solutions that might be otherwise impossible if each sector approached this with a silos logic. We will now look at one possible model where such an intersection can be created, and what solutions it opens to.

A possible solution The solution spaces outlined above address the overarching problem in a "segmented" manner but are insufficient to achieve a holistic solution. Therefore, we argue that such a solution must be constructed by drawing from all the solution spaces outlined above at the same time.

In our view, each sector should contribute with their defining features: crafts are defined by non-repetitive work crossing over with arts; high-tech industry is defined by exponential growth in terms of product and process innovation; academia by its commitment to education and use of the scientific method.

Our proposed solution is a physical and metaphorical space that we call the "MILE Lab", a space for Making, Innovating and LEarning. This idea is modelled after several inspirations: the biggest is, for sure, the maker movement and Fab Labs, but we also see the MIT Media

Lab, the Stanford school and (something European?) as inspirations. Each of the three sectors converging in the MILE Lab can be seen as the leader of one of its dimensions (crafts for making; high-tech industry for innovating; academia for learning), with the two others supporting and complementing the dimension leader.

Making, inspired by the crafts, should be unique and artful. If the core problem to be solved in crafts is that of creating resilient jobs, the focus should be put in the features of that work which are the hardest to replicate automatically. Namely, these are the artistic, creative, and cultural aspects of crafts. This type of making, however, should also be technology-aware, to avoid repeating the errors of the past and ensure turnover and scalability of a craftsman's activity. This is where we envision the collaboration of industry, which can contribute bleeding-edge products and solutions. Academia also has a key role in ensuring that making is not done for its own sake, but has purpose (educationally, and in terms of skill acquisition). Making should be visionary and flexible enough not to be a mere application of currently available technologies, but instead seen as a process independent from the tech substrate, so that expertise acquired in the process can be adapted and applied in the future.

The view of innovation driven by the high-tech industry is focused on the generation of value, since businesses need to be sustainable. Our view of the MILE Lab also sees innovation as something that should be applied, and oriented to value generation (not necessarily in monetary terms, but also in terms of social, human and community value). In the duality of radical/incremental innovation, industry has been mainly focused on the incremental side. Integrating these "continuous improvement" processes into the architecture of the laboratory can add value to both crafts and academia. Academia, on the other hand, contributes to the innovation dimension by means of interdisciplinarity. Computer Science, Electronics, Design, Social research, and many more academic disciplines all contribute to the implementation of the lab. The benefits of this interdisciplinary approach have been validated in terms of research, business, and especially education since the beginning of the 2000s [213]. The setting of the MILE Lab would allow industry to integrate these approaches to renew their commitment toward radical innovation.

Finally, the learning dimension is the true backbone of the MILE Lab. The main position that we want to take here is that learning in this lab should be researched. Epistemological stances, engagement strategies, teaching methods, outcomes and reflections should be documented and shared formally (e.g. through research papers) as well as informally (e.g. through whitepapers, workshops). We argue that our lab should follow educational models based on hands-on/experiential learning (which is also a key part of crafts) and divergent thinking (found in high-tech industry), but that these should nonetheless be subjected to the scientific method. Keeping this in mind allows to construct a framework for consolidation and incremental improvements to be put alongside the more disruptive approach that these learning strategies imply.

Conclusions In drawing some preliminary conclusions about this reflection, a first limitation comes to mind: our model for the MILE Lab ends up framing, at the end, an exercise which is still driven by academia. It would be interesting to discuss a similar model where the lab's

	Making	**Innovating**	**LEarning**
Crafts	Lead (*creativity*)	Support (*human heritage*)	Support (*hands-on learning*)
High-tech Industry	Support (*enabling solutions*)	Lead (*value generation*)	Support (*incremental, explorative learning*)
Academia	Support (*skill acquisition*)	Support (*interdisciplinarity*)	Support (*education research*)

Table 4.1. The MILE Lab

leadership is left to crafts or industry. The main problem in this case, however, would be ensuring that the organization taking the lead has enough manpower and capacity to commit to pursuing the goals of the laboratory as a whole together with their own goals. Another key factor that favours academia taking the lead is the fact that universities have a much longer lifetime as organizations than both workshops and companies.

In conclusion, with our reflection we aimed at drawing the attention at what we feel are some missing links of the models that we have taken as inspiration. In particular: 1) bringing the artistic part of crafts in the dialectics of technology-enabled making provides us a way to train students and construct jobs that are by construction harder to replace with machine; 2) the focus on value generation in such hybrid context makes this an exercise not just in creating a novel experimentation space, but one that — through its alumni — can one day feed back into the economy; 3) researching education both in a formal and informal way hopes to break one of the deadlocks that our field is facing, namely the fact that studies can be either scientifically meaningful or visionary, but hardly both.

4.2 The current architecture

In the preceding subparagraphs, two contributions were detailed that depicted the initial vision of the laboratory. It was conceived as an internal asset of the university, primarily functioning as a support facility for the student body. Over time, however, it has undergone an evolution towards a more systemic and integrated model.

The inception of the FabLab is the outcome of several initiatives undertaken by the department over the preceding decade, reflecting a dedication not only to enriching the student experience through extracurricular activities, but also to nurturing robust ties with the surrounding community. These foundational goals have, with the passage of time, morphed into a more ambitious endeavor to revolutionize educational practices across various disciplines and levels of education. This shift encompasses the adoption and implementation of constructionist theories and methodologies, aiming to foster an innovative, hands-on learning environment that encourages creativity, collaboration, and practical problem-solving skills.

Our primary aim is to promote the constructionist philosophy, which emphasizes free exploration, hands-on experimentation, and social interaction, by exploiting the protean ability of computers to embrace and facilitate learning across all the STEAM disciplines, ultimately fostering an inclusive and innovative learning environment [189].

UniTrento FabLab, in its evolution, has now become more than just a FabLab: it is a learning center, a professional development facility for teachers, and a place where university professors can meet to discuss innovative approaches to their teaching. It also serves as a social club where students can hang out, freely explore, and connect their ideas. Instead of merely “being present” and hoping that its physical existence alone would facilitate the sharing of ideas, the UniTrento FabLab actively fosters a blending of ideas and skills. It facilitates projects, connects students, and promotes design events both within and beyond the university. In doing so, it exports the skills and enthusiasm of its students throughout the region and realizes the university’s third mission toward society.

To achieve this goal, the UniTrento FabLab has established an external “arm”, namely Glow, a “cultural promotion association” (one of the legal forms of the third sector in Italy). Its objective is to showcase the innovations and designs developed within the academy, by connecting with people and communities that are typically beyond the reach of an university, such as youth organizations, town squares, mountain villages, and more. Glow plays a crucial role in our design: not only does it implement projects funded by charitable and non-profit foundations, but it also brings together volunteers and enthusiasts who believe in constructionist ideas and might not otherwise be affiliated with the university. The process of creating such an environment is ongoing. Although we only started recently (2019) and were hit by the COVID emergence like everyone else, the growth we are experiencing now is astounding. This is the time to reflect on the results achieved so far and to consider the challenges that lie ahead of us.

Building a thriving constructionist community is no easy task; it requires constant effort, adaptation, and collaboration among various stakeholders. Some of the key challenges we

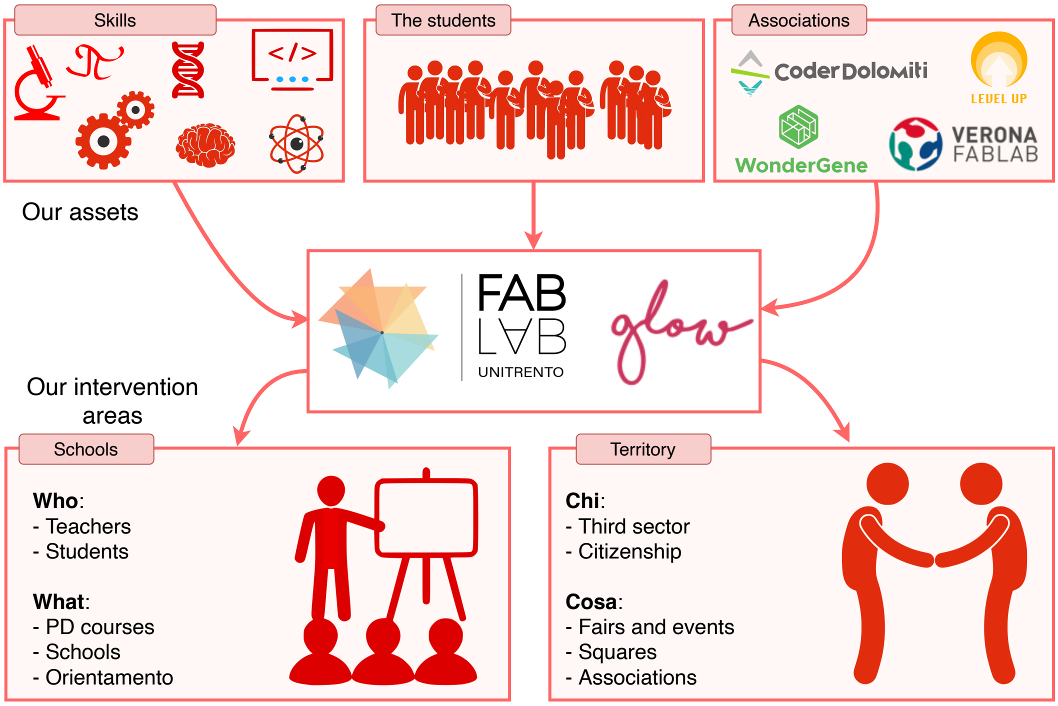

Figure 4.2. The FabLab UniTrento and GLOW Model

face include cultivating a sense of belonging and shared values among community members, while respecting and celebrating the diversity of backgrounds, disciplines, and expertise they bring to the table; establishing channels for effective communication and collaboration within the community, fostering an atmosphere of openness, trust and mutual respect; develop and maintaining partnerships with external organizations and institutions to expand the reach and impact of our initiatives; continuously assessing and refining our strategies and practices to ensure that we are effectively responding to the evolving needs and aspirations of our community members. During the process of building our community, we found immense value in the extensive literature available on constructionism and its effect on learning in formal and informal settings [169, 145, 189].

However, we observed a scarcity of research and reports addressing the broader objective for a university to create a constructionist community both within and outside its walls, ensuring its sustainability and growth [218]. While the paper presented at Constrctionism 2023 [155] may not have all the answers, we hope it offers valuable insights into the success we achieved and the challenges we encountered, and inspires other communities to embark on similar endeavors. By shedding light on the many open questions we continue to grapple with, we aim to foster a discussion not only on the most effective approaches to promote constructionist methodologies, inside and outside the university, but also on the process required to establish a thriving constructionist community.

Figure 4.2 shows a diagram of our model.

In input, there are the skills provided by the various departments of the university, embodied by our students, and a set of cultural associations and academic start ups that collaborate with us, some of which were founded by former students. At the center is the Fablab-Glow duo, operating in synergy as if it were a single entity. In output, there are our areas of intervention, not only within the university but especially in the world of education and the local community.

The FabLab UniTrento is coordinated by the author of this thesis and a professor and is equipped with a technical staff unit to ensure the operation of the devices; additionally, the author is also the founder and president of Glow. The rest of the staff is hired on a project basis, according to the competitive calls won.

4.3 The areas of intervention

The FabLab's initiatives can be broadly categorized into three main areas: supporting university students, engaging with schools, and connecting with the local community.

4.3.1 Supporting university students

Papert's constructionist vision, Resnick's creative learning approach, and the free access to new technologies provided by the maker movement are concepts that are seldom encountered in Italy's schools, particularly at higher levels. As students grow, they increasingly find themselves confined within individual disciplines, with limited opportunities for both interdisciplinarity and free experimentation. Consequently, they are forced into rigid learning patterns, becoming focused on obtaining grades and credits.

When students enter university, their experience often remains unchanged: they find themselves caught in a continuous cycle of lectures, studying, and exams, with little to no room for curiosity, serendipity, and personal exploration. This holds true even for courses employing innovative educational approaches, such as problem- and project-based methodologies [17]. The UniTrento FabLab's primary objective is to break this cycle by providing students with a unique space in which they can develop their ideas, passions, and skills within a highly interdisciplinary context. Interdisciplinarity here means the collaboration between different academic disciplines and fields, fostering an environment where students from various backgrounds can merge their unique perspectives, knowledge, and skills to explore complex problems and create innovative solutions. It encourages creative thinking, enriches the learning experience, and allows students to see beyond the confines of their particular study area. The UniTrento FabLab grants free access to students from all departments and offers basic skills training for those without technical backgrounds. To guarantee a truly authentic learning experience, the authors strongly believe that all activities offered by the FabLab should be extracurricular, not carry any credits, and be completely disconnected from any form of summative assessment [107]. Faced with this newfound freedom, students often struggle to adapt — after years of indoctrination by schools, they seem to be always waiting for someone to tell them what to do [127]. It is essential to provide them with the right prompts and create a community that can offer examples, fostering an exchange of ideas that enables a creative spark in students [201]. We offer a variety of initiatives to foster learning and growth among students:

- **introductory workshops**: We regularly organize introductory workshops to help students acquire knowledge and skills related to machine usage; examples of topics include 3D printing, parametric 3D design, laser and vinyl cutting, CNC milling and engraving. The laboratory is more than just a Fablab, however; it can take the form of a hackerspace, and meetings related to software tools have been organized as well; Flutter, OpenStreetMap, and LaTeX are just a few examples;
- **events and conferences**: We empower students to share their knowledge and transition from being learners to educators by allowing them to take on active roles in organizing workshops, seminars, and meet-ups on various topics. Some of the workshops listed above have been conducted by students;
- **resident students**: We encourage university students to live in our spaces and enhance their functionality. They often take an active role, such as welcoming newcomers and providing explanations on how the laboratory works, driven by the enthusiasm of being part of a community. When they are particularly proactive and enthusiastic, they are promoted to the role of resident students; they can access the laboratory even in the absence of staff and provide an essential contribution to the functioning of the laboratory;
- **hackathons and competitions**: We often organize challenge-based events that enable students to test their skills and collaborate with companies and associations. We participated in several international hackathons and programming competitions, such as DigiEduHack (two of our teams won the last two editions) and Google Hashcode (our hub was ranked second in the world in the last three editions). But more importantly, we support local companies in the organization of small hackathons that are used to get to know our students. The key to engaging students is helping them understand the significant contrast between the conventional learning methods they are accustomed to and the entirely distinct approach we adopt in the laboratory [114]. Once they grasp this difference, the next step is to engage them in spreading the initiative. They all become ambassadors of the FabLab, sharing their experience and recruiting new members. Moreover, they often become collaborators in activities outside of the lab, such as those described in Chapter from Chapter 5 to Chapter 8 examples are to support younger students in carrying out projects and to assist teachers as they participate in activities promoted by the FabLab.

4.3.2 Towards schools

An important aspect of the FabLab's mission is its connection with the world of primary and secondary education. The challenges faced in this context are similar to those mentioned previously – constructionist approaches are rarely applied, and teachers often resist change [135]. The strategy we are adopting involves gently guiding teachers towards a more constructionist model, without forcing them, and allowing them the necessary time to adapt. We adopt a scaffolding approach, where teachers are first introduced to a well-defined initial environment and provided with teaching materials to start. Then, they are supported by our students in the initial implementation of the activities; finally, this support is gradually withdrawn as the teachers become more independent.

- **teacher training workshops**: We organize professional development workshops for educators to learn about computational thinking, educational robotics, creative learning, and the maker approach. Our workshops provide teachers with both technical instruction and a space to discuss novel approaches to teaching, enabling them to incorporate hands-on learning and interdisciplinary problem-solving in their classrooms. More than 170 educators participated in the last edition of our main event, called Teacherdojo, which can be more aptly defined as a community of practice [234], as our trainers are experienced educators themselves who substantiate constructionist theory with real examples of activities that have been successfully implemented in the classroom.
- **curriculum development**: We partner with schools to create interdisciplinary, project-based curricula that prioritize experiential learning, teamwork, and critical thinking. This is achieved by incorporating FabLab resources and technologies into the educational programs, enabling engaging, hands-on experiences. These collaborations often arise from the workshops previously mentioned. Teachers recognize the potential advantages of these collaborations and seek support to more widely implement the constructionist approach in their teaching practices. For example, we recently developed a curriculum and materials for performing physics experiments that are instrumented with Arduino. By following a constructionist approach, the experimental materials must be assembled by the students. This provides a full and realistic experience that reflects the work of a physicist;
- **after-school programs**: a We offer after-school programs for students, where they can engage in constructionist learning activities, learn new skills, and explore their interests. A particularly captivating example is "Matematica in Gioco" (Mathematics in Play), an after-school program in which high-school students from various backgrounds—including both scientific and artistic specializations—designed and implemented board games inspired by mathematics, with the assistance of university students. When possible, these programs are co-designed with schools and teachers: the idea is to develop activities that can fit their current curriculum, but providing students time and space for free exploration. For example, we co-designed a bio-informatics activity whose goal was to identify genetic diseases in datasets provided by the Biotechnology department. In the first two years, the activity was promoted by the university and the school. Starting next year, the activity will be guided solely by school's teachers, without our intervention.

4.3.3 Towards the local community

An important aspect of the FabLab's mission is its engagement with the local community. By fostering collaborations and organizing public events, the FabLab aims to create a network of individuals and organizations that promote informal learning events in the region. In all the activities listed above, cooperation with Glow is crucial; University bureaucracy would have hindered the completion of most of them.

- **mobile Lab**: We created a mobile FabLab that brings science and technology to local communities, fostering formal and informal learning processes, creative co-planning, and community empowerment.

- **mountain cabin**: We operate a mountain cabin that hosts a variety of events, including science-focused summer camps, which immerse participants in the beauty of nature.
- **partnerships**: The FabLab-Glow collaboration serves as the hub for a network of partnerships with organizations that foster informal learning and innovative teaching in the local area. For instance, Coderdojo Trento is a youth club that encourages computational thinking via coding; Level-up is an academic startup that creates kits for learning science and physics; Wondergene is an initiative focused on making genetic analysis, typically conducted in specialized laboratories, portable and accessible to non-experts, including schools. We also cooperate with Verona Fablab, which operates in a neighboring province, and we plan to expand our reach to other local areas.
- **public events**: The FabLab organizes and participates in scientific fairs and public activities to engage with a broader audience and promote science and technology education. By showcasing the latest developments in the field and demonstrating the potential of constructionist learning, the FabLab aims to inspire community members to embrace innovative teaching methods and foster a culture of lifelong learning.

4.3.4 Online

All the previous actions have primarily focused on in-person activities. They serve as diverse containers capable of accommodating various activities for the different target audiences involved. Our latest endeavor is directed towards an online platform, **The LAAAB**: a catalog that represents us, where our approach and all the activities implemented by our research team and our partners can be further disseminated and even enriched by those who adopt them as their own.

4.4 The ingredients in our cocktail: a toolbox of possible concrete approaches

To make the discussion more tangible, we present some ideas below to propose a vision not only for computer science but also for STEAM disciplines in general, from a constructivist perspective that can make education more inclusive for everyone.

In this section some of the presented concepts will not sound new, as we described them in Chapter 2. Our goal here is to present some methodological approaches that can be employed immediately in the field of teaching and education. In the following chapters, from chapter 5 to chapter 8, we will demonstrate how we have integrated this vision into our activities.

These techniques should not be considered definitive nor placed within a value scale. They can be employed across various contexts, one or more at a time, depending on the specific needs of the situation. The following paragraph can be viewed as a type of glossary or toolbox. It aims to introduce certain approaches and methodologies that will be utilized in the activities described subsequently.

Computational Thinking and Computer Science Since the early 2000s, the term "computational thinking" has emerged strongly in educational debates, suggesting a new subject for teaching [236]. One possible definition of this concept is as follows: "The mental process involved in formulating a problem and expressing its solutions in a way that can be effectively carried out by an executor – human or artificial" [236].

In Italy, computational thinking is often replaced by the term "coding", which is imprecise and limiting. In computer science, coding involves assembling code, often taken from others, and does not imply the complex problem-solving process suggested by the definition. Consequently, activities associated with coding are often trivial, such as solving simple "programming quizzes" offered by platforms like code.org [50].

While it is necessary to elevate computer science as an autonomous discipline, encompassing elements of programming and complex problem-solving, it is also essential to recognize the cross-cutting value of computational thinking across all subjects. Using principles, tools, and methods typical of computer science to create, simulate, and execute worlds and abstractions otherwise impossible to "concretize" allows students to immerse themselves in these worlds, making the learning experience practical, authentic, and creative.

Learning-by-doing or Learning-through-making Learning-by-doing or learning-through-making refers to a practical approach to learning, where students must interact with their environment to adapt and learn [66]. As the activity is repeated, students go through multiple design cycles, gaining a better understanding of requirements, tools, and materials while making compromises and seeking to improve their prototypes.

These iterative phases allow teachers to monitor progress and ensure that students move forward toward a goal, avoiding last-minute procrastination. As Mitchel Resnick [189] states, this is a spiraling process where children imagine, create, play, share, and reflect, leading them to imagine new ideas and projects. It is through this process that students develop and refine their abilities as creative thinkers, learning to develop their own ideas, test them, experiment with alternatives, receive input from others, and generate new ideas based on their experiences.

Students should be actively and proactively engaged in the learning process, making autonomous decisions during activities. This hands-on learning, putting "hands in the dough", allows them to face real challenges and develop skills such as problem-solving, creativity, and collaboration, fundamental principles of 21st-century skills.

Challenge-based learning Challenge-based learning (CBL)'s teaching method aligns with the constructivist but also constructionism view, placing students at the forefront of their educational journey. They become active participants, identifying and addressing real-world challenges with concrete solutions, as detailed by the Politecnico de Monterrey [71]. Given that students tackle intricate problems, their learning journey becomes multidisciplinary. It integrates various stakeholder viewpoints and pursues collective, sustainable resolutions, as highlighted by Kohn Rådberg et al. in 2018. In this approach, professors act as guides, aiding teams in formulating questions, sourcing accurate information, analyzing data, proposing solutions, and ultimately implementing the results. The CBL method also prioritizes the enhancement of interpersonal skills, promotes introspection, and nurtures the expression of individual talents.

Creative Learning "Creation" lies at the heart of creativity and is meaningful only when founded on action [145]. Contrary to popular belief, creativity is not an innate talent but something that can be trained and cultivated over time. Qualities considered part of the so-called "soft skills", such as creativity, collaboration, passion, curiosity, perseverance, and teamwork, are certainly desirable for both teachers and students. While there are no specific disciplines where these skills are explicitly taught, they can be integrated into many existing activities in current school curricula.

Students learn creativity by practicing it. They can also develop self-esteem by engaging in satisfying work that they perceive as personal. Allowing students to choose what to work on based on their passions can be an excellent way to combine these aspects. Additionally, it can be an opportunity to integrate digital tools into other disciplines. For example, students can learn about "global citizenship" by creating a small video game on the 17 goals of the 2030 Agenda, build their own skateboard by designing the board from scratch, or electrify their bedroom door to prevent their sibling from entering, as one of our middle school students taught us.

When the educational community becomes a creative and productive context for learning, the results improve, and students feel more connected to each other and to their teachers, free to express themselves. By prioritizing the needs, interests, passions, talents, and curiosity of students, they demonstrate their ability to achieve unexpected things.

The Maker Movement An especially promising application to bring a different perspective to computer science is integrating the maker approach into the school curriculum. Makers are "digital artisans", inventors, authors, and artists who, out of passion, design and self-produce mechanical, electronic, open-source software, and robotic creations, as well as anything that stimulates their drive for innovation.

The maker movement is based on the democratization of the process of creating innovative solutions using digital production tools, such as 3D printers, laser cutting machines, and electronic components like Arduino or Raspberry boards equipped with sensors and actuators.

The maker approach in schools allows students to be active users and creators, rather than passive consumers of digital services. Technical skills are not an end in themselves but a lever to build new solutions, improve the surrounding environment, and address complex problems of our time. For example, during science lessons, students can build a digital microscope to observe bacteria and, in the process, learn about technology firsthand by creating original digital solutions as part of their learning journey [79]. At the didactic level, the object of study and the process of creating the object itself become a pretext to implement analysis and self-analysis paths and to implement knowledge and skills [141]. This process of digital creation is one of the greatest expressions of the learning-by-doing methodology mentioned earlier. "Doing" refers to the act of creation, utilizing new or familiar materials. Children have always made things, but their palette of tools and canvas has expanded significantly in recent years. Doing something is a powerful and personal expression of intellect. It creates "ownership", even when what is done is not perfect. People, especially the young ones, recognize themselves in what they have produced, often with pride.

Tinkering Tinkering is a uniquely human activity, combining social and creative forces that involve playing and learning. It can also be translated as "fiddling". The term seems to have been coined from the combination of "think-make-improve", representing an endless virtuous circle.

This process involves an initial phase of ideation, followed by a realization phase, and a final stage of verification and improvement, leading to the redefinition of the initial project and assumptions. For example, students can build a prototype of their creation simply by drawing a three-dimensional image and 3D printing it. Once the prototype is tested, modifications can be easily implemented by working on the three-dimensional image and 3D printing another prototype in a short time and at a low cost.

Many school activities have a defined structure and are ready to be evaluated according to pre-established criteria even before meeting the group of students. Play and free exploration are often considered activities reserved for recreation. Timetables and school bells indicate where students should be and what they should learn. Textbooks dictate the pace of learning. While such structured activities can adhere better to the "program" and predetermined curricula, ensuring greater uniformity in the class group, these constraints do not always favor learning. Their objective is primarily to provide a manageable, homogeneous, and efficient platform for teaching a predetermined content [145].

Creating a learning environment that deliberately breaks this forced structure in schools is difficult but necessary. Allowing children, especially girls, to experiment, take risks, and play with their ideas gives them permission to trust themselves. They begin to see themselves as more independent individuals, with good ideas that can be transformed into reality. Similarly, even if their ideas are not as valid, they can learn from their mistakes, understanding how these mistakes are an essential part of the learning and growth process. Referring to Resnick [189], many of the best experiences happen when we use materials from the world around us, tinkering with the things that surround us and creating a prototype. Receiving feedback and advice on what has been created is crucial for making improvements. In this iterative process, new ideas are created, advancing, and adapting to the current situation and new situations that will arise. Tinkering is where learning takes place.

Computational making Computational thinking is widely regarded as the optimal approach for instructing in computing and, on a larger scale, for problem-solving and system design. Yet, as computing evolves beyond traditional desktop environments, particularly with the growing presence of ubiquitous computing (ubicomp) technologies, our teaching methods must adapt. The maker movement offers the most straightforward access to these ubicomp technologies. Hence, we propose also to consider a shift from computational thinking to "computational making" as a foundational educational model. "Computational-making", as introduced by [193], encapsulates a holistic skill set that ought to be incorporated into STEAM education. This includes computational thinking, aesthetics, creativity, the ability to visualize multiple representations, understanding materials, and construction [193]. In essence, computational-making entails activities that require computational thinking skills while seamlessly merging craftsmanship with technology.

Failure Culture Granting students, the freedom to explore and try things on their own will inevitably lead to more errors and require more time. However, such stumbling blocks are natural and beneficial. Many contemporary books and articles celebrate the value of errors and failures as keys to innovative thinking [173].

Often, iteration is mistaken for failure, when, any iterative design cycle involves continuous improvement, retaining what works and addressing and revising what does not. This is learning, not failure. When children are allowed to think about problems, they can invent and implement different strategies to find an appropriate response, even if their path to success differs from others. Expecting a linear path that leads directly to the correct answer may save time but often does not lead to a complete understanding of the process. The purpose of education should be to encourage young people to develop such skills, enabling them to overcome challenges they encounter along the way and devise innovative solutions. Instead, we spend a lot of time telling children, especially girls, that making mistakes is bad and that they should strive for perfection, expecting them to accept rejection and try again lightly, which often does not happen. This does not mean that teachers should step back, and watch children struggle fruitlessly, but rather that they should provide a small dose of information to ensure small autonomous progress.

From this perspective, computer science can make a fundamental contribution. Unlike other STEM subjects, where, for example, it is not possible to identify an error without the teacher's input, when a student sets a goal, they can independently determine if that goal has been achieved or not and proceed by trial and error in the correction. By re-executing the program, they can assess the quality of their intervention without fear of judgment.

The Setting The setting in which education occurs is pivotal to the learning journey. It's essential for this environment to align with the core tenets of Constructionism and Maker Education. With Maker Education-based learning having the potential to occur in varied settings such as homes, classrooms, makerspaces, libraries, community centers, and even outdoors, the appearance and equipment in these spaces can widely differ. This offers a vast canvas for educators, designers, and learners to craft their ideal learning space.

Flexibility is crucial in shaping an effective educational setting.

If in Chapter 2 we based some of our methodological roots in the "Eight Big Ideas Behind the

Constructionist Learning Lab" by Dr. Seymour Papert, this section delves into the foundational principles that should underpin any Maker Education space, ensuring it embodies the true essence of Maker Education.

We started from Mark Hatch's Maker Movement Manifesto, that succinctly outlines the fundamental attributes and guiding tenets of Maker Education as follows: • Make; • Share; • Give; • Learn; • Tool up; • Play; • Participate; • Support; • Change. Guided by the hatch maker movement manifesto, we decided to review and adapt it to our constructionism vision.

The setting for educational endeavours needs careful design, especially when catering to the principles of constructionism maker education. here's a more condensed and structured perspective on the matter:

1. **Make**: central to maker education, it implies crafting and creating. the physical space should:
    - have spacious workstations like tables or benches to accommodate diverse projects;
    - offer room for building materials, tools, and frequently, a computer;
2. **Share**: this is about showcasing and disseminating one's creations and knowledge:
    - open workspaces are ideal as they promote interaction and sharing;
    - utilize tools like whiteboards and notice boards to facilitate idea exchange. partitions and doors should be minimal unless there's a specific need;
    - consider creating a "showcase corner" for displaying finished projects;
    - embrace online tools for sharing, mirroring the physical sharing mechanisms;
3. **Give**: this represents the act of gifting creations, a significant gesture filled with emotions:
    - provision for storage can ensure creations await their destined recipients;
4. **Learn**: a fundamental aspect intertwined with making:
    - ensure easy access to resources, both physical (books) and digital (computers with internet);
    - comfortable seating and ample lighting are essential to promote focused learning;
5. **Tool up**: refers to the ready accessibility of the necessary tools:
    - tools should be within arm's reach, ideally stored in cabinets within the learning space;
6. **Play**: a principle emphasizing the importance of uninhibited exploration:
    - spaces should be vibrant and lively, inviting creativity;
    - materials like lego and play-doh, but also paper and colours, can be made available to stimulate imagination;
7. **Participate**: engaging with the wider community:
    - the layout should be versatile to cater to diverse events, from seminars to exhibitions;
8. **Support**: demonstrating commitment to the collective maker ethos:
    - decorative elements, such as posters or photographs, can reinforce the spirit of the movement;

9. **Change**: acknowledging the evolving nature of making:
   - design spaces that are adaptable, allowing learners to personalize their environment.

4.5 Conclusions

Implementing "playful experiments" through computer science is a powerful idea in the context of learning. When children (but not only children) create something, they are engaged in active learning and having fun [196]. Recent studies on introducing a culture of learning-by-doing or learning-through-making in schools through labs and updating the academic curriculum suggest that students develop skills and interest in STEAM subjects and computer science [20]. Additionally, they foster critical thinking and the ability to solve complex problems. Furthermore, the realization of projects through the presented methodologies often involves an interdisciplinary approach, which is another important element in the training of citizens of tomorrow, who will face increasingly complex and transversal challenges across various branches of knowledge.

These methodologies can be applied not only to teaching STEAM-based activities but practically to every subject. Innovative and fun learning is achieved by "reserving time for play, free exploration, iteration, reflection, and sharing; [...] young people will have more opportunities to develop self-awareness, collaboration, and decision-making skills" [196]. This concept is also emphasized by the "Lifelong Kindergarten" team, which advocates that "play" also cultivates a willingness to take risks, experiment, and test boundaries [189].

By learning to learn and leveraging the iterative creation process, students also acquire the power to learn from mistakes and refine their skills through experience and perseverance. Cultivating an agile perspective on problem-solving, developing curiosity, and learning to be comfortable with "not knowing" will lead young people to develop a flexible mindset. And above all, it will help girls overcome many of the limits and stereotypes that society still imposes.

These methodologies and tools, but also the right setting in which they can explore and experiment, therefore, can be a means to prepare our young people with essential skills, competencies, and personal qualities for the 21st century, integrating computer science as a tool at their disposal. Bringing these activities to all Italian schools as a support tool for learning can be a starting point to prepare the next generation of young people to see technology as a tool for creation, change, and education. This will enable them to acquire the necessary skills to enter the workforce and overcome all barriers and stereotypes

5 Supporting university students

In this chapter, we will elucidate the evolution of our FabLab, particularly concerning our students within the University of Trento.

In the preceding paragraph, we presented a historical overview of the laboratory's inception, while also providing an insight into the current architecture of our activities. Therefore, the chapter will commence with the latest visions of the laboratory and the ecosystem it has fostered, demonstrating how this evolution is ongoing as activities within the laboratory continue to expand. We will subsequently transition to its actual core activities, such as introductory workshops, events and conferences, residents students, and hackathons and challenges, as described in Chapter 4. Mostly our activities are divided into:

- **introductory workshops**: we regularly organize workshops to help students acquire knowledge and skills related to machine usage, creativity, problem-solving, and teamwork;
- **events and conferences**: we empower students to share their knowledge and transition from being learners to educators by allowing them to take on active roles in organizing workshops, seminars, and meet-ups on various topics;
- **resident students**: we encourage students to live in our spaces and enhance their functionality. They often take an active role, such as welcoming newcomers and providing explanations on how the laboratory works, driven by the enthusiasm of being part of a community;
- **hackathons and competitions**: we often organize challenge-based events that enable students to test their skills and collaborate with companies and associations.

For the aforementioned categories of activities, concrete examples of their unfolding will be provided. This not only offers a chronological view of the FabLab's concept's evolution but also highlights our response to the challenges discussed in earlier chapters. It emphasizes our commitment to experiential learning and iterative improvement, continually refining our methods based on feedback from our participants.

5.1 FabLab 1.1

Following the embryonic iterations of the laboratory outlined in the previous chapter, we encounter the version presented in the paper titled "A Maker Approach For The Future Of Learning — Combining innovative methods of learning with a maker approach" (refer to the list of publications in Section 1.3). In this contribution, our interpretation has started to crystallize, exhibiting the nascent forms of various concepts detailed earlier, as well as the challenges we faced. Notably, it brought to the fore a plethora of open questions.

In that contribution [84] we started to define the vision that can be found in Chapter 4, based on the state of art of Chapter 2. Our focus started to be on how interdisciplinary approaches combined with active learning have recently emerged as pivotal tools in grasping our intricate world. Consequently, pedagogical frameworks are transitioning from a conventional stance to a holistic one, integrating Science, Technology, Engineering, and Mathematics with the Arts (referred to as STEAM). This shift recognizes the necessity for future generations to possess not only technical acumen but also attributes like imagination, creativity, design prowess, and analytical thinking. The research in question seeked to conceptualize, establish, and assess innovative pedagogical models that meld ICT proficiencies with the ethos of 'maker' culture. The overarching ambition is to instigate informal learning trajectories and foster inventive, collaborative planning among individuals typically sidelined in formal education settings.

Technology is not just a tool; it is an enabler that enhances citizen engagement via the STEAM disciplines. As practical arenas for these endeavors, we described the vision of the two FabLabs — one mobile unit named 'ApeLab' (that will be described more in Chapter 7) and another permanent installation within the University of Trento, intertwining technical know-how with innovation facets.

As in the previous sections, we argued that FabLabs are more than the sum of their parts. They have real potential to shape individuals lives and to create a shift in how we produce and consume everyday tools and artifacts. FabLab impact includes social impact (such as forming and connecting local communities, social capital formation, intergenerational learning, sharing and wellbeing), economic impact (such as helping to create and support entrepreneurship, assisting local and international businesses and informing non-governmental agencies and policymakers) and environmental impact (such as sustainability, food security, recycling materials, retro-engineering and shifts in where things are produced). The impact on education, as part of the social side, will be our focus.

The creation of FabLabs in universities must not only be functional to carry out normal curricular courses, but can serve as a support platform to provide the users with the aforementioned 21 century skills, as students but also as citizens. The goal is to create "creative thinkers", thus incubating proactive minds that can be adaptable to the needs of the labor market of the future. Design processes in places like FabLabs involve these design processes and critical thinking. Supported by the new technologies for digital prototyping [92] the FabLab can be one of the promising platforms for providing citizens with 21st century skills.

Blikstein listed three advantages of integrating FabLabs into schools being that FabLabs:

1. improve and enhance existing practices, skills and expertise
2. accelerate the cycles of invention and design
3. improve long-term projects and peer collaboration [28]

Posch [184] supported Blikstein's claim by stating that FabLabs play an important role in scientific and engineering training and practical learning of STEAM-related disciplines, as well as for artistic design and artifacts. These claims justify research like this to help identify the capabilities of university-established FabLabs. For academia, the Third Mission means that "propensity of structures to open up to the socio-economic context, exercised through the enhancement and transfer of knowledge" [14]. Therefore our goal must be to transfer our knowledge even outside the university setting. The objective will be to inform and to disclose but also to intrigue. Science is often overlooked and taken as something distant and boring, something for the few. Our task will be to create new educational models, which do not make the science spectacular, but which push people, especially the younger ones, to have the desire to deepen and explore more their knowledge.

The objectives to be pursued certainly start from the development of adequate educational methods. These will then be tested and re-produced both within the stable physical space, the FabLab Unitn, and on the traveling one, the ApeLab, thus reaching new audiences.

At the time of the publication,the status of the Fablab could be briefly described as "ready, but almost empty".

For the open question we readapted part of the article "A Maker Approach For The Future Of Learning — Combining innovative methods of learning with a maker approach" (see list of publications at Section 1.3).

The project started just before the pandemic and during 2021 has been possible to renovate and equip the rooms where that static FabLab is going to stay, buying the appropriate fabrication tools and hiring part of the staff. In parallel, the renovation of the Ape Car was completed and we started designing its interior to host tools and devices that can be easily brought around. The activities started, but then they are limited to students working on their thesis and Ph.D. candidates. It is important to note that we were already serving a quite diverse set of disciplines, including computer science and engineering, industrial engineering and mathematics. Unfortunately, the restrictions originated by the Covid emergence prevent us to open our premises to a larger public; for the same reasons, we are not currently able to bring our labs outside the University, so we are not able to report extensive results about the outcomes of the activities or the effectiveness of the educational methodologies.

Yet, the contingency could be translated in a unique opportunity to reflect on our goal and to design the methodology we wanted to adopt; this activity raised a large amount of key points but also questions that are worth sharing.

- **sustainability over time**: In our experience, public makerspace have a core of passionate members, who stay constant over time; their problem is to engage a larger public. Our population is the opposite; students are "resident", in the sense they spend most of their day at the university, but are bound to leave in 3–5 years. How do we create a community out of a such a transient population? How do we ensure that appropriate mindset is passed from one cohort of students to the next?
- **promoting an open mindset**: The FabLab is located closer to the scientific faculties.

Our first experiences with this population of students is that their mindset is quite bound to the curricula; they are focused on the next exam to complete, rather than the next concept to learn. How do we foster a change in mentality? How do we make them understand that tinkering and playing in a serendipitous manner can promote more important skills than rote learning?

- **involving students in the educational process**: The regular staff posses pedagogical skills and technical competences in the use of the machines, but clearly the amount of knowledge they will be able to share will be finite. How do we get students involved in the educational process? How do we make them propose courses and activities to enrich the educational offer of the Fablab?
- **involving schools**: Our department is already the hub of several initiatives for the professional development of teachers of the local province, in the field of active learning and computational thinking. The amount of activities that we organize could be much larger if we involve our students in them as tutors of less experienced teachers. How we can promote the learning-by-doing and learning-through-making approaches? How can we help students to develop the skills to act as effective tutors?
- **involving the society**: As part of the ECIU consortium of innovative universities (`https://www.eciu.org/`), UniTrento is involved in citizen science with challenge-based projects. How do we make science interesting for citizen without trivializing it or making it look like magic?
- **impact**: As argued above, we know that academic makerspaces can create meaningful experiences for students, we are already seeing this. Yet, how do we measure our impact? What kind of learning outcomes can have everyone involved? How were learning outcomes assessed during and after the process? To what extent are students developing skills and competences related to the design process (e.g. exploration, language, judgment, reflection, etc.)?

This work illustrated some preliminary work that has been carried out to establish the University Fablab at UniTrento and its mobile counterpart, the ApeLab. We really believe that an integrated approached, involving the university, the students, the schools as well as their teachers and pupils, and finally the local administrations and their citizens, can really enable our territory to embrace the digital revolution and project itself in the 21st century.

5.2 Current Fablab

During its initial years of existence, the activities of FabLab UniTrento were numerous; here, we provide an overview of what was accomplished. In this chapter we focus on the activity within the university. For a more comprehensive list, you can refer to the website `fablab.unitn.it`.

5.2.1 Introductory workshops

The FabLab serves as a central hub for hosting events, workshops, and various activities spanning the years 2022 and 2023. Our focus is directed towards post-pandemic events, aiming to acquire a more realistic perspective.

The format that has been proposed with higher frequency to students consists of introductory workshops on the usage of the machines available in the FabLab. These workshops are effective for a number of reasons. From an educational standpoint, they are a valid tool to pass not only technical knowledge and skills to students, but also vital transversal skills like creativity, problem solving and teamwork. From a more practical perspective, introductory workshops effectively reduce the need for individualized tutoring for novices. We have observed that organizing introductory workshops draws in students who might not have initially sought one-on-one guidance, encouraging them to engage with the FabLab for the first time. To determine the most effective workshop format, we have experimented with various approaches, adjusting factors like the workshop's duration, the balance between theory and hands-on application, and the number of participants. Based on our observations, the most effective format consists of a 2.5–hour workshop that starts with 1 hour of theoretical explanation followed by 1.5 hours of hands-on activities, involving 10–15 participants. Having this number of participants strikes the optimal balance between giving the chance to each student to be consistently followed by the tutor and the opportunity to engage with a group of other participants to collaborate and exchange ideas with. The platform that has been chosen to deal with the logistics is Eventbrite, which allows students to easily book a seat for the workshop. This allows also for an effortless collection of data about the participants of each workshop. The following table gives an overview of the number of participants during the year 2022 to the introductory workshops.

Eventbrite has been a useful tool also to ask feedback about the workshops in a structured way. This has been done by sending a questionnaire to the participants at the end of each workshop through the mailing list that gets automatically generated by the system. The questionnaires have the same structure for all the workshops: this allows for a general overview about the satisfaction level and effectiveness of the activities, giving at the same time the possibility to collect data about a specific workshop. Each questionnaire starts with some simple questions about the person, through which it was possible to observe that most of the participants are students of the University of Trento (91.2%), that the vast majority are male (80.7%) and that more than half are from the Information Engineering and Computer Science department (DISI), followed by the Department of Industrial engineering (DII), as it is possible to see from the following visualization.

A promising result that came from the questionnaire is about the amount of knowledge that students take away from the workshop in the FabLab. In the following figure it is possible to compare the distribution of the answers to the questions "How much did you know about the topic BEFORE the workshop?" and "How much do you know about the topic NOW?", on a scale where 0 means "no knowledge" and 10 means "expert". The strong shift of the data towards the right side gives positive feedback about the effectiveness of the workshops

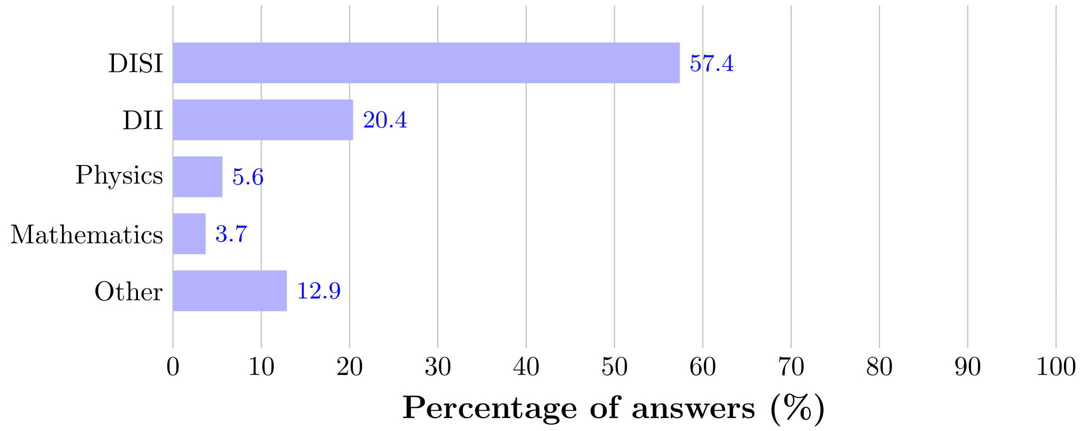

Figure 5.1. Departments of origin of the students who participated in the activities at FabLab.

Lastly it can be relevant to look into the results to the multiple-answer question "Why did you participate in this Workshop?". The fact that the most popular answer is "Personal interest" (84.2%) highlights the fact that one of the goals of the FabLab is being reached: being a space where students can follow their passions and learn in a creative way without worrying about credits and grades.

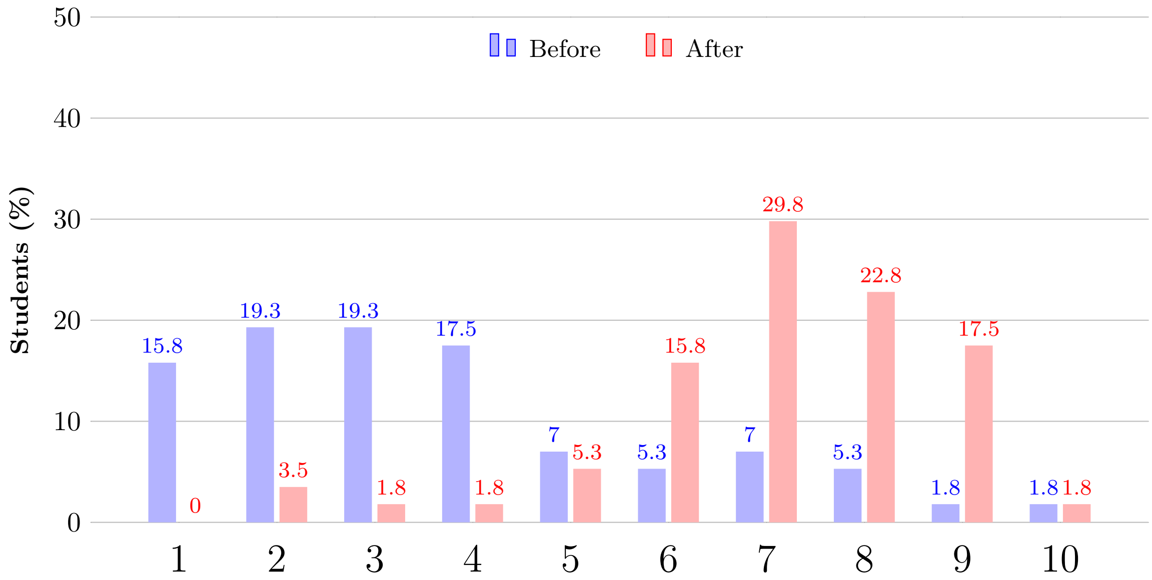

Figure 5.2. Comparison of Pre- and Post-Workshop Knowledge Levels

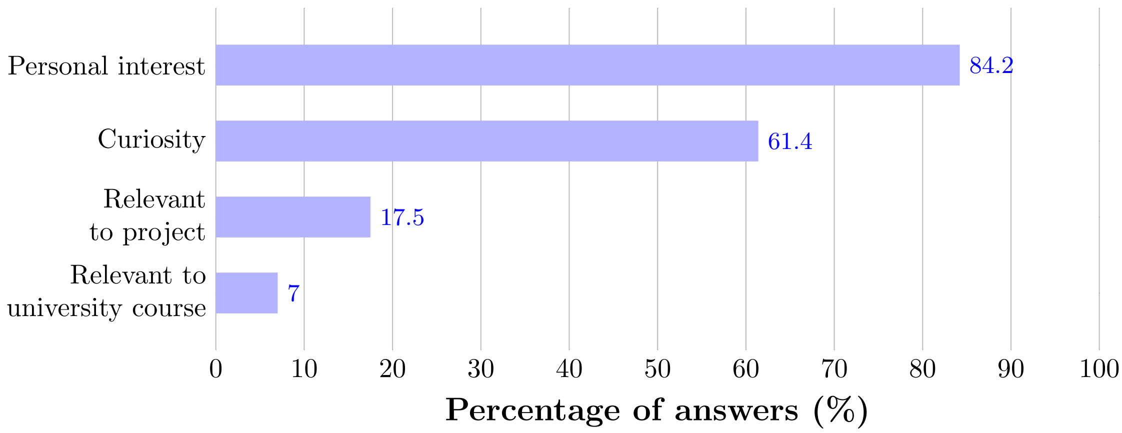

Figure 5.3. Participants' Reasons for Attending the Workshop

5.2.2 Events and conferences

During the year 2022 the FabLab has also been a space for events, conferences and hackathons. It hosted talks in the field of Data Science, such as The Data Scientist's Swiss Army Knife with Cristian Consonni and The Creativity of Data and the OpenStreetMap Ecosystem with Maurizio Napolitano, and events and hackathons in collaboration with realities such as Muse, ProM, Trentino Sviluppo and HIT – Hub Innovazione Trentino. For some of those events Eventbrite was used to collect bookings, making it possible to have an overview about the participants through the following table Table 5.1.

For some events which already require a registration on external platforms, this was not possible. Therefore, data about the participants of those events have been collected by hand.

Date	Activity	# participants
03/03/2022	Co-Design Workshop: il FabLab che vorrei	25
13/04/2022	The Data Scientist's Swiss Army Knife	18
18/05/2022	E-Agle Trento Racing Team: building electric racing vehicles from scratch	25
30/05/2022	Matematica in Gioco	13
28/11/2022	La creatività dei dati e l'ecosistema OpenStreetMap	13
29/11/2022	iProduce - CO-CREATION HACKATHON	13

Table 5.1. Events publicized through the Eventbrite platform.

5.2.3 Resident students

In the laboratory, our approach involves incorporating students, their passions, and interests. This approach sometimes translates into internships, theses, or papers. Below, we will present two success stories: MOQA and a project titled "Through Myself".

The choice to highlight these two success stories stems from the following reasons:

Concerning MOQA, our intention was to integrate a physical device that enabled us to monitor not only our new space but also its occupants, their habits in the use of the machines, and to gain insights for further improvements. This was facilitated by the involvement of regular visitors as well. Furthermore, after this initial MOQA experimentation, the project received funding from the university's strategic plan. This support has paved the way for the comprehensive monitoring of an entire university building, in collaboration with the University's Real Estate Office. The overarching objective is to enhance the optimization of energy consumption and the overall living conditions within all UniTrento buildings.

As for "Through Myself", the motivation was to extend our perspective beyond our immediate confines, striving to be even more inclusive and employing technology as a means to engage in dialogue with other disciplines, such as art, and with individuals possessing diverse abilities.

"Through Myself" is merely the inaugural instance of a project in which technology engages in dialogue with art and society. Few months subsequent to the completion of this project, another endeavor titled BASTH was presented, in partnership with the University of Bolzano. A comprehensive presentation of the BASTH project will be expounded upon in detail in Section 7.4.1.

MOQA — Enhancing Energy Efficiency and User Comfort in Educational Laboratories through Smart Monitoring Systems

Introduction The growing concern for energy consumption and environmental impact has spurred interest in exploring innovative strategies to reduce energy usage and enhance indoor environmental quality. This project was conceived by a PhD student from DICAM (Department of Civil, environmental and mechanical engineering) of the University of Trento, and focuses on the pivotal role of monitoring systems in curbing energy consumption and optimizing the indoor environment within educational laboratories. Specifically, the research delves into the question: To what extent do monitoring systems contribute to lowering electricity and energy consumption in a didactic laboratory, while simultaneously optimizing indoor environmental quality and user comfort? [39, 64]

This section describes the development and validation process of the graphical interface of the MOQA system — an accessible plug-and-play home automation solution for environmental and energy monitoring within indoor spaces. The system serves as a hub connecting to IoT devices, gathering data on energy consumption, temperature, humidity, noise levels, light exposure, and air quality. Based on this data, the system provides actionable insights to improve environmental health and reduce occupants' environmental impact through automated routines.

The MOQA system is built on the foundation of the open-source Home Assistant operating system and has been deployed at the UniTrento Fablab. Data collection occurred over a span of six months, incorporating interviews and questionnaires to enrich the analysis.

Recognizing that it is not the buildings themselves but the occupants that drive energy consumption, a key differentiator lies in the occupants' awareness. The centrality of the interface emerges as a critical factor, as data must be comprehensible, usable, and actionable. Effective strategies for heightening end-users' awareness within "smart homes" are influenced by multifaceted dimensions, including: (i) the quality of interaction (e.g. speed, brevity/easiness); (ii) information efficiency (e.g. accuracy and completeness); (iii) usability (e.g. ease of use, intuitiveness, user satisfaction); (iv) aesthetics; (v) functionality (e.g. offered features); and (vi) acceptability (e.g. cost-effectiveness, user base) [5].

The study also takes into account the Rebound effect (if a home becomes more efficient, occupants might increase consumption due to perceived "margin") [96] and the Hawthorne effect [147] (occupant behavior may change due to awareness of being monitored).

However, in environments like educational laboratories populated by students and workers, factors like the lack of direct utility bill responsibility for occupants and the perception that indoor spaces are not personal territories might come into play.

In summary, this specific success story advances our understanding of the interplay between monitoring systems, energy consumption, indoor environmental quality, and user behavior in educational laboratory settings. The subsequent sections delve deeper into the methodology, findings, and implications, ultimately contributing to the broader discourse on sustainable practices and user-centric design within built environments. Context and motivation

Researchers suggest that user interaction with comfort-energy monitoring platforms is important for improving energy efficiency and thermal comfort in buildings. Clear [49] and Harfield [104] propose monitoring platforms that empower users to make intelligent decisions about energy efficiency and comfort maximization. Becker [19] presents a generic Energy Management Panel (EMP) that connects the resident and the EMS, providing an efficient operation of the EMS complying with the individual constraints of the resident. [46] proposes a low-cost IoT sensor network for collecting real-time data and evaluating specific thermal comfort indicators. The papers suggest that user interaction with monitoring platforms can provide an engaging forum for a more inclusive building management process, and that a conversational approach in the design of comfort and energy-use interventions for the workplace is needed.

Studies suggest that data visualization can affect users' understanding of electricity consumption. Herrmann [108] found that a normalized disaggregated visualization was more effective than other forms of energy-consumption data visualizations in improving participants' knowledge of how much electricity everyday actions consume. Murugesan [158] provides design criteria for visualizations of energy consumption, which can help software engineers and researchers design effective visualizations for end-users. Costanza [56] promotes the integration of interactive energy consumption visualizations into Ubicomp systems, which can help users engage with and understand their consumption data. Hargreaves [105] explores how UK householders interacted with feedback on their domestic energy consumption in a field trial of real-time displays or smart energy monitors, and identifies significant implications for future research and policy in this area.

Case study The MOQA project was installed at the UniTrento Fablab in 2022 and focused on monitoring energy consumption and environmental quality during the use of four specific pieces of equipment: the FLSUN SuperRacer and Creality CR-10 Max 3D printers and the Trotec Rayjet R500 and Makeblock Laserbox laser cutters. This monitoring is crucial for identifying inefficiencies or environmental problems and finding solutions to improve energy efficiency and reduce environmental impact. Additionally, the MOQA project may help raise awareness among users about the importance of environmental sustainability and reducing energy consumption.

What is MOQA? The MOQA project concerns the monitoring of environmental quality and consumption, and was used as a prototype for monitoring the equipment of the FabLab at the University of Trento. The main component underlying MOQA is Home Assistant, a highly customizable open-source home automation platform that allows for the integration and control of a wide range of smart devices and services. It offers several advantages for implementing projects like MOQA that require the monitoring and control of multiple sensors and actuators. Some of the main advantages of Home Assistant are listed below:

- **flexibility**: Home Assistant supports a wide range of devices, protocols, and smart home technologies, making it suitable for the development of customized and tailored projects like MOQA;

- **modularity**: Home Assistant uses a component-based modular system, which allows for the addition or removal of functionality depending on the specific needs of the project;
- **automation**: Home Assistant offers the ability to automate various activities such as turning devices on and off, temperature control, lighting management, and more. This simplifies and optimizes the management of the entire smart home;
- **customization**: Home Assistant offers many customization options for the user interface, allowing for the creation of customized dashboards adapted to the specific needs of the MOQA project;
- **open source**: Home Assistant is an open-source project, meaning that its community of developers and users constantly contributes to the improvement of the software and the creation of new functionalities.

The first version of the MOQA project dashboard had some limitations in terms of user experience, including a lack of responsiveness. In particular, the entire interface was developed on a single YAML code file, which integrated several tabs and custom components for the creation and positioning of interface components.

The main disadvantages of the existing interface were:

- **absolute positioning**: the tabs followed absolute reference values for position, causing obvious misalignments in case of changes in monitor size/resolution. See the two figures below, which show clear misalignments when changing the monitor resolution type.

- **low usability**: The data provided was generally not very usable due to the lack of a legend or indications of good/bad values.

Methods To gain a better understanding of users' needs and improve the dashboard, semi-structured interviews and surveys were conducted. Specifically, 8 interviews were carried out with students and 2 with lab residents, both in-person and online. The interviews followed a semi-structured format that included initial questions to identify the context, specific questions about Version 1 and tasks to be performed on that version, and a general evaluation of that version. Subsequently, the new version was presented, and the same questions and tasks were asked. Based on the use of both versions, participants were asked to compare the two and suggest possible improvements and additional features.

Surveys were used to obtain both qualitative and quantitative feedback on the interface, with questions utilizing a 1 to 5 rating scale and some open-ended questions. A total of 50 surveys were collected for statistical analysis to derive findings.

Findings From the data emerged that the Fablab is considered well-organized, but with low temperatures due to the vertical "tower" cooling and proximity to the CIBIO labs. The issue of pollution and energy consumption is relevant, especially for laser cutting.

Version 1 The initial iteration was found to lack visual appeal due to a prevalent similarity in colors, resulting in a monotonous presentation. Graphs were noted to be unintelligible

Figure 5.4. Version 1 of MOQA.

and lacking in intuitive design. A scaling issue was identified, coupled with a deficiency in responsiveness. The arrangement of elements, particularly in the segmentation of rooms, exhibited potential for enhancement. While basic tasks such as retrieving historical data from graphs were generally accomplished with ease, the platform was deemed more suited for obtaining a broad overview of data as opposed to facilitating its detailed interpretation.

Version 2 Subsequent advancements in the interface design yielded a more contemporary and efficient outcome that garnered greater visual appeal. Graphs demonstrated improved clarity, though the inclusion of legends for specific values such as AQI and dynamic colors was recommended. Users appreciated the heightened responsiveness of the interface. The integration of external weather and air quality information was deemed beneficial, although it was suggested that these features could potentially be relocated to a separate tab. The presentation of instantaneous consumption and hourly cost received positive feedback; however, it was recommended that clarification be provided regarding the estimative nature of the latter. The inclusion of updated pricing information from Arera was acknowledged as valuable, although its accuracy could be bolstered by considering alternative data sources or directly utilizing real-time data from the University's electricity supplier. To enhance user engagement, the incorporation of interactive functionalities, such as controlling lighting and monitoring 3D printer material consumption, was proposed as potential avenues for improvement. The revised design facilitated tasks more effectively compared to Version 1, notably due to the dynamic color scheme employed in the graphs. Additionally, it was noted that the interface enabled users to derive feedback from the data, thereby facilitating awareness of air quality trends. Interviews conducted with users yielded suggestions for further enhancements, including optimizing the layout, enhancing interactivity, streamlining access to information, personalizing the interface, and integrating supplementary data sources.

Overall, Version 2 was regarded as a substantial improvement over its predecessor; however, it was acknowledged that further refinement and feature implementations could be pursued to capitalize on its potential.

During the interviews, participants provided insightful feedback on various aspects of the project. Overall, the Fablab was considered to be well-organized, although there were concerns about the low temperatures caused by the vertical "tower" cooling and the proximity to the CIBIO labs. Additionally, there was a significant concern about the issue of pollution and energy consumption, especially in relation to laser cutting.

Regarding the user interface of the energy monitoring system, the feedback was mixed. Version 2 was preferred over version 1, as it was more modern, efficient, and visually appealing. The graphs were clearer, although some values still required legends, and the responsiveness was appreciated. The external weather and air quality features were deemed useful, but the interviewees suggested moving them to another tab.

Furthermore, the interviewees suggested a range of possible improvements to the system, including adding interactive features like turning lights on and off, monitoring 3D printer material consumption, optimizing the layout, simplifying access to information, customizing

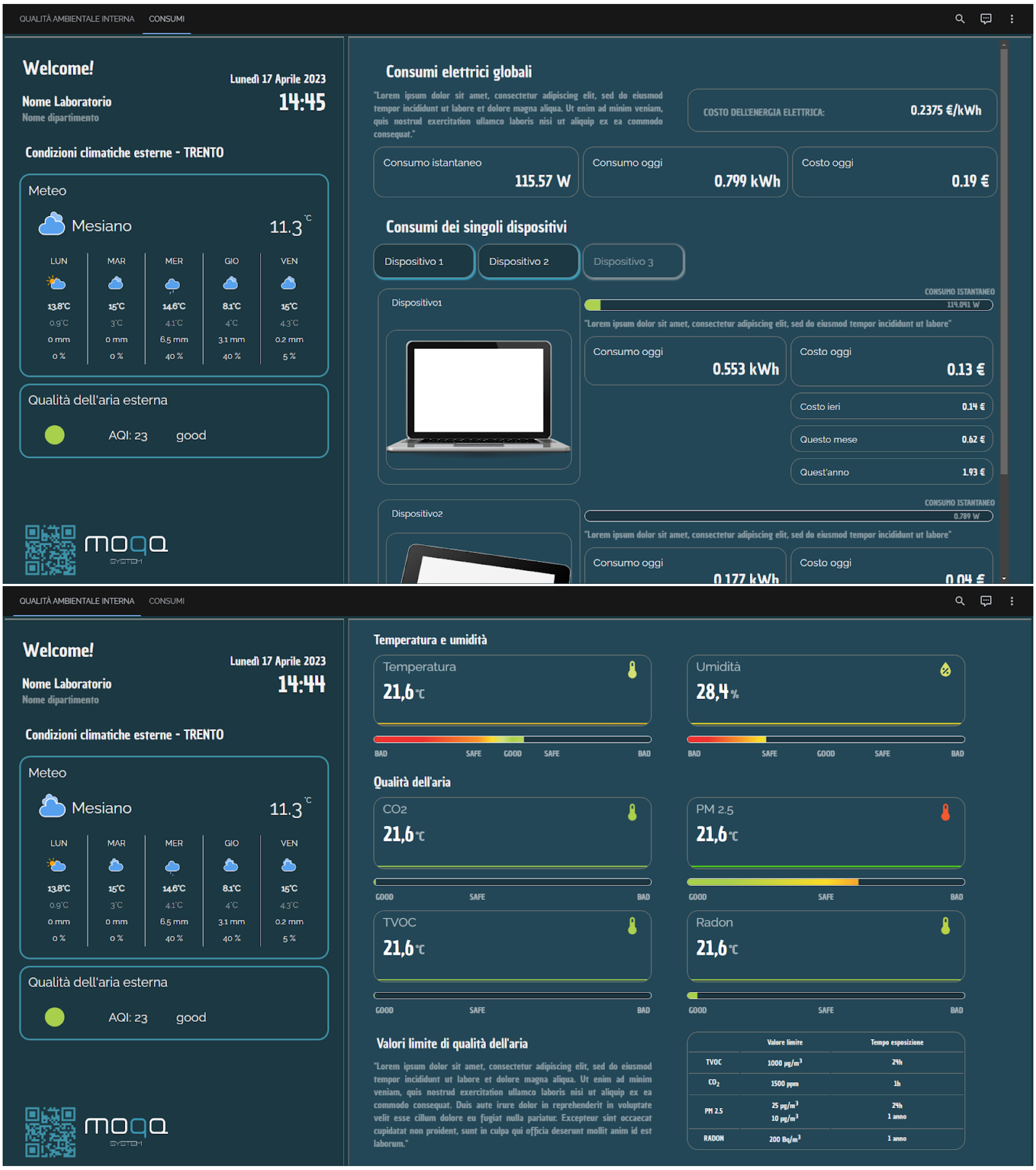

Figure 5.5. Version 2 of MOQA.

the interface, and integrating other data sources. Despite the positive reception of version 2, there was still room for further development and implementation.

There were some criticisms of the system, however. In version 1, the colors were too similar, making it difficult to differentiate between the different data points, and the graphs were unintelligible and unintuitive. Version 2 addressed some of these issues, but there were still scaling problems and a lack of responsiveness in some areas. The interviewees also felt that the organization could be improved, especially in the division of rooms. The instant consumption and hourly cost features were appreciated, but there was some confusion about whether the hourly cost was an estimate or actual data. The interviewees also suggested making the price updated by Arera more accurate, perhaps by changing the source or directly using actual data from the University's electricity supplier.

Overall, the system was considered to be useful in providing feedback from data and keeping users aware of air quality trends. However, there were still some issues that needed to be addressed, and the interviewees provided a wealth of suggestions for further improvements.

Version 3 In parallel with the validation, a process of redesigning and re-implementing the interface was initiated, using the same number of sensors and information present in the first version, while also adding new features to improve data usability.

The main changes in the second version include:

1. Development of modular code, with separate YAML files for each column or row of the dashboard. In particular, the following was developed:
    - 1.1. a common header for all three views containing logos, date/time, and a presentation mode button;
    - 1.2. in view 1 (indoor environmental quality), the leftmost column displays information about the temperature and humidity of the three laboratory rooms. The central column displays information about air quality in the laser machine room (which releases fine dust during cutting and therefore needs to be monitored), and a table legend of these values. The rightmost column includes new features for external weather and outdoor air quality;
    - 1.3. in views 2 and 3, dedicated respectively to 3D printers and laser cutting machines, a double-column design is used to display detailed machine status in each column. The display includes the machine image, daily cost and consumption in kWh, instantaneous consumption in W, estimated hourly cost calculated by multiplying instantaneous consumption by an hour and the energy cost, and a summary table of today's, yesterday's, this month's, and this year's costs and consumption. At the bottom, there is a row displaying the machine status (on/off) and the applied average cost;
2. Addition of new tabs:
    - 2.1. an external weather tab, which uses OpenWeatherMap API to monitor weather based on assigned coordinates;
    - 2.2. an outdoor air quality tab, which uses IQ Air API;

    2.3. detection of the average electricity price using a Python script that queries the ARERA website, which publishes quarterly average electricity prices for an average Italian user;
    2.4. addition of presentation mode, which uses an internal timer to cyclically switch between the three views every 30 seconds. This is especially useful when using the dashboard on an external fixed monitor that is not controlled, to have a continuous overview of all data;
    2.5. Addition of an estimated hourly cost tab.
3. improved graphical appeal:
    3.1. logical rearrangement of tabs based on location/function.
    3.2. dynamic graph coloring based on threshold values. For example, standard color for temperature between 18.5 and 27, red beyond these limits, and the same for all other sensors with appropriate limits.
    3.3. addition of responsiveness using specific CSS codes that allow for the scalability of tabs and fonts based on the width of the browser window, adapting the dashboard to different resolutions.

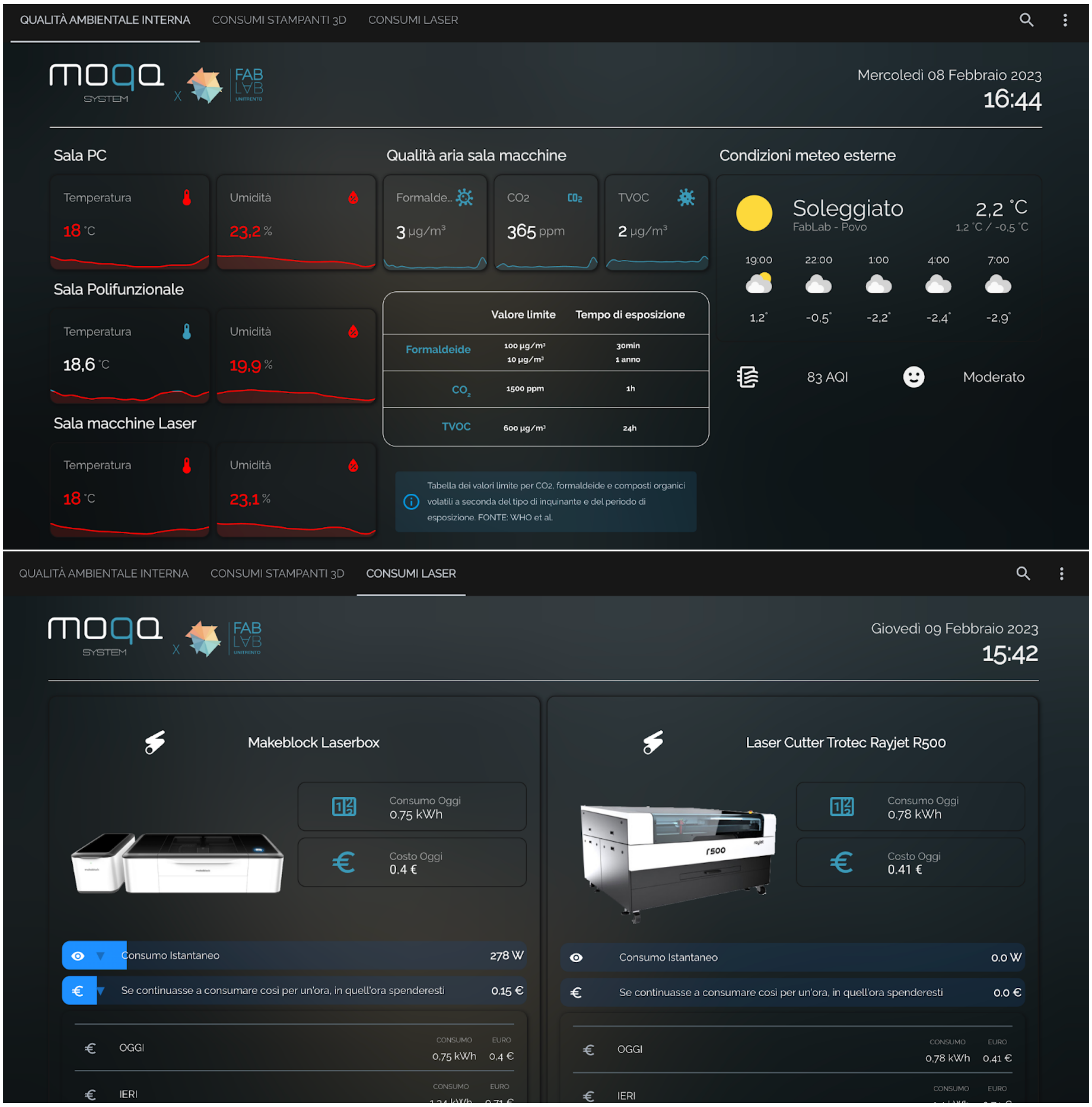

Figure 5.6. Version 3 of MOQA.

Conclusions and future steps This section described the process of creating and validating the interface to be used in the MOQA project. In the project's next phase, users (students, workers, technical staff, and researchers) in $5 + 5$ locations will be directly involved. Initially, the environment will be monitored without a display interface, followed by providing the ability to view Indoor Environmental Quality (IEQ) and consumption trends. The aim is to understand the influence of these monitoring systems on occupant behavior, their use of spaces, and the reduction of the environmental impact of their actions.

A third version of the interface is being developed to be compatible with the new evolution of the project, specifically for monitoring an arbitrary number of machines as well as improving the usability and readability of data. For instance, we added a legend bar under each graph, changed the colors and font, and intend to add a light theme as a result of what we learned from validating earlier versions. Since there is a filter selection for the devices in this implementation, we can add even more devices and only display the ones in which we are particularly interested.

"Through Myself" — Designing an inclusive activity for accessibility mediated by technology and performative arts

This is an adaptation with minor modifications of our previous work published as "'Through Myself' — Designing an inclusive activity for accessibility mediated by technology and performative arts" (see publication list at Section 1.3).

Abstract The project "Through Myself" aims to create an inclusive and accessible space in which everyone — whatever level of vision she or he has — can experience creativity through digital technologies and performative arts. To evaluate the potential effectiveness of the idea, research was conducted on existing similar activities. Several interviews were held with people with visual impairments, operators of an association for persons with vision loss, musicians, and dancers. Based on the results of the first phase, an artistic performance was designed. Participants' feedback has validated the project's intent and suggested useful insights for designing an interactive installation for inclusive educational activities. These activities can be proposed in schools or centers dedicated to inclusion and accessibility as a tool for building awareness about creativity and visual impairments. Furthermore, the project could be implemented by designing an interactive installation or environment based on the data and insights collected.

Introduction There is a wealth of evidence supporting the positive influence of arts participatory activities on well-being [164]. Furthermore, the entanglement of interactive technology and design for inclusion and accessibility in the heritage field has already demonstrated positive results. Design and art studies for society and communities have mainly been used to enhance accessibility in museums and to redesign public environments in more inclusive and accessible ways [103]. Inclusive and accessible technology in the artistic field is mainly used to build accessibility to arts [228]. Art technologies are mainly employed to promote social inclusion and build a more aware community in the public sphere. This study aims to combine art technology with purposes of social inclusion — including people having different cultures — and accessibility by designing an activity accessible to people with visual impairments to foster awareness and encourage dialogue. The idea is to exploit the potential of performing arts and artistic technologies by designing an educational activity. It would represent the first step for filling a gap. It lacks a meeting point for interactive technologies, art technologies, design for inclusion, performative arts and educational activities. They meet each other separately. It is important to remember that the end user of technology is always a human being. Educational technology must also consider creative behavior, which should be an integral part of any type of education. Human perception, experiences, and resulting behavior are reflective processes [115]. However, many technological devices require rapid jumps in attention and hardly allow for reflection, thus ignoring the complexities of our mind and body as stated by Ilgen [115].

To develop the activity, we conducted 17 interviews to explore the interest and potential usefulness of using Playtronica's TouchMe in combination with body movements and voice use for creative educational activity. TouchMe was chosen as an interactive technology designed for performative arts that measures the intensity of touch between people and turns it into sound. TouchMe operates using the tactile sense, which is one of the most used senses for exploration and experience by individuals with visual disabilities. It is a simple and intuitive haptic interface for exploring tactility. Being based on the sense of touch, it did not require any adaptation for its use with those with vision loss. With the term "disability", we refer to long-term physical, mental, intellectual, or sensory impairments that, in interaction with various barriers, may hinder full and effective participation in society on an equal basis with others — as it is stated by the United Nations human rights office of the high commissioner. There were four participants in total, two with different levels of vision loss and two without any vision loss. During the research phase, the interviews raised awareness that designing an inclusive activity required creating something for everyone, not only for those with visual impairments. Involving people with different kinds of vision was our first step in creating this workshop. Then, an artistic performance based on the activities we did was designed. At the beginning, a focus group was conducted with the participants and, at the end, interviews were made to collect qualitative data on the quality, effectiveness, and ease of the project. Based on the feedback of the participants, further research was conducted focused on already existing interactive artistic technology that could be used in such activity.

Related work Several studies and projects have been conducted on participatory arts activities and health, on the contribution of art and design to society, and on the design of interactive installations for tactile exploration for people with visual impairments. Participatory arts are gaining recognition as a non-clinical approach to the management and promotion of mental health and well-being. Recent evidence suggests that participatory arts may reduce symptoms of depression and anxiety and improve mental well-being [164]. The findings suggest that a reduction in tense arousal is a crucial component of arts-on-prescription services and establish a direct link between experiences during art workshops and changes in global well-being as stated by Holt [111]. Moreover, reviews have identified a positive effect on stress, social isolation, autonomy, and a sense of achievement [164]. Arts and health initiatives in communities grew in the late 1980s, using community arts activities to engage people in thinking about their health and to help individuals in disadvantaged areas or contexts [78]. Different artists and researchers have been using artistic practice within projects aimed at enabling researchers to collaborate with young people and communities [95]. They regularly run workshops in different contexts such as schools or as part of participatory design projects. The application of artistic practice combined with participatory design methodology in projects for education and communities is a recognized practice. Finally, there are several studies and projects proposing the design of technologically mediated exhibitions for blind and visually impaired people [228]. Most of them focus on the use of tactile or auditory systems. However, a combination of both systems would be even more effective. A multimodal combination may enhance cross-modal perception. It has been found that technological examples of simultaneous union of both senses are quite rare in communication devices for the visually impaired, and in museums, this lack is substantial [228]. All performative and participatory arts, workshop activities for educational contexts and technologies-mediated activities and exhibitions can have a great impact on creativity education and experiential learning. What about creativity? Why should we take this into consideration? One main definition of creativity is that a creative product or behaviour satisfies the criteria of being novel and appropriate [136]. There are also four major categories, known as the 4Ps, that explain clearly what creativity is. These include the creative product that results from the creative activity, the creative process involved in the creation of ideas, the creative person who creates, and the creative press or environmental influences on creativity [136]. Each of these can be useful both in the personal and professional life of a person. That is why it should be important to train creativity and make this training accessible to everyone.

Through Myself The starting point was the qualitative and quantitative data collected both from the literature review and the interviews. The main starting points for the design of the activity were different. From the perspective of the value of the activity, evidence was found in the literature on the usefulness of participatory arts activities and the use of technology-mediated experiences for people with visual disabilities. From the data collected through the interviews, the main outcome was the strong differences between blind and visually impaired people. Those who are completely blind have different challenges compared to those who have visual disabilities, as their experience of sight varies from person to person. The aim that guided the activity design was to use performative arts, such as dance and singing, in combination with a mediated-technology experience to promote body awareness and enhance creativity in an inclusive way.

Interviews and focus group To validate the activity, a qualitative approach was chosen, which was in line with the nature of the project – as it is aimed to construct an educational experience focused on emotion and creativity. Two rounds of semi-structured interviews were conducted. At the beginning of the project, 17 interviews were conducted using snowball sampling. To develop the activity, 17 interviews were conducted: 10 with people who are blind or have visual impairments, 2 with operators of an association for persons with vision loss, 3 with musicians and 2 with dancers that are also dance teachers. These interviews were conducted in Italian. The age range of the people with visual impairments was between 20 and 45 years, with 4 male and 13 female interviewees. The first contact was made through the local association for people with vision loss. The objective of the semi-structured interview was to identify the interests and the possible needs for activities aimed at educating creativity involving both the body and the use of technology. Based on thematic coding carried out during the analysis of the interviews, the activities to be implemented during the project were planned. In the second round, a focus group was organised with the 4 participants involved in the activity. At the conclusion of the activity, one interview with each participant was conducted to collect feedback. Both the focus group and the final interviews were held in English. This material was used to assess the participants' experience. We manually transcribed all the interviews and the focus group. Thematic coding and cluster analysis were performed on the data. The participants included two individuals with visual impairments and two without, all between the ages of 20 and 24, with three Italians and one Syrian. The small number was chosen because of the nature of the activity — which emphasised interpersonal contact — to allow participants to get to know each other and feel comfortable working together.

The activity designed The activity "Through myself" took place at a local dance centre. All those who expressed interest in participating during the exploratory phase were contacted; four of them accepted to participate. The proposed activity took place over four, with each meeting lasting three hours. Each meeting was focused on making participants experience a different performing art, through which they could get in touch with each other. The project started with a focus group in which the project and the operators of an association for persons with vision loss, a dancer, and a singer, were presented. Participants were asked to present themselves and then the following points were explored: What motivated you to participate? What is your opinion about creativity? What do you think about "artistic research"? Have you ever participated in a dance activity? Have you ever participated in an activity that involved using your voice and singing? What do you expect from these days and this project? What are your fears about this project? What are your desires for this project? The focus group ended by asking the participants to reflect on what they could think of if they knew they were going to meet someone new and share it with the other participants.

Framework The first day was focused on dance experimentation. The dancer worked using:

- study of musculoskeletal possibilities;
- creative workshop;
- theatre with principles of the Limón technique;
- weight study, fall and recovery [137].

The Feldenkrais method is an educational system that aims to promote deep somatic reconnection and neuromuscular relaxation through breathing. Its purpose is to reorganise movements and actions and to establish greater fluidity and awareness of your body [34]. For those who do not work daily with their bodies, it was an important tool for a first approach, giving them the opportunity to explore new parts of themselves. This was followed by the musculoskeletal work which, in addition to listening, involved the search for one's own movement and physical possibilities. This allowed participants to feel confident to move in their own space and with others. The creative workshop was then needed to foster communication and freedom of expression, leading to the use of Playtronica, experimenting with sound, touch, voice, gesture, and word, on the principles of the Limón technique "fall and recovery" based on the study of the bodies' weight [137]. The second day has been dedicated to the use of voice. The singer worked using:

- call and response;
- body percussion;
- circle singing;
- canon;
- training for collective listening.

Call and response are a succession of two distinct sentences; it is one of the basic elements of musical forms (typical of blues forms) that corresponds to the same concept of "question and answer" of human communication. It is useful for developing the melodic sense and interaction between multiple subjects. Body percussion involves using the body like a percussion instrument, allowing participants to directly experience the pulse, the rhythm, and the metric of words, while also developing their motor coordination. Circle Singing is a spontaneous practice that originated in Africa and involves using singing as a means of communication and community building. Participants typically arrange themselves in a semicircle or circle and create an improvised choral song together. Usually, there is a conductor who suggests musical phrases to the other participants by ordering when to start, when to stop and when to change the melody, through visible gestures. In this case, the visible gestures have been replaced by touch or simple speech. Canon is a contrapuntal composition that combines a melody with one or more imitations, which overlap progressively. It is a fun and, at the same time, complex exercise for a beginner, and is useful to develop their own autonomy and useful to maintain high concentration. Training for collective listening works as follows: among the participants, there were some who had never been part of a choir or sung together with several people. This can be disorienting. For this reason, it was necessary to train the ear to a collective listening that included both itself, perceived as an isolated element, and itself, as part of the whole of the other voices. So as also to take care of the dynamics and respect the space of others as much as your own. On the third day of the meetings, the operation and use of the TouchMe were explained. In addition to the exercises from previous days, the TouchMe was used to design an artistic performance as the result of the activities carried out in a group. The last day was dedicated to the performance, which was an open show organised for the public as a short event. The event was open to everyone, but it was primarily advertised to the local community and the personal networks of those involved.

TouchMe TouchMe (youtube) is a MIDI controller developed by Playtronica that allows users to create sound through touch and a digital audio workstation. The device is a thin metal plate about 15 centimetres long and 5 centimetres high, and the ends are round and produce sound when touched. The sound is generated by an algorithm programmed with Ableton Live software, which is managed by a workstation connected to the TouchMe. To allow participants to move freely in the space, a 10-metre `USB 3.0` extension cable is used to link the MIDI controller to the workstation.

The performance The performance was designed to incorporate body movement, vocalisation, and technologically mediated tactile experiences that produced sounds. In particular, the TouchMe device was used to enable tactile interaction between participants, which generated music when touched. The sound produced was a combination of synthesised sounds designed in collaboration with a sound designer.

Analysis The starting point was the qualitative data collected by the interviews and the review of the data both qualitative and quantitative found in the literature review that is constituted by the related work. There has been a significant improvement in well-being

Figure 5.7. Performance done as a conclusive event of the activity designed.

in terms of contentment, perceived energy level, and reduction of tension in participation in participatory arts activities. From this evidence, the question was: could be effective to combine participative art activities with art technology to design an educational inclusive activity? It was decided to use thematic coding and cluster analysis in the interviews and the focus group made to highlight the possible usefulness and difficulty of the project idea. The aim was to triangulate the data by mixing existing data reviewed with the qualitative one collected and through the experimental social project performed. The thematic coding of the interviews highlighted several points.

Results The results of the thematic coding of the first round of the 17 interviews highlighted four macro categories: relationship with the body, relationship with the environment, relationship with creativity, and relationship with technology. All this information resulted from the interviews with people with vision loss and the operators of an association for persons with vision loss.

The body The analysis revealed the challenges of educating individuals who are blind or visually impaired in managing their posture and manipulating objects in relation to others. These difficulties are especially prevalent during growth and development. Much of their education is focused on developing their own strategies for managing their body and its needs. It is important to note that each person with a visual impairment is unique and requires individual attention. While touch and hearing are often used to recognize others and objects, those who are blind face different challenges than those with visual disabilities. For them, vision varies greatly from case to case, and touch is often the preferred mode of interaction.

The environment Various devices are employed to aid in the movement and mapping of space. The white cane is one of the primary tools used for this purpose [125]. As emerged from the interviews, not all people with visual impairments use the white cane or need it.Generally, it is important that there are no obstacles in the space that are not visible or recognizable by the white cane. The space should also have clear angles to facilitate mapping. Audio sources can serve as helpful guides in space, but also become annoying and create difficulties, depending on the clarity of the sound source and whether it is stationary or moving. Creativity has generally been described as a creative activity and a possibility of personal and emotional expression. Frequent use of creative activities in the education of people with visual disabilities has been found. A feeling of greater confidence in doing tactile activities rather than music or dance was recorded. Many of the respondents had experiences with tactile installations to enjoy works of art or creative workshops. None of them ever participated or were aware of an activity that combined body movement, sound, and tactile experience.

Activities technology-mediated Technology is very important for blind and visually impaired people because it helps them in carrying out different activities. The most used technologies are speech synthesis. The interest in possible new accessible technologies, for creativity and not, was unanimous. In the focus group and the interviews carried out with the participants of the project a thematic coding was made and on this a cluster analysis. Three main categories emerged, each relating to creativity and artistic research, interaction with artistic technologies, and the design of the project itself.

Creativity, artistic research and Interaction with artistic technologies There is a lack of space to cultivate and educate creativity. This lack is to a greater extent for people above school age. Creativity is felt as a need. Common prejudices on creativity have been recognized as being more tied to artistic activity. Experimentation with TouchMe has revealed the need for the presence of tactile affordances in the interaction with the device. These observations were made by visually impaired participants, who would have preferred more tactile guidance on the surface of the device rather than just audio feedback.

Through myself The value of a project structured around long-term activities and regular meetings became clear from the feedback of participants. They expressed a desire to engage in more in-depth exploration and experimentation over a longer period. Participants noted that activities focused on creativity and experiential learning are typically geared toward children and young people, rather than adults. Additionally, each participant observed that the activities were conducted uniformly across the group.

Discussion The results of the project demonstrated its effectiveness and positive impact. By focusing on common skills between sighted and visually impaired individuals and combining technological arts with performing arts, the project achieved a positive outcome. The study utilised a mix of data from previous research and qualitative data that was collected and analysed. It would also be interesting to bring the project to schools and test its effectiveness with a larger and different target audience. All the participants shared how the nature of the activities — based on the body movements, the use of voice, and the use of TouchMe — involved the senses that all of them can use, making them feel living the same experience. The main contribution is the design of a framework that can be reused for the design of educational activities both in school and social to raise awareness of visual disabilities and educate creativity. Furthermore, the data collected from the project suggests the possibility of implementing similar activities in the future. The feedback gathered can serve as a basis for designing objects or interactive environments for inclusive and outreach activities.

Future work Future work focuses primarily on two issues. The first issue is to implement the activities of the "Through myself" project, based on the feedback collected on the experience of interaction with the technology used. After analysing the data, the question arose: could a larger object with different ergonomic characteristics be more impactful? It has been searched for if similar interactive installations exist. An interesting work from which the project could take inspiration is Tone Ladder by Christopher Bauder. It is a household ladder extended with sensors that turns into a real musical instrument. If you step on a rung or touch it with your hand, a sound or rhythm is created that varies from step to step. An individual piece of music is created by climbing up and down or by touching several rungs of the Tone Ladder at the same time. The ladder would be an object of the environment with better ergonomics features for dimensions and the possibility to map the space by posting them. It would be designed as an interactive installation dedicated to socially inclusive activities starting from existing installations like this. The second issue should be to keep collecting data and quantitative ones involving much more participants in the project.

Conclusion Within the project, the collaboration between the dancer-performer and the singer was important for the design of the activities. It was also important the contribution of a sound designer to design the synthesised sounds for using TouchMe. This project presents an innovative project that utilises interactive digital technology and performance to co-design an inclusive educational activity for people who have visual loss. "Through myself" can contribute both in educational and performative arts activities for experiencing and training creativity and education to inclusion and experience diversity.

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5.3 Hackathons and competitions

One approach to ignite the ideas of our students is to adopt a challenge-based learning [71]. The FabLab regularly orchestrates hackathons, design sprints, and programming competitions in collaboration with companies and associations. This initiative began gradually over a decade ago, and now our students eagerly anticipate such opportunities to test their skills in diverse challenges. We have achieved international recognition, winning the DigiEduHack competition for two consecutive years and securing a second-place global ranking in the Google Hashcode competition. More significantly, students are now independently organizing these competitions.

We hosted diverse kind of competitions:

- DigiEduHack, a worldwide competition focused on digital innovation in education, or
- programming competitions such as Google HashCode and Reply Code Challenge,
- and has collaborated with others to organize several events including OpenAccessHackathon and Arduino Week in collaboration with Muse,
- and iProduce, a Co Creation Hackathon in collaboration with Trentino Sviluppo and HIT — Hub Innovazione Trentino.

For better understanding a typical hackathon that we organize we will use an adaptation with minor modifications of our previous work published as "Challenge-based learning as a tool for creativity and talent expression" (see publication list at Section 1.3).

Abstract After the stop caused by the pandemic, the University of Trento and its newly born FabLab reopened the doors to DigiEduHack (https://digieduhack.com/en/), the decentralized hackathon dedicated to the most pressing challenges of digital and innovative education.

More than 30 multidisciplinary students have ventured into the design of innovative learning tools to meet the challenge thrown at them: prototyping educational board games; multimedia artifacts and installations at the intersection of big data, art and technology; co-designing festivals in a combination of art, science and fun; laboratory images to be presented in the classroom.

In this short paper, as a case study one, we will outline the DigiEduHack initiative, focusing on the potential of a challenge-based approach in stimulating and strengthening introspection, creative thinking and talent's expression. Supported by a set of qualitative data collected before and after the event, this work reports an education case study and shows the progress and preliminary reflections of the students and educators involved.

Introduction

Challenge-based learning The Challenged Based Learning approach (CBL) found fruitful context at the University of Trento that is open to innovating teaching and learning, is embedded in a dynamic innovation ecosystem and is pushed to spread out stakeholders' networks.

The pedagogy of CBL can be inscribed in the constructivism perspective where students are the main characters of their learning process: they identify, analyse, and design a solution that solves a real-world issue [71]. Due to the fact that students approach complex problems, the learning experience is multidisciplinary, it includes stakeholders' perspectives, and it aims to collaboratively find a sustainable solution [187].

Professors are facilitators and help teams in the process of building guiding questions, gathering the right information, processing data, presenting solutions, and eventually executing the outcomes. Improving soft skills, self-reflection, and stimulating talent expression are another important asset of the CBL approach.

Hackathon In the context of CBL, hackathons are one of the most widely used formats. They are highly engaging, limited-time competitions in which participants, divided into groups, design and develop a solution in the form of an idea or artifact to a proposed challenge. Rosell, Kumar and Shepherd [194] identify four constitutive attributes of hackathons: (i) focus on activity caused by the limited nature of time and space, (ii) novelty in both doing (creating something that did not exist before) and knowing (learning something new) dimensions, (iii) collaboration stimulated by time constraint, and (iv) reward that can act as an incentive for participation and productivity.

Given their attributes, they represent a subclass of the so-called Innovation Contests: competition of innovators who use their skills, experiences and creativity to provide a solution for a particular contest challenge defined by an organizer [35].

Case study

DigiEduHack at the University of Trento The UniTrento Fablab joined DigiEduhack, the international initiative of the European Institute of Innovation and Technology (EIT), for the third consecutive year, as part of the European Union Digital Education Action Plan that takes place worldwide on the same dates. As stated by their website, "DigiEduHack is a global movement dedicated to solving the toughest digital education challenges organisations face today, which is manifested in a 24-hour hackathon taking place simultaneously in major cities around the world" [235].

After the virtual edition of last year, the third edition of the local DigiEduHack challenge, organized by the Department of Information Engineering and Computer Science — DISI in collaboration with SOI (School of Innovation) and HIT (Hub Innovazione Trentino), in the framework of the Boogie-U project (Boosting Innovation and Entrepreneurship through European Universities) returned again on 9th and 10th November 2021 at the University of Trento.

Students applied in order to participate in this optional initiative. More than 30 students with different backgrounds have tried their hand at designing innovative learning tools to meet the challenge launched by the organizers: prototyping educational board games; multimedia artefacts, installations at the intersection of big data, art, and technology; festivals able to combine art, science, and fun; laboratory activities to be conducted in the classroom.

The five competing teams co-designed tools and activities, with the support of mentors from the SOI, HIT and the two FabLabs of the University of Trento and the University of Bolzano. For the second, consecutive, year the winning team from the Trento edition also won in the global competition, this time with the project Hachi, an application for smartphones and tablets that can facilitate the understanding of abstract concepts thanks to augmented reality (AR).

DigiEduHack survey methodology CBL, as a new model of learning, requires new assessment tools that monitor the self-reflection capabilities and soft skills acquisition process. Specifically, reflective learning tools can support this assessment through the process of remembering acts and events and then exploring why things went a certain way, and finally, taking possible actions for further experiences. In this context, we provided an online 15-question survey through which we explored, in three parts, the quality of the learning experience, the level of awareness about students' soft skills and the follow-up of the ideas developed during the hackathon. The soft skills' awareness was measured through the use of the IMI scale (Intrinsic Motivation Inventory), a multidimensional measurement device intended to assess participants' subjective experience [197]. The instrument assesses participants Interest/Enjoyment, Effort/Importance, Perceived Competence, Relatedness. In "Findings", we discuss the main findings for each part of the survey. 12 out of 30 students answered the questionnaire.

Findings Analysing the results of the questionnaires, we found out that most of the participants (75%) judged the contribution of the mentors as really useful and 25% as useful. During the hackathon they succeeded in boosting team working leveraging two types of personal assets: expertise and charisma. Mentors have indeed been associated by some participants with the word "passion" and their presence has been labelled as "tangible and inspiring". These findings further underline the positive role model embodied by mentors during hackathons [159].

More in details, students also evaluated in a positive way:

- the teamwork, the cooperation and collaboration among students coming from different disciplinary backgrounds;
- the friendly competition vibes;
- the creativity shown by every group;
- the positive and playful learning atmosphere — still remaining serious and challenging.

In fact, also from the IMI scale, most of the students found the activity pleasant but also empowering, due to the collaborational aspects with their team and the feeling of competence given by their work mixed with the guidance received by the mentors. They felt challenged, but not under-challenged, during the activity and this leaded to a full commitment to the task they were performing, "losing track of time". With regard to what could be improved in the future, suggestions were mainly related to the event duration and its expected outcome. Despite time constraint being a key factor in hackathons, participants would have preferred to have at least 24 full hours for solving the proposed challenge, which means starting earlier in the morning or/and staying overnight. Moreover, they would have appreciated more precise indications on what the expected outcome should have been (e.g. tangible vs. intangible artefacts), even using real examples of previous hackathons.

Conclusions This short paper illustrates some results of the DigieduHack initiative, as an education case study. In designing the activity we focused on creating a participatory learning experience for the participants. Our goal was to provide students with the tools to reflect upon their soft skills, strengthen creative thinking and best express their own potential.

This result was achieved by mixing the topic of the challenge, apparently very stimulating for them, but also the support given by the mentors during the challenge. The informal — but challenging — climate made students feel challenged but also empowered by the results they managed to obtain, perhaps initially unexpected even for them given the limited time available. Reading their feedback in the questionnaires was very helpful for the research team, also in view of future events with this format. We believe that this combination has been successful in stimulating their creativity but at the same time increasing their awareness about the abilities and the results they can obtain.

Acknowledgments The researchers wish to acknowledge some colleagues that have been instrumental in developing the DigiEduHack event in our university:

- the FabLab UniTrento and all its staff for the space and the great effort and contribution;
- HIT – Hub Innovazione Trentino;
- SOI – School of Innovation;
- Boogie – U project funded by HEI Innovate;
- ECIU (European Consortium of Innovative Universities) for the research on CBL;
- all the mentors and students who participated.

6 Towards schools

An important aspect of the FabLab's mission is its connection with the world of primary and secondary education. The challenges faced in this context are similar to those mentioned previously — constructionist approaches are rarely applied, and teachers often resist change. The most effective strategy involves gently guiding teachers towards a more constructionist model, without forcing them, and allowing them the necessary time to adapt. This is similar to utilizing a scaffolding approach with students, where a well-defined initial environment is provided, and support is gradually withdrawn as teachers become more independent.

- **Teacher training workshops**: we organize professional development workshops for educators to learn about constructionist pedagogy, creative learning, and the maker approach. Our workshops provide teachers with new teaching techniques and resources, enabling them to incorporate hands-on learning and interdisciplinary problem-solving in their classrooms. More than 170 educators participated in the last edition of our workshop, which can be more aptly defined as a community of practice [234], as our trainers are experienced educators themselves who substantiate constructionist theory with real examples of activities that have been successfully implemented in the classroom;
- **Curriculum development**: we partner with schools to create interdisciplinary, project-based curricula that prioritize experiential learning, teamwork, and critical thinking. This is achieved by incorporating FabLab resources and technologies into the educational programs, enabling engaging, hands-on experiences. These collaborations frequently stem from the workshops previously mentioned; as teachers recognize the potential advantages for their instruction, they pursue support to further implement the constructionist approach throughout their teaching practices. For example, we recently developed a curriculum and materials to perform physics experiments instrumented with Arduino; following a constructionist approach, the experiment materials need to be assembled, providing a full and realistic experience about the work of a physicist.
  - Computational Thinking Academy for Inclusion: an Erasmus+ project bringing teachers closer to computational thinking while trying to contribute in bridging the gender gap in STEM subjects;
  - PRIMM: a research-action activity in the academic year 2022-23 with the aim of experimenting with the PRIMM methodology for teaching programming in the Computer Science subject of the "Applied Sciences" option of the Scientific High School;
  - Stem-KIT: an interdisciplinary approach to learning physics and computer science;

- **Student workshops and after-school programs**: we offer workshops and after-school programs for students, where they can engage in constructionist learning activities, learn new skills, and explore their interests. When possible, these programs are co-designed with schools: the idea is to develop activities that can fit their current curriculum, but providing students time and space for free exploration. For example, we co-designed a bio-informatics activity whose goal was to identify genetic diseases in datasets provided by the Biotechnology department. In the first two years, the activity was promoted by the university and the school. Starting next year, the activity will be guided solely by school's teachers, without our intervention.

6.1 Teacherdojo: workshop on computational thinking and creative learning

In our pursuit to elevate the standards of educational practice, we systematically orchestrate professional development workshops tailored specifically for educators, drawing emphasis on the principles of constructionist pedagogy, the nuances of creative learning, and the underlying ethos of the maker approach. Rooted in the firm belief that pedagogical evolution is a cornerstone to academic success, our meticulously designed workshops serve not just as platforms for imparting knowledge but as catalysts to invoke innovative teaching methodologies.

Participants of our workshops are presented with a rich tapestry of teaching techniques and resources in the field of the STEAM disciplines. The objective is clear: to capacitate them with the tools and knowledge required to seamlessly embed hands-on learning experiences within their teaching regimes and facilitate interdisciplinary problem-solving challenges that are both engaging and effective. Reflecting on the sheer scale and impact of our endeavors, the last edition of our workshop (2023) witnessed the participation of over 170 dedicated educators. However, characterizing these sessions merely as workshops would be a gross underestimation. Drawing inspiration from [234] concept, they are better conceptualized as 'communities of practice'. This is not just a nomenclature but a testament to the depth and breadth of shared learning that transpires within these sessions. Bolstering the credibility of our initiatives, our trainers are not mere academicians or theorists; they are senior educators with extensive classroom experience. This allows them to extrapolate the constructionist theory from the realm of abstraction and ground it with tangible examples, illustrating real-world activities that have been efficaciously operationalized in diverse classroom settings.

In essence, we do not just preach pedagogical innovation; we provide a blueprint for its practical implementation, transforming traditional classrooms into hubs of active learning and critical thinking.

Thus, *TeacherDojo* — this is the name of our event for training the trainers -is a workshop for primary and secondary school teachers on the topics of teaching computer science, computational thinking and creative learning. The course focuses on teaching computer science without computers, visual programming and maker activities. The workshop allows teachers to learn how to use creative software and innovative technologies, and how to pass this knowledge on to students to introduce them to the world of computer science in a fun way. The workshop title comes from the CoderDojos, which are programming clubs for kids, and illustrates the spirit of the workshop. The teacher is at the center of the course; the word dojo ("gym" in Japanese) denotes a common space where teachers meet to "train" with new technologies, guided by experienced trainers, teachers themselves, trying to put into practice immediately what they have learned. In 2022, 173 teachers participated in the three-day workshop, which included 21 classes and 75 hours of training. In 2023, we had 192 teachers attending. Given this trend we hope it will increase yaer after year. The full program of the latest edition can be seen here https://fablab.unitn.it/teacherdojo/.

One of our mentor at work — A group of teachers working during TeacherDojo.

Figure 6.1. People interacting during TeacherDojo

6.2 Curriculum development

In this section, we will discuss various examples of educational experiments conducted with teachers as well as students. The aim is to demonstrate how minor modifications to school curricula can make them more engaging and captivating for students. Furthermore, this serves as an opportunity to illustrate to educators that there are alternative and perhaps more stimulating and enjoyable approaches to addressing the same topics.

6.2.1 Computational Thinking Academy for Inclusion

The project Erasmus+ Computational Thinking Academy for Inclusion (CT-Academy) started in February 2022, with the goal of bringing teachers closer to computational thinking while trying to contribute in bridging the gender gap in STEM subjects. The project will develop a Computational Thinking Academy (CT-Academy): a collection of resources specifically designed for primary school teachers to help the integration of computational thinking in their courses. The academy will provide:

1. a handbook designed for teachers illustrating the cultural and scientific aspects related to computational thinking;
2. a Massive Open Online Course (MOOC) on the technological aspects;
3. CPD (Continuing Professional Development) courses that help teachers to embed computational thinking in a cross-cutting and gender equality way within their own school.

The partners of the project are Catholic Education Flanders (Belgium), Ingenious Knowledge (Germany) and Östra Grundskolan (Sweden).

Working with secondary schools can be an effective way to transfer research results outside the academic community (third mission), which is one of the main goals of the FabLab. During the year 2022, multiple collaborations with researchers from other departments resulted in the creation of projects and activities that have been proposed to students of different age groups. In 2023, a handbook on computational thinking was created with the research group, which will soon be available under Creative Commons licence.

6.2.2 Experimentation with the PRIMM method for teaching programming

This is an adaptation with minor modifications of our previous work published as "Sperimentazione del metodo PRIMM per l'insegnamento della programmazione - Experimentation of the PRIMM method for teaching programming" (see publication list at Section 1.3).

Introduction The project "Algorithmically: from problem solving to computer science" carried out a research-action activity in the academic year 2022-23 with the aim of experimenting with the PRIMM methodology [205, 206] for teaching programming in the Computer Science subject of the "Applied Sciences" option of the Scientific High School. The project was proposed by the "Leonardo da Vinci" High School in Trento, in collaboration with the University of Trento and the Cultural Association Glow, and was funded by the Caritro Foundation.

The basic idea of the PRIMM methodology (Predict, Run, Investigate, Modify, Make) stems from the observation that the "traditional" teaching of programming requires students to write code right from the start. This differs from methodologies used in language learning (including one's native language), where the production activity is preceded by reading and understanding the text.

Starting from the observation that the cognitive load required to get to the writing of the code is very high, the PRIMM methodology inverts the traditional sequence, starting first with understanding the text and only later proceeding to the actual writing of code. In particular, the proposed approach is divided into five activities:

- **Predict**: students read a segment of code, written in Python, and make predictions about what the code will do when executed;
- **Run**: students execute the code proposed in the previous activity, comparing the actual behavior to their prediction;
- **Investigate**: students are required to analyze the code or its variants in greater depth, using various types of exercises, such as bug corrections, code annotation, use of Parson Puzzles, exploratory questions, etc;
- **Modify**: students are asked to modify the code, starting with very simple variations and then with increasingly complex changes;

- **Make**: finally, students create an entirely new program, drawing inspiration from the code seen earlier, but implementing a new feature or solving a different problem.

From a theoretical point of view, PRIMM is situated at the intersection between a more structured approach based on guided discovery and direct instruction, and a more constructionist approach [172] based on pure discovery and open problems. Following the suggestions of Grover et al., the five stages start from heavily guided activities to reach entirely free activities, gradually reducing the level of scaffolding [99].

As much as possible, many of the activities are carried out favoring group work and peer exchange, following the idea that verbal articulation of solutions generally promotes learning, especially in the field of programming where the linguistic component is essential.

In the rest of the section, we will describe the context in which we operated, the activities carried out, and the results of the experimentation. We will conclude with a reflection on the validity of the approach and possible improvements to be applied in the following years.

Description of the context The "Leonardo Da Vinci" Scientific High School consists of 75 classes with a total of 1,530 students. There are 42 classes for the applied sciences track and 33 for the standard track, with an average of 20 students per class. Computer science is taught in the Applied Sciences option for two hours a week, from the first to the fifth grade; however, it is from the second grade that programming is introduced using the Python language.

The educational experimentation was applied in five second-grade classes of the high school (102 students), out of a total of nine, under the guidance of teachers Giulia Peserico, Maria Serafini, and Francesca Voltolini. In the other four second-grade classes (86 students), which served as control classes, traditional teaching methodologies were adopted. Table 6.1 contains the list of the involved and control classes, the responsible teacher, and the number of students with the gender breakdown.

For four of the involved classes, each activity lasted 100 minutes, while for the fifth class, the activities took place in two sessions of 50 minutes each.

Class Name	Teacher	Schedule	N° of students	M	F
Primm1	Teacher1	100’	23	13	10
Primm2	Teacher1	100’	20	8	12
Primm3	Teacher1	100’	25	14	11
Primm4	Teacher2	100’	19	15	4
Primm5	Teacher3	50’ + 50’	18	13	5
Control1	Teacher4	50’ + 50’	21	16	5
Control2	Teacher4	50’ + 50’	20	11	9
Control3	Teacher5	50’ + 50’	21	13	8
Control4	Teacher6	50’ + 50’	22	13	9

Table 6.1. List of involved classes, with teachers, schedule, and size.

Description of the activities For the five classes involved in the experimentation, educational worksheets were created to introduce the basic concepts of programming in the Python language (variables, types, Boolean operators, selection, iteration, lists, strings, use of the Turtle library).

Most of the proposed activities were structured in pairs, often organized by skill level groups, and included:

- 3-4 *Predict* proposals, introducing a new concept for which students were asked to anticipate its functioning, each followed by a *Run* phase, in which students copied and executed the code to verify their prediction;
- some exploratory questions, where students were asked to explain in words their understanding of the new concept, also comparing it with previously learned concepts;
- a code segment in which some errors were to be identified (syntax, execution, semantics);
- a Parson's Puzzle;
- several code modification exercises (*Modify*);
- several code writing exercises (*Make*).

All the lessons were conducted in a computer lab, and each student had a computer (with the Thonny interpreter [13]) available for work. At the end of each activity, homework assignments were given to study and review what was learned in class and some Modify and Make activities.

After the initial lessons, where basic concepts were introduced, the worksheets were structured to reduce the *Predict-Run* parts, removing the Parson's Puzzle, and increasing the *Modify* and *Make* activities during paired activities. It was also decided to introduce at the beginning of each worksheet a brief explanation of the new concepts and a collective session to revisit the introduced content, as it was found that the homework was not always done with the necessary attention.

Throughout the year, assessments were carried out, both of a structured type (with multiple choice and open-ended questions, questions similar to the *Predict* activities, error detection), and of a practical type, consisting of writing 3-4 programs to solve as many problems.

At the end of the article, we provide an example of the worksheet used for the explanation of the simple *if (single-way)* construct. In the first phase of the worksheet, three *Predict* exercises were proposed, called "*What does the code do?*", each with related in-depth questions (Figure 6.2, Figure 6.3 and Figure 6.4). A simple error search exercise was then added (Figure 6.5), followed by a Parson's Puzzle (Figure 6.6 and its solution Figure 6.7). Finally, after summarizing and reviewing the key terms with the students (Figure 6.8), the *Modify* and *Make* phases were started (Figure 6.9 and Figure 6.10).

Results To verify the effectiveness of the PRIMM method, three types of data were collected from the five experimental classes and the four control classes:

- the first type of data concerns student motivation to perform these activities. The tool used to collect this data was the Intrinsic Motivation Inventory (IMI) [146], which was translated and adapted, using only the modules that were deemed useful for this experiment, namely: Interest/Satisfaction, Effort/Importance, Perception of Competence, Value/Utility, and Pressure/Stress;

- the second type of data relates to the learning of knowledge and skills concerning programming and was detected through a carefully prepared test;
- the third type of data includes class membership, gender, and final grades in various school subjects.

The first two types of data were collected according to a quasi-experimental Pre-Post design, meaning they were collected before the start of the experiment and after its conclusion to detect any effects and differences between the experimental and control groups. The results of the analysis, for which a linear regression with robust standard errors was used to account for the heterogeneity of the groups, highlight the following findings:

- there is no statistically significant correlation between belonging to the experimental group and an increase in the test score. Despite this, the test score increases in the experimental group are slightly higher than those in the control group;
- there is a statistically significant correlation between belonging to the experimental group and an increase in the IMI Effort/Importance score. The PRIMM methodology might therefore promote students' engagement in the activities and understanding of their importance;
- there is a highly significant correlation between belonging to the experimental group and an increase in the IMI Perception of Competence score. The PRIMM methodology could therefore enhance the perception of one's competence and students' confidence in programming tasks. Students might also be able to self-assess more accurately;
- students with the most marked improvement in the final test score compared to the initial one achieved higher grades in computer science;
- belonging to the experimental group and therefore the PRIMM methodology could have a positive impact on computer science grades; the result of the analysis approaches statistical significance;
- the gender difference in the results was also explored. While there are no conclusive results, the analysis reveals a greater imbalance in the interest by male students compared to female students in the control group, suggesting that male students in the control group might have been more interested in the teaching activities than female students. This indicates that the PRIMM methodology might be more inclusive than the traditional one.

Reflections and Conclusions The first iteration of this action-research produced promising results, but also suggests the need to refine the sample and some methodologies and procedures. For instance, some items in the test seem to require verification because they don't produce results consistent with all other indicators. Moreover, many activities were conducted with groups divided by the student's level. This could have influenced the fact that students with greater improvement in the test score also achieved higher grades in computer science. In future iterations, the groups will be divided with a peer tutoring perspective [8]. In general,

Lavoro in coppia

Di seguito c'è del codice scritto in Python:

```
print("Benvenuto nel mio programma di conversazione")
print()
print("Ti piace andare in bicicletta? Rispondi si o no")
risposta = input()
if risposta == "si":
    print("Molto bene! Ti terrai in forma.")
print("Ciao ciao.")
```

Secondo voi, che cosa appare sul monitor all'esecuzione?
Ora scrivete il codice in Thonny e controllate. Fa quello che vi aspettavate? Se non lo fa, descrivete nel dettaglio cosa accade in modo diverso.

Rispondete alle seguenti domande:

1. Cosa succede se si digita "Si" invece di "si" quando si esegue il programma? (provate e verificate)
2. Qual è la differenza tra = e == ? In questo programma vengono utilizzati entrambi?

Figure 6.2. Predict - 1

the adoption of the PRIMM method seems promising, and it's already clear that it has a significant positive impact on students' approach to programming, especially on their sense of competence, commitment, and the importance given to the proposed activities. However, further research and repetitions are needed to optimize its effectiveness.

At the end of the year, we asked students for feedback on the experimented PRIMM working method. A large group of students lamented the lack of "classic" frontal lectures with a teacher's explanation before tackling laboratory activities; we can hypothesize that this is due to an (italian) school path heavily focused on frontal lectures and students not being familiar with innovative approaches. Some students also stated that pair work by level was not productive, and they would have preferred to be paired with better-performing peers, who would assist them more in the work. Lastly, a large number of students noted that this working method allowed them to "go at their own pace", completing the assigned tasks without the rush of group work, and then revisiting them at home. All in all, the work was appreciated by the students and will be proposed again in the future.

Lavoro in coppia

Di seguito c'è del codice scritto in Python:

```
print("Come è andata la verifica?")
voto = float(input("Scrivi il voto che hai preso: "))
if voto > 6:
    print("Bene. Hai preso di più della sufficienza!")

print("Alla prossima!")
```

Secondo voi, che cosa appare sul monitor all'esecuzione?
Ora scrivete il codice in Thonny e controllate. Fa quello che ti aspettavate? Se non lo fa, descrivete nel dettaglio cosa accade in modo diverso.

Rispondete alle seguenti domande:

3. Cosa accadrebbe se usassimo il controllo `if voto >= 6`?
4. Cosa accadrebbe se usassimo il controllo `if voto < 6`?
5. Cosa accadrebbe se usassimo il controllo `if voto != 6`?

Figure 6.3. Predict - 2

Lavoro in coppia

Di seguito c'è del codice scritto in Python:

```
print("Come è andata la verifica?")
voto = float(input("Scrivi il voto che hai preso: "))
if voto > 6:
    print("Bene. Hai preso più della sufficienza!")
    risposta = input("Sei contento del voto? Rispondi si o no")
    if risposta=="si":
        print("Ottimo! Anch'io sono contento per te!")
```

Secondo voi, che cosa appare sul monitor all'esecuzione?
Ora scrivete il codice in Thonny e controllate. Fa quello che ti aspettavate? Se non lo fa, descrivete nel dettaglio cosa accade in modo diverso.

Rispondete alle seguenti domande

6. Avete notato che il secondo `if` è spostato più internamente? Cosa vuol dire?
7. Se noi avessimo messo il secondo `if` allineato al primo, quale sarebbe stato l'output? (prova a modificare il codice e vedere su Thonny il risultato.)

Figure 6.4. Predict - 3

Lavoro in coppia

In questo programma ci sono **2 errori**, riesci ad individuarli? Evidenziali con un colore.
(Se non riesci a trovare alcuni errori puoi aiutarti copiando il codice in Thonny e verificandone il funzionamento)

```
print("Ciao! sono un po' curioso.")
risposta = input("Ti piace la pizza?")
if risposta > "si"
   print("Bene. Allora possiamo fare una serata pizza e cinema.")
print("A presto.")
```

Figure 6.5. Find the Mistakes

```
if (somma >= 10):
print("la somma e' compresa tra 10 e 15")
addendo1 = int(input("Inserisci il primo addendo: "))
somma = addendo1 + addendo2
print("la somma e' maggiore o uguale a 10")
addendo2 = int(input("Inserisci il secondo addendo: "))
print("Ciao! Facciamo il controllo della somma.")
if (somma <= 15):
print("Ciao, alla prossima!")
```

Figure 6.6. Parson's Puzzle

```
print("Ciao! Facciamo il controllo della somma.")
addendo1 = int(input("Inserisci il primo addendo: "))
addendo2 = int(input("Inserisci il secondo addendo: "))
somma = addendo1 + addendo2
if (somma >= 10):
    print("la somma e' maggiore o uguale a 10")
    if (somma <= 15):
        print("la somma e' compresa tra 10 e 15")
print("Ciao, alla prossima!")
```

Figure 6.7. Parson's Puzzle - solution

TERMINE	SIGNIFICATO	PYTHON
Operatore relazionale	Un simbolo che serve per fare un confronto tra due dati.	>, >=, <, <=, ==, != sono gli operatori relazionali di Python
Condizione	Il test che inseriamo nel costrutto *if*. Si costruisce inserendo un *operatore relazionale* tra due dati. Il risultato della condizione deve essere vero (**True**) o falso (**False**)	risposta == "sì" a > 5 b != 7 10 >= x b == a
Selezione	Quando nel codice c'è un punto in cui viene effettuata una scelta e viene utilizzato il costrutto *if* per creare percorsi alternativi	`if a > 10:` `    print("ciao")`

Indentare	Scrivere una o più istruzioni "rientrate" (di 4 spazi) rispetto alle istruzioni precedenti/successive	`if a > 10:`
		`    print("ciao")`
		
		L'istruzione print è **indentata** rispetto a if

Annidare	Scrivere una selezione dentro un'altra selezione	`if numero > 5:`
		`    if numero < 10:`
		`        print("numero tra 5 e 10")`

Figure 6.8. Keywords

1. Cosa stampa il seguente codice?

```
numero = int(input("inserisci un numero"))
if numero%3==0:
    print("il numero va bene")
```

   Ricopia il codice per accertarti di aver risposto correttamente e modificalo in modo tale che venga controllato se un numero è divisibile per 5.

2. Modifica il codice dell'esercizio precedente per verificare se dati due numeri (interi) inseriti dall'utente, il primo è multiplo del secondo.

3. Cosa stampa il seguente codice?

```
lato1  = float(input("inserisci la misura del primo lato"))
lato2  = float(input("inserisci la misura del secondo lato"))
if lato1==lato2:
    print("il triangolo è isoscele")
```

   Ricopia il codice per accertarti di aver risposto correttamente e modificalo in modo tale che venga verificato se il triangolo è equilatero.

4. Cosa stampa il seguente codice?

```
prezzo  = float(input("inserisci il prezzo del biglietto"))
numero  = int(input("inserisci il numero di biglietti acquistati"))
if numero > 20:
    numero = numero-1
totale = numero * prezzo
print("il totale da pagare è", totale)
```

   Ricopia il codice per accertarti di aver risposto correttamente e modificalo in modo tale che venga regalato un biglietto omaggio **ogni** 20 biglietti (se si acquistano 30 biglietti se ne pagano 29, acquistandone 50 se ne pagano 48, ecc).

Figure 6.9. Modify

5. Calcolare il totale speso per acquistare delle pesche sapendo che se si superano i 10 euro si ha il 20% di sconto.
6. Calcolare il costo della bolletta di consumo del gas (espresso in metri cubi) ottenuto dalla somma delle seguenti voci:
    - quota fissa pari a 20€
    - 0,575€ al metro cubo per i primi 500 metri cubi
    - 0,783€ al metro cubo per ogni metro cubo eccedente i primi 500
7. Comperando un'automobile, se spendo più di 20.000 € ho uno sconto del 10%. Indipendentemente dal prezzo, se pago in contanti uno sconto di 1.000. Visualizzare quanto si spende.

Figure 6.10. Make

6.3 Stem-KIT: An interdisciplinary approach to learning physics and computer science

This is an adaptation with minor modifications of our previous work published as "Stem-KIT: An interdisciplinary approach to learning physics and computer science" (see publication list at Section 1.3).

Abstract : This study aimed to develop, test, and evaluate an educational kit for high schools that fosters a multidisciplinary bond between physics and computer science. Grounded in constructionism, the kit encourages students to take a more practical approach towards STEM subjects by using simple Arduino-based boards and sensors to measure physical quantities during simple experiments. The project was a collaborative effort between the University of Trento and Level Up, a local company that produces innovative educational materials related to physics and science for schools. The study involved 16 high schools with over 300 students and about 20 physics and informatics teachers. The kits were validated through questionnaires and interviews, with an emphasis on assessing changes in student motivation, interest in STEM subjects, and practical experience.

Background: The learning-by-doing approach is central to constructionism, which emphasizes the importance of hands-on, experiential learning in education. This approach is often neglected in the Italian school system, which tends to prioritize theoretical studies that are distant from real-world problems and applications. Part of the problem is the lack of experimental sets available to each student.

Intended outcomes: First, to create an educational kit that high school teachers could use to provide their students with practical experience in their physics curricula and enable them to apply their knowledge of computer science to arrive at better results. Second, to measure a change in students' interest in STEM subjects once they experience a more practical approach using the educational instrumentation created in the project. Another goal was to increase their motivation and engagement in the learning-by-doing process and to help them understand the importance of a multidisciplinary approach.

Findings: The students who participated in the project were asked to complete two questionnaires regarding their approach and motivation towards STEM subjects, both before and after using the educational kit. The answers were divided by gender to determine if there were any differences in approach. The study recorded a very positive response from the students and a growing motivation towards this type of hands-on method used during classes.

Introduction STEM education is critical in the 21st century due to the increasing demand for STEM skills in the workforce [98]. However, traditional teaching methods often fail to engage students and cultivate interest in these subjects.

Historically, STEM education has been characterized by rote memorization and theoretical teaching methodologies [33]. These traditional methods often fail to provide students with real-world context and practical applications for the concepts they are learning. As a result, many students find STEM subjects abstract, difficult to understand, and ultimately, uninteresting.

Moreover, the lack of experiential learning opportunities in traditional STEM education presents another barrier to student engagement. Research has repeatedly shown that hands-on, applied learning experiences increase student interest, comprehension, and retention in STEM subjects [88, 130]. Despite this evidence, many educational systems continue to emphasize theoretical instruction over practical learning experiences.

Furthermore, the interdisciplinary nature of real-world STEM problems is often not reflected in STEM education. Instead, science, technology, engineering, and math are frequently taught as separate, isolated subjects, which can prevent students from understanding the interconnected nature of these fields [112].

To tackle these issues, this project focused on the development, testing, and evaluation of an innovative educational kit designed to bridge the gap between physics and computer science in high school education. This endeavor was the result of a partnership between the University of Trento and Level Up, a company specializing in creating educational materials for physics and science.

The educational kit employs Arduino-based boards and sensors to enable students to conduct simple experiments and measure physical quantities, thereby offering a hands-on approach to learning. This strategy is a marked departure from the traditional Italian education system, which leans heavily towards theoretical instruction, often at the expense of real-world application.

The project's primary objectives included creating a tool that would enhance the practical aspect of physics education and allow students to leverage their computer science knowledge to optimize results. We also sought to gauge changes in students' interest in STEM subjects and their motivation levels when exposed to a more practical, hands-on approach.

Over the course of the project, we developed and distributed the educational kit to 16 high schools in the Trentino region of Italy. The design of the kit encourages cooperative learning, with two or three students working together to assemble and operate the instrument, test its functions in varying situations and environments, and even devise an experiment to verify a physics law from their curriculum.

This study is grounded in the learning theory of constructionism, which posits that learning is most effective when students are actively involved in a constructive process [171]. This theory emphasizes the importance of hands-on, experiential learning, a concept often neglected in traditional education systems. Our work aligns with this theory, as we advocate for a learning-by-doing approach to foster a multidisciplinary bond between physics and computer science. The use of hands-on activities in science education has been shown to be an effective way to engage students and enhance their understanding of complex concepts. Additionally, learning is more meaningful and relevant when connected to real-world applications and problem-solving. Our goal was to shift the focus from rote learning towards an experiential, problem-solving approach using our educational kit.

Since our kit is based on new technologies, i.e. Arduino and a set of sensors, we are framing our work inside the "Technological, Pedagogical and Content Knowledge" framework [152, 222]. Specifically, we are interested in the study of the intersections between *technology knowledge* (Arduino), *content knowledge* (Coding and Physics) and *pedagogical knowledge*.

In this section, we explore the use of the Stem-kit, a ready-made educational kit that allows students to conduct experiments and analyze data in a hands-on manner. We examine the experiences and perspectives of thirteen high school physics and computer science teachers who used the kit in their classrooms. By analyzing their feedback, we aim to shed light on the strengths and limitations of the kit, as well as its potential for promoting constructionist learning in science education.

Findings from the study indicated a positive response from the students, with a notable increase in motivation and interest in STEM subjects. This project underscores the potential benefits of a more practical, experiential approach in STEM education, setting a strong case for its broader application in the educational system.

Background and significance The main objective of this project is to promote the development, research, and experimentation of innovative interdisciplinary teaching methodologies in STEM fields. Specifically, the project aims to bring together two disciplinary areas — physics and computer science — which are normally taught separately, encouraging collaboration and hands-on experimentation.

The project primarily targets high school students (from 8th since 12th grade) and STEM subject teachers (mathematics, sciences, physics and computer science). Its main output is an interdisciplinary teaching path based on educational research in computer science and physics. This path leverages new technologies related to low-cost sensors (such as Arduino) and methodologies typical of makerspaces and Fablabs to investigate the world from a physics point of view.

The purpose of this path is to promote technical-scientific culture in the school world, with the collaboration of both physics and computer science laboratories. Specifically, this path consists of the following components:

- a specific kit designed by the University of Trento and a local firm specializing in educational products, Level Up; The kit is composed of hardware systems, sensors, and instrumentation aimed at facilitating the realization of personal experiments using easily available and low-cost components;
- documentation for teachers and worksheets for students, which illustrate the possibilities offered by the kit and encourage personal exploration;
- training activities for teachers on the use of the kit and associated teaching methodologies, led by trainers from partner organizations.

This path (kit, activities, training) enables the exploration of physical phenomena through the combination of physics, technology, and computer science. It allows for the construction of instrumentation, including its programming, which is necessary for conducting experiments.

One of the strengths of the project is its ability to introduce computer science paths in school contexts where coding paths are often lacking. This is particularly important in the present digital context, where a lack of computer science education is unacceptable.

Kit design The Stem-kit, developed during the project, consists of an Arduino Uno board, five different sensors, and various materials created using typical Fablab machinery. All the educational materials for students and teachers, including scripts and an introductory manual for learning about Arduino, its software, and the available sensors, can be found on the Level Up website (`https://leveluptrento.com/kitmisura/`). In addition, the design files to independently create the various parts that make up the kit can also be downloaded from the website.

The instruments created during the project focused on the broad measurement aspect in STEM subjects (science, technology, engineering, and mathematics) and the challenges associated with obtaining accurate measurements and constructing an optimal experimental apparatus. The objectives chosen for the kit are twofold: firstly, to bring the study of measurement closer; secondly, to enable laboratory work with an experimental approach closer to that of a researcher's work method.

In addition to the objectives previously mentioned, the kit also has several positive aspects. Its hands-on structure and small volume make it highly practical and portable. Moreover, the educational materials already prepared for the teachers to use are highly beneficial, especially for those schools that do not have physics and computer science as curricular subjects, or lack a physics laboratory and the necessary instrumentation to carry out experiments. Thanks to the kit, these schools are able to have an almost complete physics laboratory in their own classroom. The only object not included is a computer for every group of students, however, this tool is now available in almost every school. Overall, the kit provides an effective solution for schools with limited resources to offer students a high-quality STEM education.

The kit delves into the different stages of the scientific method and the laboratory research methods, drawing inspiration from the daily activities of a physics laboratory in a university setting. Students are encouraged to think like researchers, who are investigating a poorly understood phenomenon. To accomplish this, they must construct their own measuring instrument from the ground up, utilizing the Arduino Uno and one or more sensors. After creating the tool, they must grasp its functionality, limitations, and usefulness in studying the selected physical phenomenon.

The project has developed eight experiments that can be carried out progressively throughout high school years. Teachers can choose to address a specific topic at any point or jump from one topic to another, depending on their preference. Here is a list of the experiments:

- reproducibility;
- calibration;
- range and sensitivity;

- responsiveness;
- comparison of measurements: Beer-Lambert's law;
- measuring the invisible by studying polarization;
- measuring variations: the coefficient of friction;
- measuring moving objects: analysis of sliding motion along an inclined plane.

The first four experiments are related to the concept of measurement. The initial experiment prompts students to consider what constitutes a scientifically accurate and accepted measurement, specifically the idea of reproducibility. Students contemplate experimental equipment and setup, as well as external factors that may impact a measurement and ways to take these factors into account or limit them when possible. The second experiment helps students reflect on the calibration of a measuring instrument and presents alternative solutions in case calibration is too challenging to achieve. In the third experiment, students are encouraged to understand the limits of their instrument, including range, sensitivity, and minimum measurement. Finally, the fourth experiment prompts students to reflect on the responsiveness of a sensor, which can negatively impact measurements made in certain types of experiments, such as those measuring very rapid phenomena or moving objects. These activities can be carried out using almost all the sensors available in the kit.

The next four experiments are complete investigations that require the application of the concepts learned in the previous activities. These experiments aim to study a physical phenomenon taking measures under different conditions and using various approaches. In the fifth experiment, students use the photoresistor to study Beer-Lambert's law, which is typically not covered in the curriculum, with the goal to observe an exponential trend in a graph. The sixth experiment explores the phenomenon of light polarization and the associated trigonometric law. In the seventh experiment, students measure the coefficient of friction of different materials using a gyroscope, while the eighth experiment involves analyzing the sliding motion of an object on an inclined plane.

Methodology The study was conducted in two northern Italian regions, namely the Autonomous Province of Trento and Veneto. During the development of the first prototype of the kit, a pilot test was conducted in five different groups of high school students to improve the materials and experimental setup. The activity's duration varied among the schools to study the effect of adapting the same activity to different time constraints. These initial meetings were critical in evaluating students' autonomy, the necessary time for each phase, and identifying the most interesting topics requested by teachers. The goal was also to ensure that the materials were easily accessible and low-cost. As part of the pilot test, students were asked to provide feedback on the kit's usefulness and impact via a survey.

After developing the kit, 16 high schools in the area were selected to receive 10 units each and test them under the guidance of an expert. Prior to commencing the testing phase, three training sessions were held to acquaint teachers with the use of the new equipment, which was unfamiliar to most of them.

Students' sample and data collection Pre and post-meeting surveys have been conducted to collect feedback from students who participated in the project.

A brief introductory questionnaire was administered before the expert arrived in class to gauge previous experience with Arduino, self-assess students' skills, and interest in STEM subjects, particularly physics and computer science. The pre-meeting questionnaire yielded a total of 385 responses, with all students completing it as assigned homework. The survey was organized into two sections. The first section asked students basic questions about their school, class, and gender. The second section focused on their interest in STEM subjects and willingness to learn about coding and Arduino.

The post-meeting questionnaire was conducted in class at the end of the activity, resulting in 324 responses from students. Of these, 188 identified as male, 122 as female, and 14 (less than 5%) did not specify their gender. Due to the small number of unspecified gender responses, this data was excluded from analysis. The second survey focused on the impact of the activity on the students, including whether it changed their minds about STEM subjects and their appreciation of these types of classes.

Of the 324 responses, a significant majority of 73.7% were from students attending a scientific high school (Liceo Scientifico), whereas 12.6% attended a humanities high school (Liceo Classico and Liceo Scienze Umane), 10.4% a technical school, and 3.3% attended an artistic high school (Liceo Artistico). This bias towards scientific high schools can be attributed to the greater interest among teachers working in those institutions, where more time is dedicated to the teaching of physics. In contrast, in technical schools, computer science is an important subject, while physics is primarily taught only in the first few years. Humanities and artistic high schools have little to no exposure to computer science and very limited time dedicated to physics.

From the point of view of age, the examined sample was highly diverse, with students from every age group. The largest group was composed of first-year high school students, accounting for 38% of the total number, while the smallest group was made up of fifth-year students, accounting for only 4.9% of them. The remaining students were distributed as follows: second-year students made up 22.8%, third-year students made up 15.7%, and fourth-year students made up 18.5%.

Teachers' sample and data collection In addition to the data collected from anonymous student questionnaires, teachers were also invited to share their opinions on the Stem-kit to help identify areas for improvement and to evaluate the strengths and weaknesses of the educational materials. Due to the large geographic area covered by the project, the interviews were conducted online to efficiently gather data within a limited timeframe. The questions were designed to focus the teachers' responses on topics of greatest interest, while still allowing them to express their opinions freely. The interviews were kept to a maximum of 30 minutes to avoid becoming overly detailed, which would not serve the purpose of the project. Participation in this phase of the research was voluntary, and while all 28 teachers were contacted, interviews were conducted only with those who were available.

Thirteen teachers, comprising 9 females and 4 males, agreed to participate in the interview. Most of them teach physics and mathematics, while one teacher specializes in systems and networks, and two teachers focus on computer science. To maintain the anonymity of the data, each teacher is interviewed individually, even if some of them belong to the same school. The collected data are then aggregated using cluster analysis. About 69% of the interviewed teachers come from scientific high schools, which aligns with the majority of the students' schools. The remaining 31% is equally split between artistic and technical high schools.

The interview was structured into three phases. In the first one, the teachers were asked questions about their daily teaching practices. The second one focused specifically on the Stem-kit and its implementation in their school. Finally, the third and last phase explored the buying habits of schools and how schools choose to allocate their resources.

Result and discussion

Students' feedback The students showed a high level of appreciation towards the activity conducted in class with the Stem-kit, with 65% of the responses rating it above 4 on a scale of 1 to 5, where 1 indicated "not interested at all" and 5 indicated "very interested". This scale was used in the whole survey, pre and post meeting. The difference in responses between males and females is negligible: the curve for males is slightly skewed towards grades 4 and 5, while for females, it is shifted towards grades 3 and 4. The peak of the response for both genders is recorded at grade 4.

One of the essential aspects that we investigated was how well the students assessed their competences in the subjects covered by the kit. The first question focused on their proficiency in physics (Figure 6.11). The results from the pre-meeting survey show that neither gender expressed a high level of confidence, with both genders peaking at rating 3. In particular, the female gender tended to indicate a medium-low rating regarding their preparedness on physics, with ratings 2 and 3 accounting for around 37% of the votes. Conversely, the male gender showed a pyramidal trend centered on rating 3.

In the post-meeting survey, it was evident that the students were more confident in their competences on the physics topics covered during the activity (Figure 6.12). The peak for both genders shifted noticeably towards rating 4. The male gender showed a generally lower distribution, which was more evenly distributed among ratings 3, 4, and 5 and less peaked than the previous responses. On the other hand, for the female gender, there was a significant difference in the results. The peak of the distribution was at rating 2.5 before, but now it is at rating 4 with a remarkable increase of almost 20%, compared to less than 5% previously. Moreover, rating 2 had a drastic drop from 38% to 16%.

The researchers also investigated the students' preparedness in computer science topics. The initial survey results revealed a trend of average-low grades for both genders, with females scoring lower (Figure 6.13). This pattern could be attributed to the absence of computer science as part of the curriculum in many schools. However, after using the Stem-kit, students realized that the required computer knowledge was achievable (Figure 6.14). Consequently,

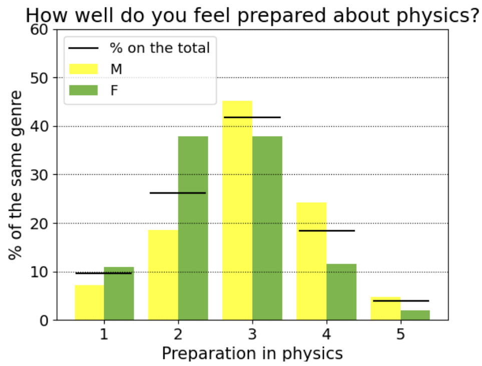


Figure 6.11. The self-assessed proficiency of the students in physics *before* the activity with Stem-kit.

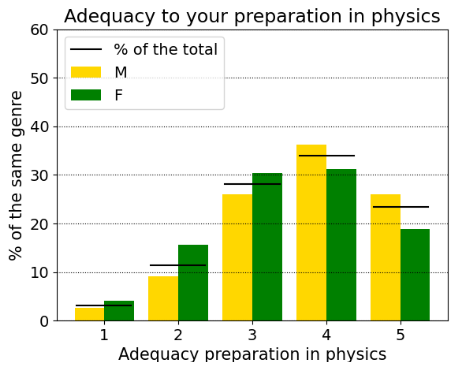


Figure 6.12. The perceived proficiency of the students in physics *after* the activity with Stem-kit.

both genders showed an improvement in their grades, with the female gender peaking at grade 3 and the male gender slightly higher at grade 4. It appears that males feel more confident and comfortable in dealing with the demand for computer science knowledge, while females, despite an improvement, still feel generally less prepared in these topics.

Another aspect investigated was whether the students' liking for computer science was influenced by the use of the Stem-kit. The pre-meeting survey data revealed a significant gender disparity, with the male gender showing a peak of votes at 4 and the female gender having a pyramidal distribution centered on 3 (Figure 6.15). However, after the activity, the distributions became more similar (Figure 6.16). The male gender distribution remained mostly unchanged, with a slight decrease in votes at 4 and an increase in votes at 2. On the other hand, the female gender distribution shifted significantly towards higher votes, with over 40% of female students giving a score of 4 or higher. By showing female students that they are capable of mastering computer science concepts, the kit may have increased their confidence and sense of belonging in the field. This increased confidence may have translated into a greater enjoyment of the subject matter.

The survey included questions about the students' level of engagement and interest during both the regular classes (Figure 6.17) and the activity with the Stem-kit (Figure 6.18). The results indicated a medium to high level of interest, with male students showing a peak at mark 4 and female students at mark 3, although the overall distributions were quite similar. In

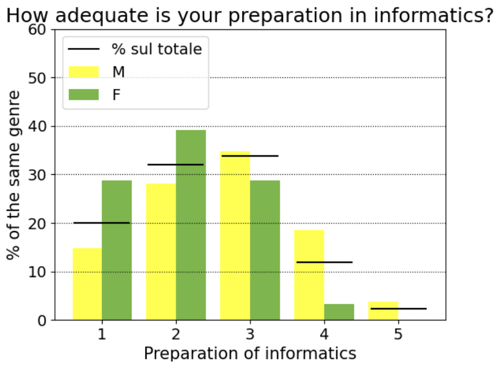


Figure 6.13. The self-assessed proficiency of the students in computer science *before* the activity with Stem-kit.

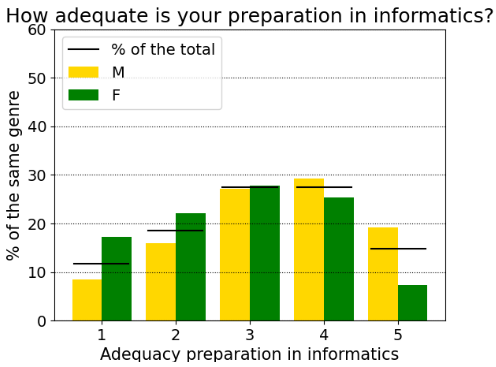


Figure 6.14. The self-assessed proficiency of the students in computer science *after* the activity with Stem-kit.

the post-meeting survey, a marked shift towards higher scores was observed for both genders, especially for male students.

One of the key questions in the survey was the level of interest in STEM subjects that each student had and how the use of the Stem-kit affected their interest. The pre-activity data revealed two similar distributions for both genders, with peaks at mark 4 (Figure 6.19). The male responses were slightly shifted towards higher marks, while the female responses were flatter, with 30% of marks equal to or less than 2. After the activity, the male responses remained almost unchanged, while the female responses showed a large plateau between marks 2, 3, and 4, and a significant decrease in marks 5 (Figure 6.20). The peak shifted to mark 3. The second survey question was “Do you feel more curious about scientific subjects than before?” The data suggested that the male gender recorded greater interest and curiosity towards STEM subjects after engaging with the Stem-kit, whereas the female gender did not feel equally stimulated by the proposed activity. The pre-meeting data confirmed that female students were already quite interested in STEM subjects, and their interest remained unchanged.

Interviews with teachers Several teachers were interviewed, and they explained that their yearly curriculum is determined by both the ministry’s plan and their institute’s internal planning at the departmental level. The internal planning is designed to ensure a consistent progression of classes and to guarantee that parallel tests are conducted between classes of

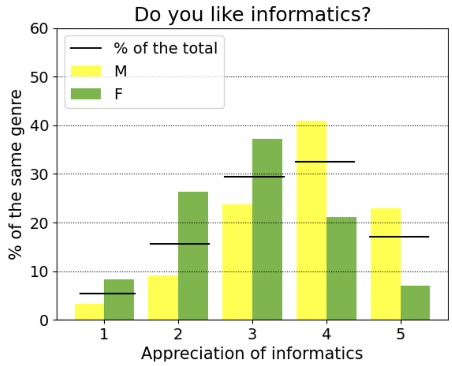


Figure 6.15. The interest of the students in computer science *before* the activity with Stem-kit.

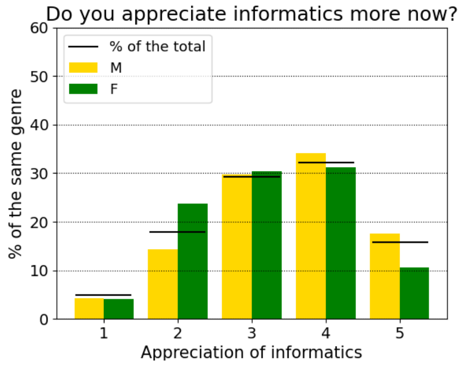


Figure 6.16. The interest of the students in computer science *after* the activity with Stem-kit.

the same year. However, the teachers also pointed out that the number of topics covered during the year can be overwhelming, which affects the amount of time dedicated to practical activities and the use of laboratories. Despite this, the teachers acknowledged that practical methodologies are the most effective in engaging and retaining students' interest in the subject matter. To strike a balance between theoretical and practical lessons, many teachers try to alternate between them to involve students more effectively. However, the availability of time remains a significant obstacle in implementing this approach.

Around 50% of the interviewed teachers aim to utilize the laboratory once a month for each topic covered in their curriculum. However, there are two distinct approaches adopted by teachers towards laboratory-based activities. Some teachers conduct relatively complex experiments either at their desk or with the assistance of a laboratory technician, while the students observe and record the data for later analysis either in class or as homework through report writing. On the other hand, some teachers prefer to engage their students in more hands-on activities, where they themselves carry out the experiment, sometimes with the help of a pre-compiled laboratory sheet, especially in the first two years of high school. The latter approach is often due to the limited availability of equipment that students can utilize or the lack of sufficient equipment to cater to an entire class. While experiments carried out by teachers at their desk are more effective than theoretical frontal lessons, they can be less engaging for students, thereby reducing their effectiveness in understanding the concepts related to the activity.

Many teachers are fortunate to have access to a wealth of technological teaching materials,

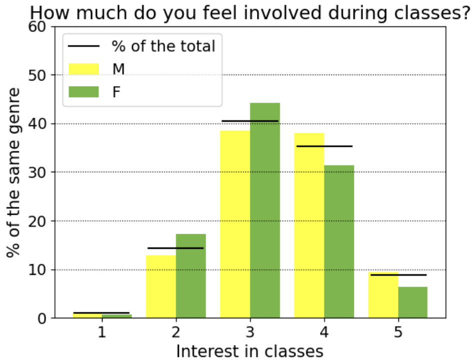


Figure 6.17. The level of involvement and interest of the students during classes *before* the activity with Stem-kit.

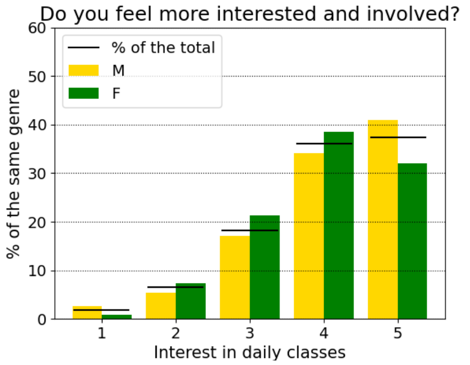


Figure 6.18. The level of involvement and interest of the students during classes *after* the activity with Stem-kit.

often acquired through various grants that support laboratory equipment renewal and teacher training. These materials include software simulators that allow students to conduct virtual experiments while modifying input parameters and analyzing the results obtained with their computers. In addition, teachers use various software programs to analyze data and create graphs, as well as microcontrollers such as Arduino, Raspberry, and Microbit to design simple experiments, which are not always related to the physics or computer science curriculum. These microcontrollers are often used in extracurricular activities, such as robotics and IoT.

However, despite the availability of such tools, a significant number of teachers are not using them effectively. One reason for this is the lack of proper training, which is necessary to use these tools effectively. Many teachers feel that they are not adequately equipped to use these tools independently, which often leads to their reluctance to integrate technology into their teaching practice. As a result, only a small proportion of the teaching staff uses these advanced technological tools.

Regarding the Stem-kit activity, more than half of the interviewed teachers decided to participate because it allows students to put their knowledge into practice, conduct experiments from start to finish and receive technological materials that remain available to the school. Almost half of the teachers also acknowledged the multidisciplinary aspect of the kit as an attractive feature, which distinguishes it from other materials available in the market. In addition, some teachers emphasized the importance of discovery activities, which are possible

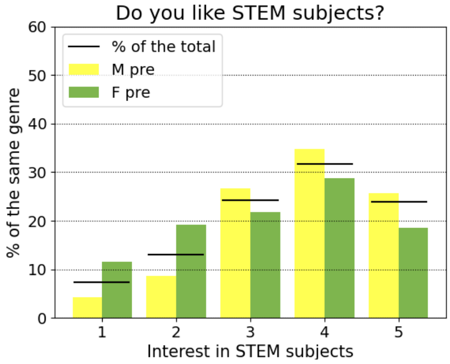


Figure 6.19. The interest in STEM subjects *before* the activity with Stem-kit.

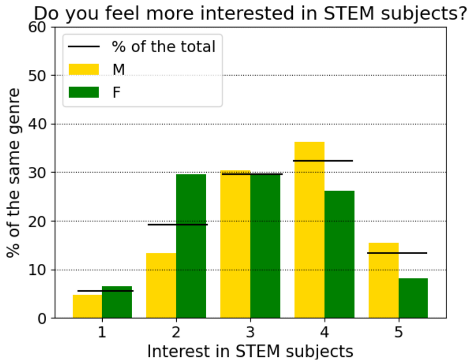


Figure 6.20. The interest in STEM subjects *after* the activity with Stem-kit.

with the Stem-kit, as an essential aspect for students.

According to the teachers, the level of student engagement with the Stem-kit activity was generally similar to that of traditional laboratory activities. Some students exhibited greater motivation, especially those who typically have more difficulty paying attention and are less interested in the subject matter, although not all teachers shared this opinion. Several teachers observed differences in attitude between male and female students. They noted that girls tended to be more cautious when it came to the computer aspect of the activity, fearing mistakes. However, once they understood the task and felt more comfortable, they often achieved better results. Male students on the other hand, tended to be more eager to participate and more willing to take risks, sometimes overlooking the need to fully understand the task before diving in.

The majority of teachers (8 out of 13) confirmed that the Stem-kit is comprehensive in terms of both materials and didactic instructions. However, the remaining teachers had differing opinions. Some felt that the instructions were too lengthy and detailed, leading students to skip over them. Others pointed out that some requests were not explained clearly enough. Two teachers suggested that interactive sheets be provided for completion, as it would be helpful for students, particularly those in their first two years of study, to have a guide to follow when writing their reports.

The interviewed teachers have expressed overwhelmingly positive opinions about the Stem-kit, particularly in comparison to other available kits in the market. The experiments found in these kits were often found to be poorly defined and lacked appropriate references to the concepts covered during the school year. In contrast, the Stem-kit was highly praised for its strong educational content, which allowed for hands-on experimentation with the ability to apply learned concepts. Another significant benefit of the Stem-kit is its portability, which enables teachers to perform experiments in the classroom, especially useful for schools that do not have a dedicated laboratory and adequate instrumentation. Finally, the aspect of interdisciplinarity was highly appreciated, as it allowed students to work collaboratively in small groups, building experiments and accompanying students in the personal discovery of the activity.

Conclusion In conclusion, the development and evaluation of the educational kit proved to be a successful endeavor in promoting a more practical approach towards STEM subjects among high school students. The kit enabled students to gain hands-on experience in constructing and operating instruments while learning about the close relationship between physics and computer science. The multidisciplinary aspect of the kit encouraged students to think creatively and solve problems in a collaborative setting, increasing their motivation and engagement in the learning process. The positive response from students and teachers validates the effectiveness of the kit in promoting a more practical and engaging approach towards STEM education. This project could serve as a model for other schools and institutions seeking to promote hands-on, interdisciplinary learning in their curricula.

6.4 School-Work Alternation

In 2022, the FabLab had an active role in the organization of three School-work alternation projects, which reached around 50 students from between the ages of 15 and 18. The following table gives an overview about the students who participated in each of the activities.

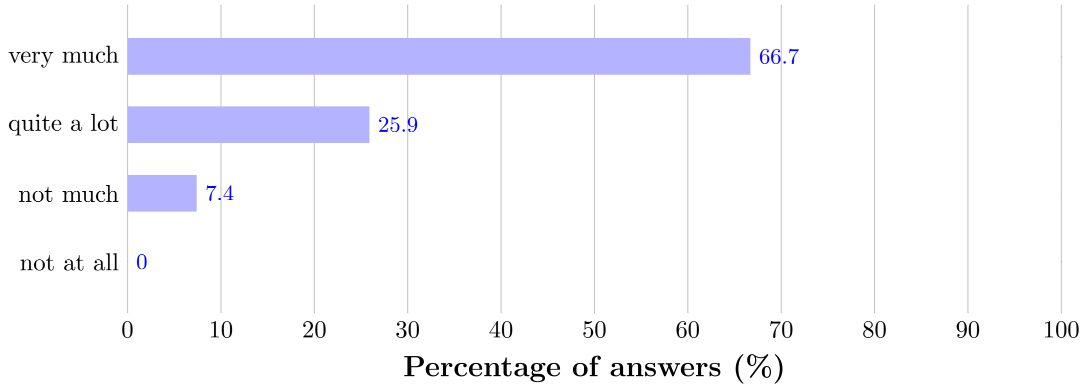
Activity	Participant	Gender	Age	Background
Bioinformatics	26	6F 20M	18 - 3rd grade 8 - 4th grade	6 environmental biotechnologies 6 health biotechnologies
Mathematical Games	19	7F 11M	11 - 3rd grade 8 - 4th grade	8 Liceo Scientifico 7 Liceo Artistico 3 Manufacturing Designer 1 Liceo Classico
Manufacturing Designer Internship	3	1F 2M	3 - 3rd grade	3 Manufacturing Designer

Table 6.2. School-work alternation projects.

Bioinformatics

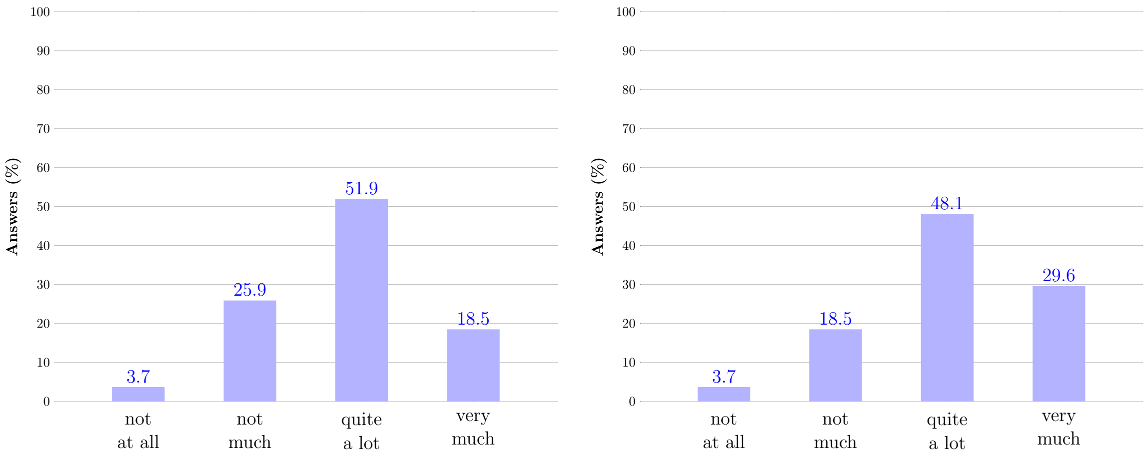
This project is a 40-hour course about Bioinformatics offered to 3rd and 4th grade students in high schools in the Province of Trento, organized in collaboration with the Department of Cellular, Computational and Integrative Biology (CIBIO). The course focused on some activities in the Bioinformatics field, where technology enables students to address biological questions and analyze data from experiments, through analytical and quantitative approaches of computer science. In particular, the focus of the course was the analysis of DNA sequences for the identification of mutations related to genetic diseases. The course included training on tools and techniques specific to computer science and biology, group activities that allowed students to work on their own projects under the guidance of experienced mentors, and moments of preparation for a public presentation of the work done.

Figure 6.21. Did you find it useful to collaborate with students from another curriculum? (%).



To measure the effectiveness of the project, a questionnaire was sent to all the participants. A relevant aspect to investigate was about the decision to propose the activity to students with different backgrounds (half of the participants have a biology background and the other half a computer science background). The answers to the question "Did you find it useful to collaborate with students from another curriculum?" highlighted that the collaboration aspect of the project was perceived positively by the students, as can be seen in the following visualization.

Figure 6.22. Evaluation of the Bio-informatic Activity . . . (% of answers).

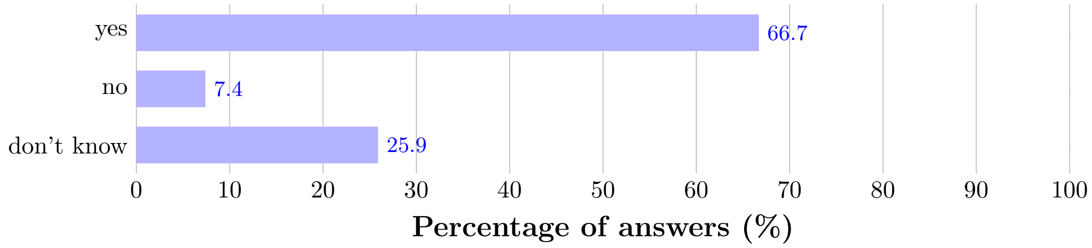


Do you think you have widened your knowledge in the biological field?

Do you think you have widened your knowldge in the computer science field?

The questionnaire contained questions about the expansion of knowledge in the fields of biology and computer science (Figure fig:knowledge. The results were mostly positive, since on average three-quarters of the students said that the project allowed them to widen their previous knowledge in both areas, as it is possible to see from the following diagrams (on

Figure 6.23. Do you find that participating in this project has opened up new scenarios for your future study path? (%).



average: 50% widen their knowledge by quite a lot, 24% by very much).

A project of this kind can also be effective in opening up new perspectives for students. Evidence of this can be found in the positive answers to the question "Do you think that participating in this project has opened up new scenarios for your future study path?", which are displayed in Figure 6.23.

Manufacturing designer internship

During Spring 2022, the FabLab hosted students from MaDe — Manufacturing Designer institute in Rovereto for a three-weeks long internship. MaDe students are trained to know how to use digital manufacturing tools, know modeling techniques, craft and industrial procedures and rules for fast prototyping. Therefore, their internship at the FabLab was an opportunity to get involved in a different context, where they had the chance to work on new projects and get in touch with the university.

At the end of the internship, students have been asked to reply to a questionnaire about the experience, to get an overview about what worked and what could be improved. Overall, the feedback was positive: all the students would choose this internship again and are planning to come back to the FabLab for their personal projects in the future. One of the main goals of the internship was to make it both fun and challenging for the participants. According to the questionnaire, this result has been reached since the answers to both questions "This activity was fun" and "I put a lot of effort into this activity" were positive, as it is possible to observe from the following diagrams (1 indicates "strongly disagree" and 7 indicates "strongly agree").

6.4.1 Training for coding challenges: Palestra di algoritmi

Introduction For many, computer science is perceived as a purely technical subject: a hobby for tech enthusiasts or wizards of technology. This is not the case. Computer science is, above all, a science. For those who use a computer, it is seen as a tool to solve their problems, whether they be mathematical, scientific, financial, and so on. However, for computer scientists, it's the science that studies the general methods to solve problems, at least those that are indeed solvable. As such, it addresses problems in all their aspects: how they are described (models), how they are represented (data), and how they are solved (algorithms). For instance, breaking a problem down into sub-problems until these can be solved simply, and then gradually

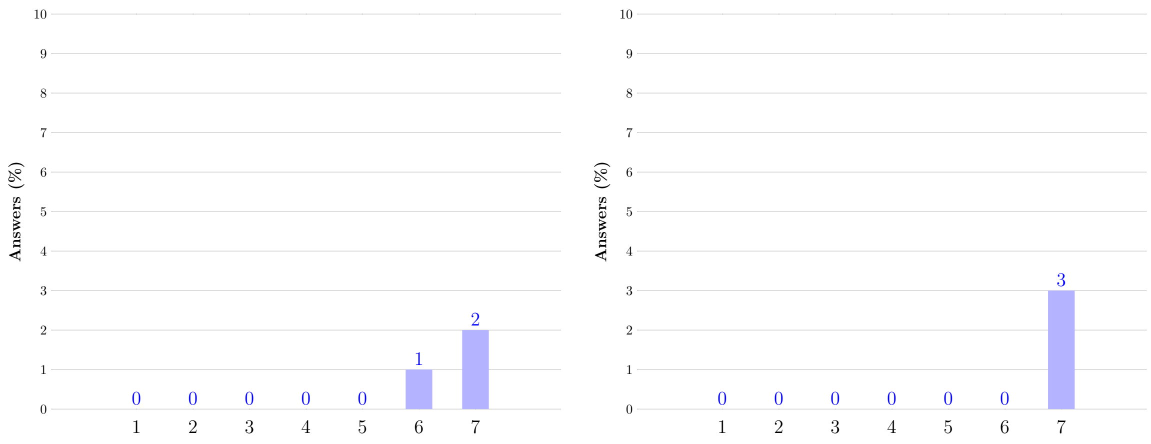


Figure 6.24. Engagement of the students in the activity"Manufacturing Designer Internship"

recombining the intermediate solutions to reach the complete solution, is a typical computer science principle called divide-and-conquer. In the realm of problem-solving, the methods derived from computer science originate from mathematics but extend it in new ways only made possible by the presence of an automatic executor. Acquiring and practicing the methods specific to computer science also affects the mental approach used to address everyday problems. Recognizing the scientific nature of computer science also has an orientation aspect: it means appreciating its unique language, worthy of being studied just like other sciences.

Objectives This training program has several goals:

- Introduce students to the study of algorithms as one of the fundamental subjects of computer science.
- Broaden the base of students participating in the Computer Science Olympiad competitions, both individual and group.
- Provide outstanding students with an edge in problem-solving, by supplying a broader set of foundational concepts in the field of data structures and algorithms.

Requirements

- Knowledge of an imperative programming language among those used in the Computer Science Olympiad, such as C or C++.
- And of course, the desire to challenge oneself!

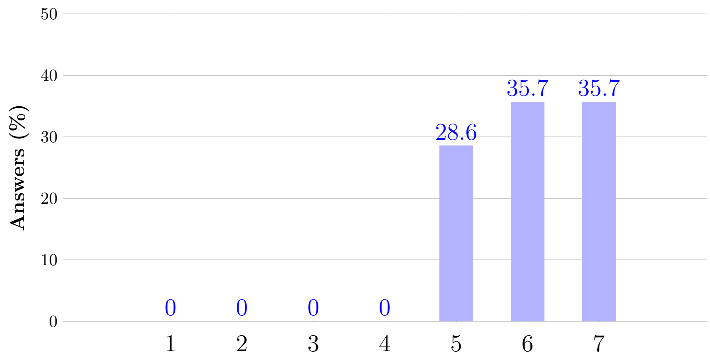
More info can be found here https://cricca.disi.unitn.it/montresor/labcominfo/palestra-di-algoritmi/

Mathematical games

The project "Matematica in Gioco" is the result of a collaboration with the PopMat Laboratory of the Department of Mathematics. It involved a group of students from the bachelor's in mathematics and 19 high school students that had the chance to design, implement and test some original proposals for mathematical games. The project involved several experts who covered theoretical and technical topics (historical and educational aspects of mathematics, use of software and machines for prototyping). The participants contributed to the project through individual and group work dealing with the analysis of playability, the design of the games, the consultation of historical-mathematical sources, the practical realization of the game components and the writing of the rules. All files created during the project to make the games using a 3D printer or laser cutter are now openly available, along with the rules of the games.

The project started in March 2022 and ended on the 30th of May, with an event that gave the participants the chance to present the games to the public. At the end, a questionnaire was sent to the participants, to get feedback about the whole project. A positive result that came in was about the enthusiasm of the students: almost all of them (92,2%) are happy with the choice of this activity and would choose it again. In addition, the participants would recommend it to their classmates, as can be visualized through the following diagram (1 indicates “strongly disagree” and 7 indicates “strongly agree”).

Figure 6.25. Would you recommend this activity to your classmates who did not participate? (%).

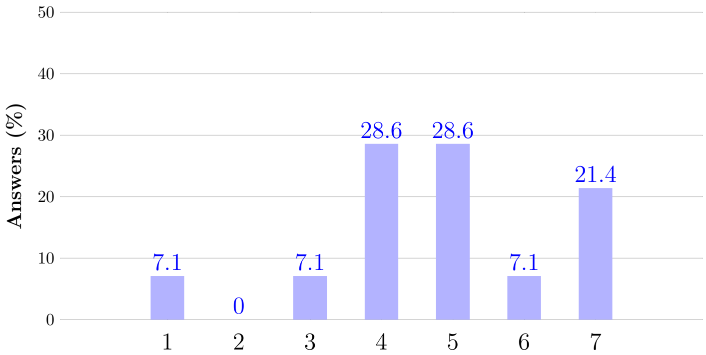


From the point of view of the FabLab, one of the goals of the project was to make students aware of the laboratory and introduce them to the world of digital fabrication. The following graph displays the answers to the question “Do you think you will return to the FabLab in the future to work on your personal projects?” and gives a promising result about the interest of the students in the FabLab.

School	City	Lessons	Participants (avg)	Tutors
Liceo Russell	Cles	4	6	1
Liceo Da Vinci	Trento	6	3	1
ITT Marconi	Rovereto	7	10	1
ITT Buonarroti	Trento	16	7	2
Liceo Galilei	Trento	17	7	2
Liceo Rosmini	Trento	8	17	3
ITET - C.A. Pilati	Cles	12	4	1
no. of schools: 7				11

Table 6.3. Schools that participated in the 'Palestra di Algoritmi' Project

Figure 6.26. Do you think you will return to the FabLab in the future to work on your personal projects? (%).



6.4.2 Guided tours of the FabLab for secondary school students

Upon request, the FabLab opens its doors to high school students for guided tours of the space and a presentation of the machines. These tours also include a workshop, in which the tutor works together with the students to design, for example, a simple 3D model that will then be printed to show the whole process step by step. These activities are a great way to introduce high school students to the world of digital fabrication and to put them in touch with the university environment.

7 Towards the local community

An important aspect of the FabLab's mission is its engagement with the local community. By fostering collaborations and organizing public events, the FabLab aims to create a network of individuals and organizations that promote informal learning and innovative teaching in the region. In all the activities described in this and the previous chapters, the cooperation with Glow is crucial; bureaucracy would have hindered the completion of most of them. In this chapter we first describe what Glow is, then we describe some of the main activities toward the local community:

- **mobile lab**: We created a mobile FabLab that brings science and technology to local communities, fostering formal and informal learning processes, creative co-planning, and community empowerment.
- **mountain cabin**: We operate a mountain cabin that hosts a variety of events, including science-focused summer camps, which immerse participants in the beauty of nature.
- **partnerships and projects**: The FabLab-Glow collaboration serves as the hub for a network of partnerships with organizations that foster informal learning and innovative teaching in the local area.
- **public events**: The FabLab organizes and participates in scientific fairs and public activities to engage with a broader audience and promote science and technology education. By showcasing the latest developments in the field and demonstrating the potential of constructionist learning, the FabLab aims to inspire community members to embrace innovative teaching methods and foster a culture of lifelong learning.

7.1 What Glow is

Glow is a cultural association that serves as a vibrant melting pot for makers, designers, educators, professionals, and visionaries. Established in 2018, Glow's mission is to foster a collaborative network in the Trentino region, aiming to generate and disseminate innovative ideas and projects across every stratum of society.

Glow's undertakings can be broadly classified into three main domains:

- **education**: Believing that education is the most potent tool to expand horizons and build a society adaptable to change, Glow focuses on a range of subjects. These include innovation, global citizenship, gender relations, digital storytelling, coding, digital prototyping, and the entirety of STEAM topics;

- **design**: With a commitment to collaborative, participatory, and human-centered design principles, Glow views design as an instrumental method to conceptualize, build, and launch both physical and digital products and tools. At its core, the welfare of the individual in society is prioritized;
- **public engagement**: Glow emphasizes the importance of sharing knowledge outside traditional lab settings or incubator environments. Through cultural and scientific outreach events, Glow aims to nurture a citizenry that's informed, inclusive, and resilient in facing present and future challenges.

Since its inception, Glow has made significant strides in its mission. The association has:

- engaged over 60 professional educators and industry experts;
- mobilized more than 250 volunteers;
- reached over 3,000 students across schools and universities;
- organized and participated in over 300 events in Trento and its province, involving over 5,000 citizens.

Through collaborative codesign, Glow crafts initiatives with significant added value for all involved stakeholders. They harness the expertise of participative methodology specialists and domain-specific content experts to ensure the efficacy of their projects.

The activities promoted and organized by Glow are also made possible by the network of associations, organizations, and public institutions that contribute in various ways to the development and well-being of the local area and surroundings. For example, but not limited to: social cooperatives (Kaleidoscopio, Samuele, Progetto 92, Abilnova, Irecoop, Punto di Incontro), associations (Carpe diem, Gioco degli specchi, Deina, Coder dolomiti, Libera, Dulcamara), cultural institutions (Muse, Fablab UniTrento, Fondazione Museo Civico di Rovereto), prototyping facilities (Prom), foundations and banking institutions (Fondazione De Marchi, Caritro, Casse Rurali), companies (La Sportiva, Felicetti, Level Up, Wondergene, Tito Speck, Menz&Gasser), public bodies (districts of the municipality of Trento, youth activities plans, family districts).

In the manifesto on `glow.earth` you can find our main values:

- What we do: We weave together the worlds of tech and design, engage in continual learning and offer training to others, and embark on research initiatives that transform spaces. Our activities range from designing workshops and events to perpetually feeding our insatiable curiosity. Our mission is to create connections, methodologies, events, products, and artifacts that help us and others understand the complexities of the world around us;
- What we stand for: We operate under the belief that the most pressing challenges in our world are intricate, demanding interdisciplinary solutions. This is why we are devoted to bringing together a diverse group of individuals to think, dream, and work collectively — ensuring mutual learning and creation that is greater than the sum of its parts. Observing things from a multitude of perspectives is vital, and we utilize art and design as tools to facilitate this endeavor. Our work is ever-evolving, with contributions

from numerous collaborators across varied contexts.

Here are our five guiding principles that steer the vision and actions of every Glow member:

- **the power of collaboration**: we are anchored in the belief that collaboration is potent. Everyone has a unique gift to offer, with the potential to harness it for the greater good.
- **resource maximization**: while our ideas are rich and expansive, we are also frugal. We appreciate cost-effective innovations and emphasize the culture of recycling.
- **global actions, local thoughts** (and *vice versa*): based in a small city in Northern Italy, our scope is not confined to Trento. We are an inclusive, multicultural team in an international city. Many of us aspire to take Trento's ideas worldwide, while also absorbing best practices from elsewhere and tailoring them to benefit our local environment.
- **belief in the human element**: society's issues require people-centric solutions. Adopting a human-centered approach ensures that our problem-solving is genuine and relevant.
- **ground-up approach**: grassroots methodologies, symbolizing mature democracy, are our foundation, especially when backed hand-in-hand by both public and private sectors (`about us`).

A paramount aspect of Glow's contributions lies in its pedagogical endeavors. These educational activities primarily branch into two main strands. The first, which represents Glow's longer historical engagement, focuses on the 2030 Agenda, communication paradigms, media landscapes, gender representations, and the often deeply entrenched stereotypes within societal fabrics. The second strand accentuates the multifaceted realms of STEAM disciplines. It is worth noting that while this overview does not delve into the granular specifics of these didactic undertakings, they can be extensively explored on the association's official website.

In subsequent sections, we will elucidate two of Glow's seminal initiatives: the "Apelab" project and the intriguing "Biblioteca nel Bosco" initiative, conducted at Fontana dei Gai. These projects are not only testaments to Glow's commitment to education but also encapsulate its innovative approach to knowledge dissemination and community engagement.

7.2 The "Apelab": A mobile lab on wheels

This is an adaptation with minor modifications of our previous work published as "The design process of the ApeLab: a Fablab on wheels" (see the publication list in Chapter 1).

Abstract Recently developed at the University of Trento in Italy, in collaboration with the Cultural Association Glow, ApeLab is a Fablab on wheels that encompasses the concept, design, and tools necessary to provide a mobile laboratory experience. The Piaggio Ape Car has been converted into a Fablab, making ApeLab a portable space equipped with digital manufacturing machines and other features. The project aims to promote STEAM education and digital manufacturing through hands-on learning activities, encourage scientific communication in an easy and creative way, and generate curiosity and creativity among people of all ages by

raising awareness of important scientific topics that are often overlooked.

The objective of FabLabs is to eliminate barriers, both between the departments that make up disciplinary silos and between the university and its surrounding area. Although university FabLabs and mobile maker vans have already been proposed and discussed in literature [148, 156], our approach is unique in its integrated approach both within and outside the university. Our vision is to promote innovation and creativity while generating new value. The purpose of this paragraph is to introduce the problem we wish to address, our vision, and in particular, our work in developing a mobile laboratory: the Apelab.

The ApeLab concept Although academia could potentially play a vital role in the ongoing cultural revolution, it often appears to be disconnected from the general population. Academic institutions must overcome structural barriers and embrace the "Third Mission", which involves enhancing and transferring knowledge to the broader community [14]. Therefore, our objective should be to disseminate academic knowledge beyond the university environment, informing, disclosing, and intriguing people, particularly the younger generation. As researchers, we should aim to create new educational models that encourage people to deepen their understanding of science and technology.

In Chapter 6, we explored how the maker culture and Fablab philosophy could be integrated into education. By introducing these activities, enriched with academic knowledge, to all Italian schools, we can prepare the next generation of young Italians to view technology as a tool for creation, change, and training, equipping them with the skills necessary to confront the challenges of the future [29].

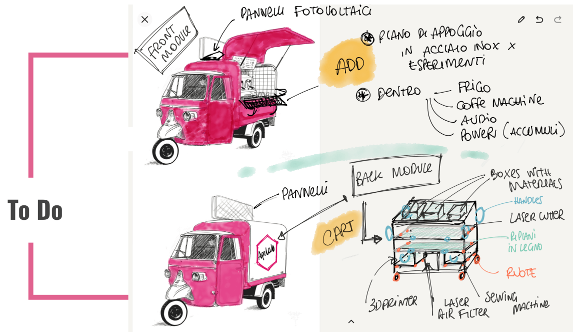
Ape Car is a versatile and well-known vehicle used for various purposes worldwide. However, its use for scientific dissemination is less obvious. The ApeLab project was created as an itinerant branch of the Fablab UniTrento, conceived as part of one of the authors' PhD work and developed as the final project of the FabAcademy course. ApeLab is a mobile Fablab, a travelling experimental lab for social innovation that provides a service to local communities where knowledge is shared. The project seeks to encourage citizen empowerment and active citizenship, where people of all ages can see and experiment with tools and machinery present in a Fablab, prototype, create, and innovate. The aim is to create an informal and friendly environment that encourages formal and informal learning processes, creative and innovative co-planning among citizens who are usually not involved in formal learning spaces. For a creative society, people need to learn to learn and adapt, and to achieve this goal, it is necessary to bring together different voices and reach new audiences, integrating them into the discussion.

The concept of Fablabs established in trucks or vans is not new [148]. On the other hand, Fablabs were born in universities [92]. What makes this project unique is the combination of the two. We have designed a model where first students are contaminated by the maker culture inside the University. Later, they help us by bringing what they learned outside the walls of the universities, getting closer to the schools and to the population, "bringing out" some projects developed within the STEM departments of our university towards citizenship, in a mobile and itinerant way.

The Province of Trento is a culturally rich region composed of many valleys and rural communities often not reached by innovative educational projects.

The ApeLab project aims to provide these under-served communities with tools for experimentation, innovation, and creativity in an itinerant science workshop. By using the maker philosophy and tools described above, technology becomes an educational tool capable of creating connections, innovative models, and boosting ideas.

The ApeLab Design and Process The genesis of this project can be traced back to an old, pink Piaggio Ape Car that was once used as a food truck to prepare creapes and waffles for children. This three-wheeled vehicle was popular in fairs, on the street, and at birthday parties, particularly among younger kids. Additionally, in the Italian region where we are located, the Ape Car is a common mode of transportation that teenagers are excited to acquire for their 14th birthday. Due to its enclosed structure, it enables them to travel even in snowy conditions, unlike mopeds and motorcycles. It is also used by older adults for its versatility and adaptability. The Ape 50 model we used is renowned for its ability to perform well in rural settings, as well as for its efficiency in urban transportation, making it a perfect fit for a wide range of professional and non-professional needs. Given its versatility and popularity, why not leverage it to make science more engaging and captivating?



(a) Initial Sketch: possible internal implementation

(b) 3D model in Fusion360

Figure 7.1. Sketching process

Fablabs are typically characterized by machines that fall into two broad categories: *subtractive* and *additive*. In our ApeLab, we aimed to incorporate both types of machines. Our basic equipment includes a Makeblock laser cutter and a Roland vinyl cutter as subtractive tools. The laser cutter has both cutting and engraving capabilities and is especially useful for schools. Its user-friendly software makes it simple to use, and it can create designs on a variety of materials, such as wood, paper, cardboard, acrylic, and leather, using 2D vector files. Even younger students can use it thanks to its simplified interface. The vinyl cutter is another machine that is great for having fun while learning the basics of 2D vector drawing. It is primarily used to create stickers and pop-up cards, but it can also cut circuits from conductive materials, which is useful in computer science. As for additive machines, we have a 3D printer that can create 3D objects. We can use this machine for activities with both elementary school children and university students, adapting the difficulty level to the participants. The design

Figure 7.2. Sandblasting and painting process.

Figure 7.3. Carts preparation and Sharper Night in Trento, Italy.

software we use also varies according to the skill level of the users: we start with TinkerCad for children and use Fusion 360 for engineering students.

When deciding on the tools and machines to include in our mobile lab, we had to figure out how to restore and waterproof the old pink Piaggio Ape Car. We also had to determine how to safely load and allocate the machines within the vehicle. This process began with some sketches, which are depicted in Figure 7.1a and Figure 7.1b.

After this first design step, with the help of a coach-builder we filled all the holes in the iron, sandblasted and painted our vehicle (Figure 7.2).

After waterproofing and insulating the exterior of the Ape Car, the interior was next on the list. We utilized polyurethane foam and silicone panels to create an insulating layer over the entire internal surface of the cargo bed, which was then covered with a thin layer of plywood cut to size with a laser cutter machine. Every piece was designed and constructed using digital prototyping machines typically found in a Fablab. The entire restoration process can be viewed in a video showcasing the ApeLab [80].

To ensure safe and efficient transport of the machines inside the ApeLab, we designed two carts that could be loaded into the ApeLab's wagon and easily maneuvered through doorways in different schools (Figure 7.3, on the left). The main cart, measuring 1m wide and 55cm deep, stores the 40W CO2 laser cutter and its filter. A second cart, measuring 1m wide and 45cm deep, can accommodate the vinyl cutter, two 3D printers, a sewing machine, filament spools, soldering stations, and various hand tools.

The ApeLab provides a solution for space constraints and enables us to meet with students and teachers in their own classrooms or other locations. This mobile Fablab has the potential to reach informal environments such as parks and squares, allowing us to interact with new audiences and provide a higher degree of exposure to the tools for citizens.

Implementation and Considerations The ApeLab project was primarily developed during the Covid-19 pandemic, and its first public releases were made during the summer of 2021. We conducted four digital prototyping workshops involving small groups of individuals aged between 10 to 25 years old, with around 70 participants in total. Due to safety concerns, all the workshops were held outdoors.

In September 2021, we showcased the ApeLab at the Sharper Night event in Trento, Italy, which drew in approximately 200 participants, including students, teachers, children, and families (Figure 7.3, on the right). The same experience was repeated in 2023. We also presented the ApeLab at the Maker Faire Rome — European Edition and the Science Festival in Genova in 2022, where hundreds of individuals visited our stand. Currently, ApeLab attends events either by invitation or through our own initiatives to reach underserved areas.

The initial response to the ApeLab has been overwhelmingly positive, especially in regards to its ability to provide engaging educational experiences in peripheral and informal settings.

By utilizing maker culture and hands-on learning methods, we fostered a collaborative environment that emphasized playful experimentation, tinkering, and sharing. This was made possible thanks to the involvement of our university students. After undergoing brief training, these students were ready to mentor younger peers. Doing so, together we conducted sessions using predefined activities or, at times, improvised on the spot to demonstrate the functionalities of the machines on the ApeLab.

Working with middle school students using peer-education in particular was a rewarding experience, as they were able to unleash their creativity and discover a new approach to science education. We received comments such as "I wish they did it in my school" and "who thought science could be fun" from the students. These kinds of comments motivate us and reinforce our belief in the importance of a different approach to education.

As organizers, we faced challenges that required us to think on our feet and come up with creative solutions due to the flexibility required in the various educational and geographic settings we visited. The success of the initial pilot workshops led to interest from more than ten schools and several municipalities in the area, who are eager to host a visit from the pink ApeLab. This will provide us with an opportunity to conduct a more comprehensive study, supported by both qualitative and quantitative data.

Conclusion This paper presents the design and development of Apelab, a mobile Fablab. We initiated four pilot workshops to test our initial prototype and to gather valuable feedback.

Figure 7.4. The Fontana dei Gai mountain cabin, located in the Marzola forest.

Encouraged by the positive responses we received, we are now collaborating with ten secondary schools and five municipalities to strategize and execute a structured testing framework. This framework is designed for a specific selection of FabLab educational activities that foster creative experiences in computational thinking and product development utilizing tools such as 3D printers, laser cutters, and CNC routers.

We firmly believe that a comprehensive approach involving universities, schools, local administrations, and citizens is crucial for our region to adapt to this cultural and educational shift. By fostering synergies and sharing knowledge, resources, and expertise, we can cultivate an environment conducive to cross-disciplinary and non-traditional activities. Such initiatives help young people explore new passions and talents in fields they may not have previously considered. As we move forward, our guiding principles will remain rooted in scientific dissemination, 'making', curiosity, creativity, and passion.

7.3 Mountain cabin

Since May 2022, following a public tender, the Association Glow has obtained a 6-year management lease for the "Fontana dei Gai" cabin located in the Marzola forest, on one of the mountains that define the Adige Valley where Trento is situated. The primary objective of this facility is to be an operational branch for the association to host events and initiatives targeting various age groups, with a particular focus on the younger generations. The space is available for training courses and creative and digital workshops, in close collaboration with the University of Trento and the departments located in Povo. The aim is to ensure that what originates within the academic walls can find practical application within the local community and the surrounding territory.

"La biblioteca nel bosco" Project

In summer 2023, with a group of students we co-designed the project "La biblioteca nel bosco" (The library in the wood). The project was partially funded by the Municipality of the city of Trento and its youth office.

The project stems from the necessity to provide students in the city with a different approach to studying, by establishing a library in the Marzola Forest, near the Fontana dei Gai cabin. The goal is to offer university students the opportunity to learn outdoors, reconnect with nature and the surrounding environment, thereby promoting their well-being.

The proposed timeframe for implementing the project was the end of the summer 2023, as it was believed to be the best time for young individuals to review before their university exams, engage in the final moments of study in the company of peers, and thus, rehearse aloud in a space different from the usual libraries.

The cultural association Glow tried to achieve this objective in an entirely innovative manner. The intention was to bring science to a remote location where it is not typically expected to be addressed. This has been accomplished by creating an environmentally friendly, zero-impact study area and organizing in-depth workshops on topics such as beekeeping and energy. The aim is to enhance and revitalize the Trento community space, as the cabin is for public use, by involving people through the educational activities and artistic and cultural events featuring local artists. This approach fosters social interaction among participants.

Therefore, the forest, typically regarded as a remote area, becomes a place of gathering. It is dynamic and uncertain; an unexpected location where young individuals can learn from each other. The recreational events organized by the Association, which alternated with study sessions, enabled them to seek solutions to the challenges they encounter, discover their limits, assist one another, strengthen their independence and self-esteem, and enhance their capacity for socialization and group organization [200].

Project Goals Regarding the specific objectives, the first was to provide students with an environment immersed in nature that can promote their well-being and alleviate the stress caused by their studies. Through this communal space, the aim is to encourage socialization, which has been challenged by the years of the pandemic, negatively impacting the well-being of young individuals. Therefore, study periods were interspersed with leisure moments, thus promoting a healthy balance between study, rest, and socialization. In this way, the goal is for students to rediscover the pleasure of learning and engaging in daily activities in a wholesome environment. Indeed, spending time in open spaces makes individuals more dynamic and mentally alert. An additional favorable aspect of the forest is the positive emotional state experienced by young individuals when immersed in nature, as the forest contributes to facilitating socialization skills and establishing a harmonious connection with the surrounding environment [200].

The second objective that the project aimed to pursue was to enhance the competencies of students through the pedagogical strategy of learning-by-doing, a practical approach that involves increasing one's abilities and knowledge through concrete activities. Study periods, therefore, were interspersed with educational activities focused on two overarching themes: the world of bee-keeping and renewable energies. With this objective, the aim was to introduce scientific topics to a location where they are not typically expected to be addressed and to promote awareness among young individuals regarding the natural environment, which served as the backdrop for this experience.

The third objective of the project was to highlight a communal space that belongs to the community. Through the phases of co-design and the activities conducted during the two weeks in which the project was realized, the intention was to engage young individuals, aiming to cultivate in them a sense of community towards the territory and provide them with the opportunity to feel part of a larger community.

The "Library in the Woods" project targeted numerous beneficiaries, primarily categorized as direct and indirect recipients. The direct beneficiaries were the young university students. Additionally, any individuals from the city of Trento or the Trentino region interested in specific events can also become part of the project. Consequently, this approach facilitates interaction, socialization, and exchange between the student community and Trentino residents.

An indirect recipient of the project was represented by the Trento Forest Corps, as the forested area in which the study area will be installed will be enhanced and cared for. The study space is fully environmentally respectful; the library will indeed have zero environmental impact. Therefore, no invasive operations were conducted within the forest, and no tree clearing took place. Instead, the project utilized the natural space offered by the forest to position tables and hammocks. Additionally, renewable energy has been generated through solar panels to power the batteries that students can connect their devices to.

Final Considerations: The Role of Nature in the Project The "Library in the Woods" project aimed to create an outdoor study area nestled within the Marzola Forest. The benefits of being in contact with nature are manifold. A Dutch study involving nearly 350,000 individuals demonstrated that being in a green environment helps alleviate stress and fatigue resulting from excessive sensory stimulation. It reduces negative emotions such as anger, aggression, and frustration, while increasing positive ones like self-esteem and self-control [62]. This effect was also mentioned by the participants of the project.

Secondly, the forest enhanced socialization among the young participants in the project. They lived together for two weeks, sharing a common indoor and outdoor space that hosted events and training activities. This created a sense of community and unity among the group.

Lastly, the Marzola Forest served as a meeting place between university students and the Trento community, which often represent two distinct realms. The forest is often associated with the image of a remote and isolated place, but with the "Library in the Woods" project, it became an opportunity for exchange and dialogue between the residents and the university community, allowing them to fully embrace the territory. For this reason, despite being a project operating at the local level, closely tied to the Trentino region, we believe that the project can align with a broader vision of global education in which a student community and the civilian community come together thanks to the valuable natural contribution of citizen science. By the time of the writing of this thesis, the data about this experience are still under review and analysis, but, given the first enthusiastic feedback, for sure the experience will be replicated in the next years.

7.4 Partnerships and projects

For the ongoing academic year (2023–2024), with the Glow association, we have meticulously planned and scheduled over 400 hours of educational training sessions, spanning both primary and secondary schools across the entire Trentino region. This reaffirms our unwavering commitment to fostering an informed and enlightened future generation.

In addition to our steadfast endeavours within the educational sphere, we have also initiated a plethora of collaborations with local cooperatives, associations, and libraries, further solidifying our footprint in Trentino's socio-cultural landscape.

We continue our enduring legacy of conducting workshops on active and global citizenship, inclusivity, and scientific disciplines. Our relentless pursuit of these programs underscores our enduring commitment to community engagement, education, and societal progress.

7.4.1 The synergy between FabLab UniTrento and Glow: Bridging institutional and grassroots approaches

The activities elaborated upon have been made feasible through the collaborative efforts of FabLab UniTrento and Glow. This intricate fusion, which brings together the gravitas of a renowned institution like the University of Trento and a grassroots third-sector organization like Glow, harnesses the strengths inherent in both domains. It epitomizes the essence of 'third mission' engagements, which are crucial for the dissemination of science and knowledge within the region. Stepping beyond the confines of academia is imperative to effectively engage with diverse urban factions, thereby responding adeptly to their needs.

In the subsequent table, a catalogue of projects funded over the past three years, which were designed by or involved the author of this manuscript, are presented. While it is often challenging to collect precise data, elucidating the tangible impacts stemming from these endeavours, we believe that the consistent funding secured year upon year stands as testimony to the efficacy of our initiatives. It underscores their indispensable value, particularly for the upcoming generations.

Table 7.1: Awards won by the Association GLOW and FabLab UniTrento from 2019 to 2023

Title	Name and entity	Leader	Partner	Total amount	Glow amount	DISI amount
2023						
Smart Materials and Computing for All	Euregio Mobility Funds	Università di Bolzano	Fablab Unitrento	6000	-	4900
Learning informatics	PRIN 2022 - MUR	Fablab Unitrento	Università di Milano, Università di Bologna, Libera Università di Bolzano, Università di Tor Vergata	214 338	-	46 730
M&ASURE Monitoring & Automating UNITN workSpaces toward UseR awareness and Energy savings	Piano strategico di ateneo	DICAM	Fablab Unitrento	56 000	-	10 000
MINERVA: STEAM al femminile	U.O. Programmazione e Politiche del lavoro	Fondazione ENAC Veneto C.F.P. Canossiano	-	415 000	-	30 100
Lagorai, tesoro nascosto: Conoscere e vivere consapevolmente il nostro territorio	PGZ Val di Fiemme	Glow	Bel da Matti, Astrofili di Tesero, Progetto 92, SAT, Croce Bianca di Tesero, Gruppo Soccorso Alpino Val di Fiemme, Corpo Forestale, Bluebiloba, Wondergene.	3300	3300	-
The House of Tridentum	PGZ Trento	Glow	Centro studi Interdisciplinari di Genere, Associazione Prodigio ODV	3300	3300	-
Biblioteca nel bosco	PGZ Trento	Glow	Fondazione Museo Civico di Rovereto, Ciclocinema, Ludimus, Cuscus, UniversitaryMeals	5550	5550	-

Continued on next page

Table 7.1: Awards won by the Association GLOW and FabLab UniTrento from 2019 to 2023 (Continued)

Title	Name and entity	Leader	Partner	Total amount	Glow amount	DISI amount
HarpoLab	Giovani spazi creativi	Il Funambolo	HarpoLab, Glow, Fondazione museo Storico, Trentino Film Commission, FBK, Fablab Unitrento	35 000	5000	-
LIGNEO: Legno per l'Inclusione: Giovani Nuove tEcnologie e Orizzonti	Caritro – Bando Sperimentazione didattica ENAIP TRENTINO	Glow, AbilNova Cooperativa Sociale, Associazione Bel da Matti	24900	9600	-	
Bando formazione docenti Caritro	IC1	Glow, Fablab Unitrento	34175	3000	3000	
Bando formazione docenti 2024	Caritro	Liceo Bertrand Russell, Cles Trento	Glow	11 775	6000	-
Attivi Digitali – Bando formazione docenti Caritro	IC Valsugana	Glow	3500	500	-	
Trento. Ieri, oggi, domani – Bando Reti Scuola Territorio 2022	Caritro	Glow	Il Liceo Classico "Prati", il Liceo "Galilei", L'Ufficio Politiche Giovanili Comune di Trento, il Museo Storico del Trentino	24 900	24 900	-
Sustainable Week - HACKATHON	Caritro – Bando Reti Scuola Territorio 2023	ENAIP TRENTINO	GLOW, Menz&Gasser, Junior Achievent Italia	21 800	7500	-
2022-2023						
Donne & STE(A)M: dalla consapevolezza alla *mentorship*	Caritro – Bando Filiere formazione-lavoro 2022	Glow	WonderGene, OWL	17 000	17 000	-

Continued on next page

Table 7.1: Awards won by the Association GLOW and FabLab UniTrento from 2019 to 2023 (Continued)

Title	**Name and entity**	**Leader**	**Partner**	**Total amount**	**Glow amount**	**DISI amount**
Che GENERE di diritti?	Bando Reti Scuola Territorio 2022	Glow	Deina Trentino APS, Liceo classico “G. Prati”, Liceo scientifico “Galileo Galieli”, Ufficio delle Politiche Giovanili del Comune di Trento	17 000	17 000	-
2022						
Laboratorio di robotica e Internet of things PON FSE Sapere per saper essere	PON FSE	Liceo Scientifico Leonardo Da Vinci	Glow	76 230	5600	-
STEM:KIT - Capire la fisica con l’informatica	MUR	Fablab Unitrento	Level Up	100 000	-	70 000
Computational Thinking Academy for inclusion	Eramsus+	DISI	Katholiek Onderwijs Vlaanderen	250 399	-	53 295
Bel da Matti	PGZ Val di Fiemme	Glow	Fiemme Calcio a 5, ASD Futsal Fiemme, ASD Fiemme Casse Rurali e A.S. Cauriol	5900	5900	-
Case di Domani	PGZ Trento	Glow	Fablab Unitrento	4200	4200	-
SPACE BIO TINKERING	Sostegno di progetti per la realizzazione di eventi socio-culturali di prossimità – estate 2022	Glow	WonderGene	3500	3500	-

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Table 7.1: Awards won by the Association GLOW and FabLab UniTrento from 2019 to 2023 (Continued)

Title	**Name and entity**	**Leader**	**Partner**	**Total amount**	**Glow amount**	**DISI amount**
PER sFIdarli DObbiamo impegnarci	Bando Reti Scuola Territorio Istituto di Istruzione Superiore "Martino Martini"	Glow	12530	7500	-	
PRONTI... ATTENTI... STEAM!	Bando Reti Scuola Territorio 2022	Istituto Comprensivo Vigolo Vattari	Glow, DISI	12 000	2500	-
2021–2022						
Algoritmicamente: dal *problem solving* all'Informatica	Bando Sperimentazione didattica 2021/2023	Liceo Scientifico Leonardo Da Vinci	Glow	16 000	4000	6000
2021						
Matematica in gioco	INDAM – Prima implementazione di un protocollo di disseminazione: università, scuola e società	Popmat	Fablab Unitrento	4000	-	4000
Comunicatori scientifici - Percorso formativo per aspiranti divulgatori e docenti	Caritro – Bando Filiere formazione-lavoro 2021	Glow	Level Up, Cieffe	28 000	28 000	-
ApeLab - laboratori di comunità	Bando Cultura di prossimità 2021	Glow	-	5000	5000	-
Rinforzi@moci 2	Ministrero del lavoro e delle politiche sociali	Aps Carpe Diem	Progetto 92, GLOW, trento 7	26 351	7500	-

Continued on next page

Table 7.1: Awards won by the Association GLOW and FabLab UniTrento from 2019 to 2023 (Continued)

Title	Name and entity	Leader	Partner	Total amount	Glow amount	DISI amount
"hello world"	Avviso pubblico per il sostegno di eventi culturali nel comune di Trento, che unicano monda universitario e cittadino	Glow	Level UP, coder dolomiti	16 560	3600	-
2020						
Rinforzi@moci	Bando Reti Scuola Territorio 2021	Trento 7	Aps Carpe Diem, Progetto 92	15 000	4700	-
			Sums	1 453 933	178 150	228 025

Note: Please note that the abstracts are located in the Appendix section of this document.

Table 7.2: Grants submitted in 2023 by the Association GLOW and FabLab UniTrento with Pending Outcomes

Title	Name and entity	Leader	Partner	Total amount	Glow amount	DISI amount
submitted						
A.STR.I@school	riassumi in breve	Glow		171 600	171 600	-
hiSTORIC Kids - grandi storie a misura di bambino	Caritro, terzo bando per il volontariato sociale	Associazione Il seme ODV		8090	4750	-
2023						
BAHST - Bridge Art, Humanities, Computer Science, and Technology	-	UniBZ	Fablab Unitrento	548 500	-	260 700
			Sums	728 190	176 350	260 700

8 Towards a broader community

Going online

All the previous actions have primarily focused on in-person activities, serving as versatile platforms capable of accommodating a range of activities for the diverse audiences involved.

Our latest endeavor is directed towards the development of an online platform named The Laaab– a comprehensive catalog that mirrors our ethos. This platform showcases our approach alongside all the activities implemented by us and our partners, providing a space where these activities can be further disseminated and enriched by those who adopt them.

For this chapter, we would like to express our sincere gratitude to the dedicated group of students from the Human Computer Interaction (HCI) Master's program, specifically from the Visual Design and Participatory Design courses, who have significantly contributed to the development and success of The Laaab platform. Their tireless efforts and creative insights have played a crucial role in shaping the platform into what it is today.

We extend special appreciation to Francesco Coppola and Riccardo Carretta, who not only participated in the courses but also joined the FabLab Unitrento as interns. Their continued dedication and expertise were instrumental during both the development and testing phases of the platform. Their commitment to excellence and innovative thinking greatly enhanced the functionality and user experience of The Laaab. Their valuable contributions have not only enriched the platform but have also strengthened the collaboration between the academic and practical aspects of our project.

8.1 The Laaab Platform

Brief The Laaab is an innovative platform designed specifically for educators and teachers seeking to explore, discover, and draw inspiration from a diverse range of workshops and creative ideas for educational activities. Our primary objective is to cultivate a vibrant network that offers meticulously crafted guidelines for workshops, fostering a community dedicated to enhancing educational experiences. By introducing a standardized and intuitive structure, we aim to revolutionize the way education and collaboration are presented.

While numerous platforms currently curate workshops and small projects, they often suffer from various limitations and lack aesthetic appeal. Addressing these shortcomings, The Laaab emerges as a solution that not only prioritizes visual appeal but also delivers robust functionality. Most notably, we have tackled the absence of mechanisms for accrediting reputable publishers, such as universities and schools. By partnering with certified publishers, we ensure a consistent framework enriched with reliable information and trustworthy content.

The primary beneficiaries of The Laaab comprise educators from educational institutions ranging from schools to universities, as well as creative spaces like fab labs. These individuals seek comprehensive and detailed educational resources to enrich their teaching methods. Moreover, The Laaab stands as an open-source platform, welcoming anyone in search of insightful workshops and enriching events.

In essence, The Laaab serves as a groundbreaking nexus where educators can discover a wealth of certified workshops and educational activities and experiences, while also providing a collaborative space for those passionate about learning to access valuable resources. Our commitment to excellence, visual appeal, and credible content sets us apart as a transformative platform in the realm of education.

Starting point Considering the requirements for this website and the limitations of the existing platforms, The Laaab needed to incorporate certain dynamics:

- **Account creation and verification procedure**: considering that there will be two primary user types–those seeking workshops and those publishing content, a registration and loing processes will be needed. For content publishers, a verification procedure is necessary before allowing them to upload workshops and events.
- **Engagement features (comments, likes, and shares)**: These features are essential to foster community engagement, evaluate content quality, and provide feedback to workshop creators.
- **Event section**: A dedicated section where users can register for and attend the workshops of interest.
- **Workshops section**: A section dedicated to showcasing all available workshops.
- **Organizations representation**: A feature to represent contributing organizations, underscoring that The Laaab is part of a trusted network.

8.2 Framework

8.2.1 Competitor analysis and benchmark

There are many online platforms which include educational content similar to the one offered by The Laaab. We conducted the competitor analysis observing three different platforms: Thingiverse[1], Instructables[2] and FEM[3].

MakerBot's Thingiverse MakerBot's Thingiverse is a design community for discovering, making, and sharing 3D printable things. They are the world's largest 3D printing community, no matter the technical expertise or previous experience of the user.

[1] https://www.thingiverse.com/
[2] https://www.instructables.com/
[3] https://fem.digital/

Strengths	Weaknesses
• easy to explore • gallery on top of the project • education section • groups	• focused only on 3D printing • small descriptions, not groped into sections • likes are not visible from the detail of a project • messy and poorly positioned interface

Instructable Instructable is an online platform dedicated to step-by-step collaboration among members for building a variety of projects. Users post instructions related to their projects, usually accompanied by visual aids. The community can interact through a specific comment section below each Instructable step as well in topic forums.

Strengths	Weaknesses
• popular choice • the first platform of its kind • step sections • comments and tips • PDFs downloading • teacher section	• old and raw look

FEM FEM is an Italian initiative dedicated to enhancing the impact of education within society by providing a range of solutions—including lessons, workshops, professional courses, and events—for schools, educators, and professionals. Specifically for schools, they organize both workshops and longer paths ("curricoli per l'innovazione").

Strengths	Weaknesses
• easy to explore • links with schools • workshops that integrate the curricular didactic offer • section tailored for schools • platform for teachers that aims at helping them discover activities, teaching methodologies, and create a community • PDF with activities	• closed plataform: each workshop is described with a few sentences; to access it, you must have an agreement. The PDF file in which the activities can be viewed in more detail is still not at all complete and only gives a brief description of the workshops • no external opinions on the proposed workshops

The Laaab's competitive advantage was explored also through a positioning map (Figure 8.1). The chosen axis values were *quality*, since the *quality* of the offered workshops is crucial for the commercial success of the platform, and *attractiveness*, because of the novelty of the platform and its need to be positively recognized and remembered by users.

Starting an analysis of the strengths of each platform, we selected a list of features that we wanted to include also in our platform as it can be seen in Table 8.1.

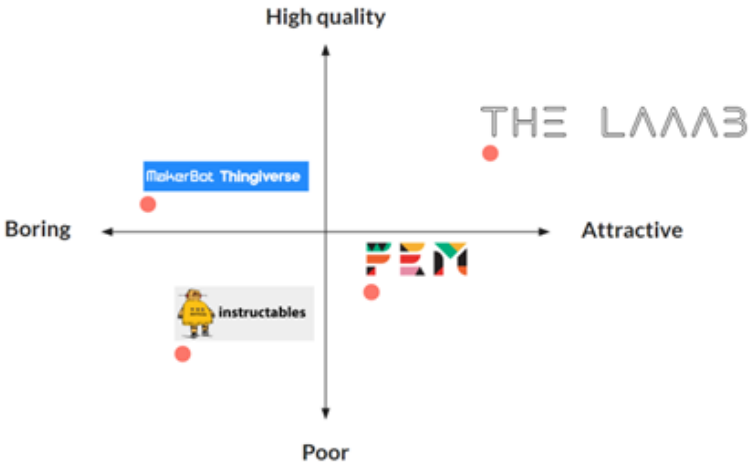


Figure 8.1. Competitor analysis and benchmark

User Goals/Main Features	Instructables	Thingiverse	EM	The Laaab
Platform Functionalities				
Explore section	✓	✓	✓	✓
Like/Favorite for the project	✓	✓	✗	✓
Share project	✓	✓	✗	✓
Filter project by	✓	✓	✗	✓
Add tip to project	✓	✗	✗	✗
Comments on project	✓	✓	✗	✓
Categories of projects	✓	✓	✓	✓
Pleasant UI	✗	✗	✓	✓
All users can post	✓	✓	✗	✗
Contest section	✓	✗	✗	✗
Description of project in steps	✓	✗	✗	✓
Mailing list	✗	✗	✓	✓
Events	✗	✗	✓	✓
News/Blog	✗	✗	✓	✓
Educational Features				
Teacher/education section	✓	✓	✗	✓
Project has its own images	✓	✓	✗	✓
Works with schools/institutions	✗	✗	✓	✓
Has material for schools	✓	✗	✓	✓
Teacher has advanced features	✗	✗	✗	✓

Table 8.1. Main features comparison.

8.2.2 Framing problems

The Laaab's brief included many specific desired features:

- verification procedure and information about the verification;
- possibility to access and create an account;
- comment, like, and share functions for published projects;
- event section;
- workshops section;
- organizations section.

In addition to these features, starting from the brief, we framed some sub-problems to address through specific elements, which were finally included in our layout.

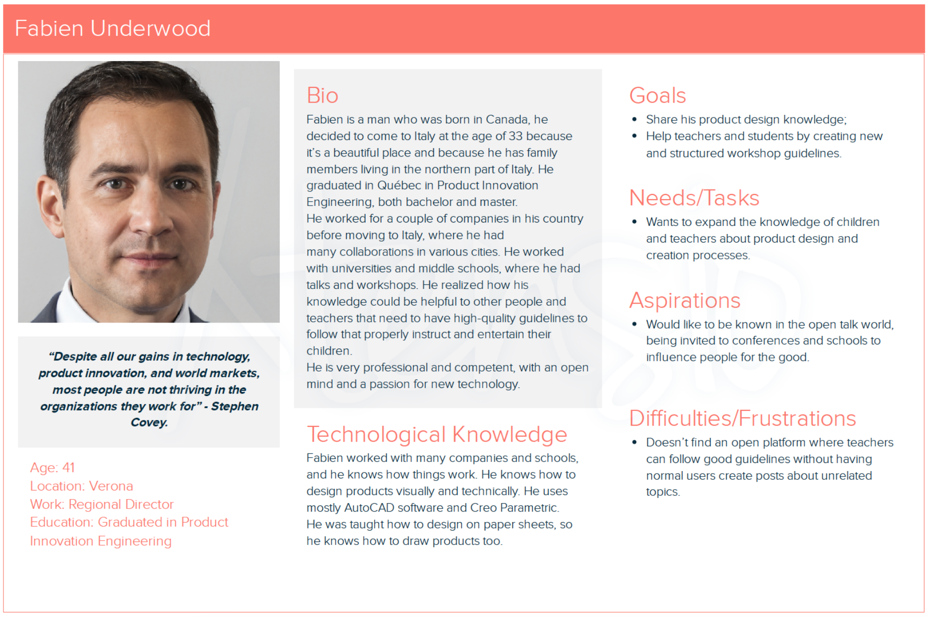
Content hierarchy problem: cards solution As highlighted in the brief, the cornerstone of the platform's business model is user-generated content. This underscores the importance of devising a method to showcase a vast array of projects and information without causing confusion. To address this challenge, we opted for a card-based design. Cards are distinct components that encapsulate content and actions related to a single topic, in a way that aptly indicates hierarchy. They are invaluable as they facilitate easy scanning for relevant and actionable information. Images and text generated by users will be placed on them.

Different users problem: colors solution The Laaab is a platform catering to diverse user needs: downloading workshops, uploading new ones, or finding relevant events. A clear visual code is essential to address this. In our design, colors signify specific meanings (main color = workshops, yellow = events, blue = institutions), aiding users in easily locating pertinent information based on their objectives. Accordingly, the main color and the yellow ones are more vibrant and engaging, in accordance with workshops and events; while the professional blue tone represents schools and organizations.

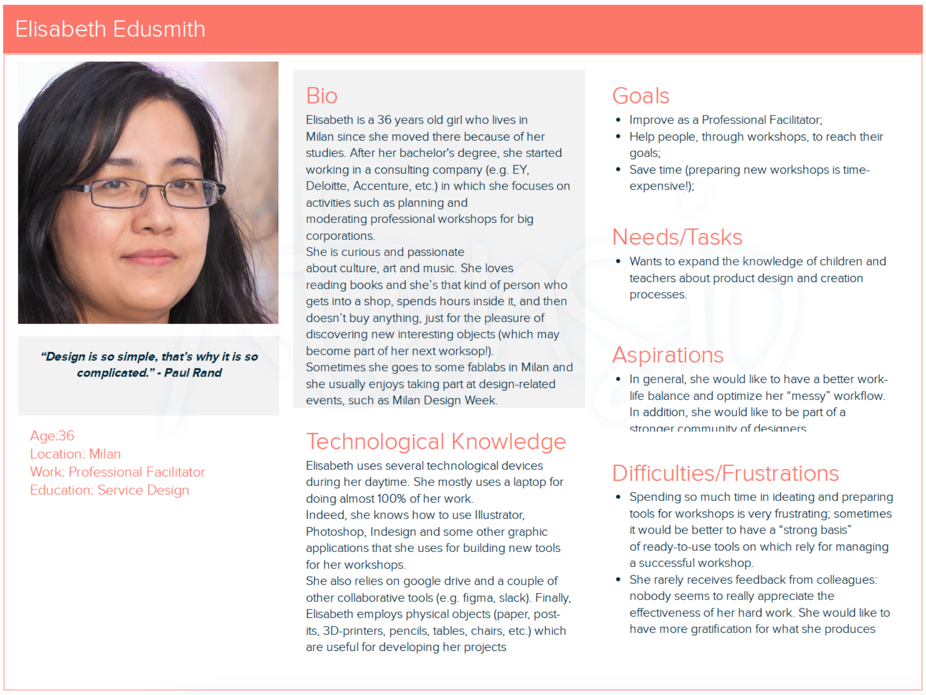
Engaging problem: banners solution Engaging individuals can be challenging, particularly when a brand is nascent and its reputation is yet to be established through experience. To bolster user engagement and address this issue, we designated a "special section" at the bottom of each page to house a specific call-to-action aimed at user engagement. Each banner serves to motivate active user participation, thereby contributing to the platform's growth.

8.2.3 User research

In the exploration of the user-centric platform The Laaab, three specific personas emerge, each bringing a unique perspective and set of needs to the table. First, we have Fabien Underwood, a 41-year-old Workshop Creator from Verona with a background in Product Innovation Engineering. Fabien seeks a platform where he can share his extensive knowledge and help educators by providing structured workshop guidelines. Next, there's Elisabeth Edusmith, a 36-year-old Professional Facilitator from Milan, whose prowess in Service Design propels her towards improving her workshop facilitation skills and finding a community of like-minded professionals. Lastly, we meet Angelica, a 29-year-old Science Teacher from Bologna, whose passion for teaching drives her to seek engaging and quality-assured resources to enrich her classroom experiences. Each of these personas, with their distinct objectives and challenges, shapes the diverse user base of The Laaab, illuminating the platform's potential to cater to a wide array of educational and professional needs.

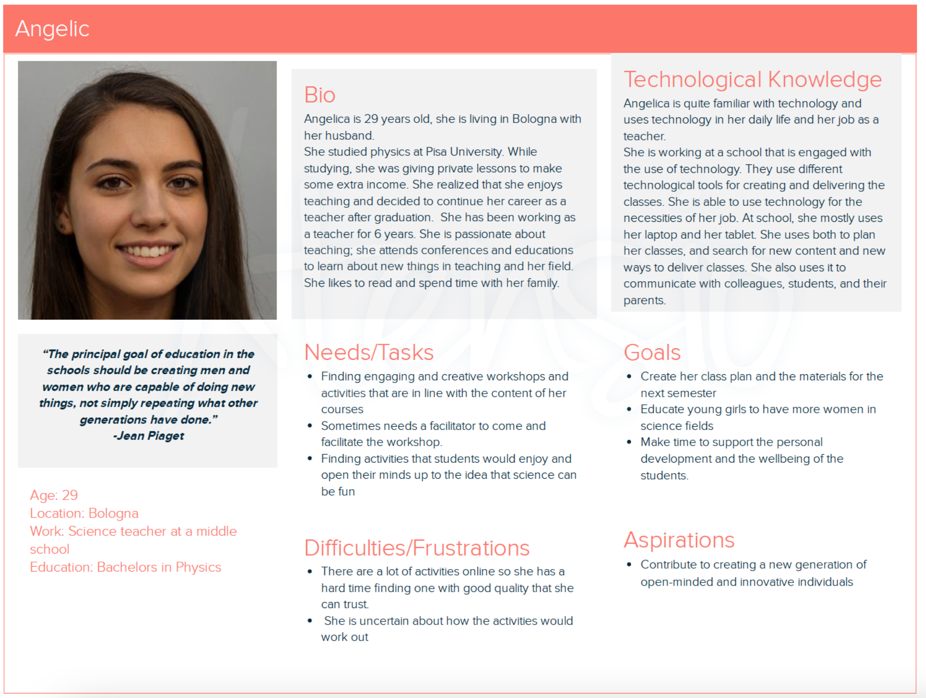


(a) Personas 1



(b) Personas 2

Figure 8.2. Personas



(c) Personas 3

Figure 8.2. Personas

8.3 Define

8.3.1 Concept

Final Moodboard The Laaab is envisioned as a platform primarily geared towards educational endeavours. Typically, educational content is experienced as useful, beneficial, albeit dreadfully dull. The main challenge was to craft a moodboard that could encapsulate both a "serious" and "playful" essence.

These characteristics were crucial in capturing teachers' interest, as they are slated to be the primary users of the platform. They are well aware that delivering monotonous learning materials to students, ranging from elementary school to university, often results in subpar learning outcomes.

Since we were developing a new-brand online platform, we specifically included in the moodboard logo, font, colors, illustrations, pictures, and some web-design elements.

8.3.2 Specification

Logo At the beginning, the whole brand identity development started from a sketchy logo. The main characteristics of a hypothetical desired logo were: 1) straight geometric lines, for conveying a transparent, friendly and professional feeling 2) black and white color, for keeping a simple and minimalistic look which could possibly suits in different contexts and surfaces, like wood, paper and fabric 3) thin outlines, because of the need of easily printing it with lasers, 3D printers and pyrographers.

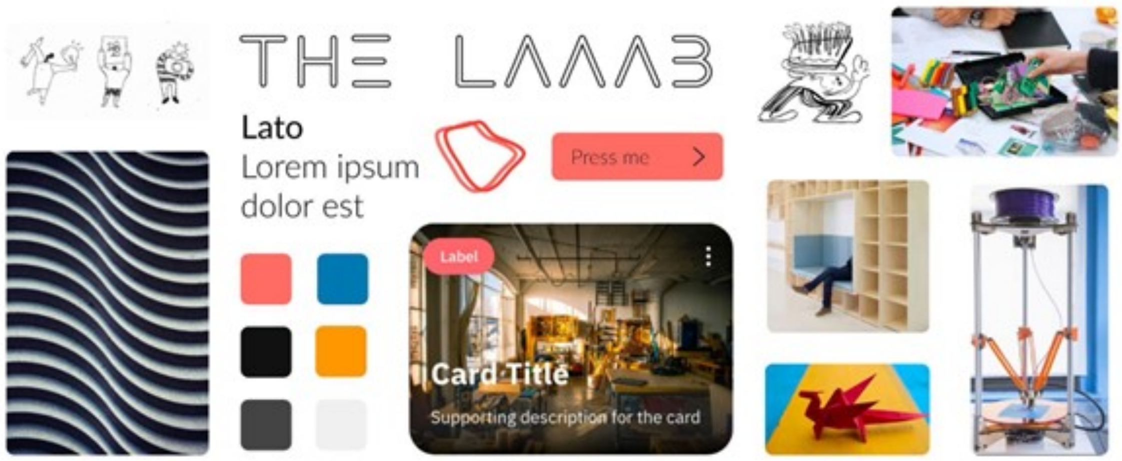


Figure 8.3. Moodboard

The final logo that could be similar to the sketchy one, except for the removal of the "constraints" conveyed by the outer box, plus the introduction of "more friendly" smooth curved lines.

(a) TheLaaab Logo Initial (b) TheLaaab Logo Final

Figure 8.4. TheLaaab Logo

Font Lato was the font we chose to adopt for the entire project. Lato is a humanist sans-serif typeface designed by Łukasz Dziedzic, a Polish designer, in 2010[4]. It was released as a Google Font in 2015. The name "Lato" is Polish for "summer", aligning with the general ethos of The Laaab platform: learning while having fun. Indeed, the semi-rounded details of Lato's letters evoke a sense of warmth, while the strong structure, evident in the stems of the letters, imparts stability and seriousness.

We opted for a single font because, according to Łukasz Dziedzic, the intention was to craft a typeface that would appear quite "transparent" when used in body text yet exhibit some original traits when displayed in larger sizes. These characteristics were perfect for the usage on various parts of the platform.

Colors The main color we adopted is PANTONE *Living Coral*, color of the year 2019. According to Pantone, it evokes people's innate need for optimism, social interactions and playful expression. Besides being the main color, Living Coral was assigned to workshop-related items on the platform.

The color palette was developed starting from a Living Coral based palette, proposed by Pantone, whose name is *Shimmering Sunset*. According to Pantone, this palette evokes the flashes of radiant colors that dot the sky at sunrise and sunset, suggesting energy, vitality, and warmth.

[4] https://fonts.google.com/specimen/Lato/about

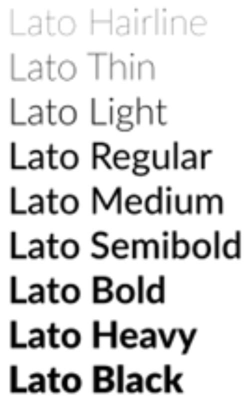


Figure 8.5. TheLaaab Font: Lato

The original palette, instead of the blue color, was composed of violet. We decided to replace that color with blue, which was assigned to institution-related items on the platform. Indeed, the blue color is often associated with calm, seriousness, trust and business. Finally, yellow (originally present on the palette) represents joy, hence it was assigned to events, as a signifier for the joy of being together.

Figure 8.6. Main Colour

Illustrations Illustrations are pivotal for The Laaab platform, as individuals tend to scan a web page rather than read it meticulously. Indeed, meaningful illustrations serve as effective tools that bolster the information conveyed in the text, delivering clear and universal messages readily grasped at a glance.

In accordance with the logo, we decided to employ a simple, black and white and hand-made illustrative style.


Figure 8.7. TheLaaab Illustrations

Pictures The main purpose of pictures which will be displayed on The Laaab platform is to provide an overview of each workshop. Pictures will be uploaded by the workshop's creators, so they do not have to follow a specific photographic style, but at least they should present clear and understandable content related to the workshop.

Figure 8.8. TheLaaab Protyping Workshop

Web design elements The moodboard encompasses also some web-design elements that we took as inspiration for developing the design system. Elements features will be described later on this document.

8.3.3 Ideate

Customer Journey — User Flow

The customer journey sheds light on how users navigate through the website to achieve a specific goal, and it provides insights into their emotions and potential pain points along the way. Drawing upon the three personas of the teacher, facilitator, and content creator, we identified their primary objectives.

The teacher persona In The Laaab, the login process is designed to align with user habits; however, feedback indicates dissatisfaction with the login process, leading to the assumption that our users may find this step tedious. To locate a workshop, a teacher would navigate to the workshops page and employ the filters to search for specific content or age groups.

Selecting a workshop is likely the most time-consuming action for the user due to the multitude of options available. Users may find themselves toggling between the workshops page and the detailed pages of individual workshops. Upon choosing a workshop, the user can view its details, see some facilitators who have previously conducted this workshop, and reach out to a facilitator. Post-workshop, the teacher has the option to review both the workshop and the facilitator.

The content creator The content creator aims to upload a workshop to share their knowledge and establish a reputable and recognized presence within the community. To publish a workshop, the content creator must first navigate through the login process. Once on the

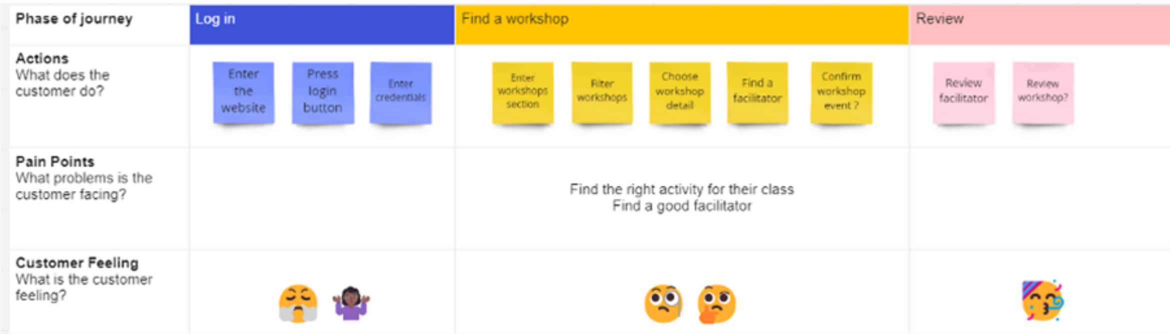


Figure 8.9. Teacher's Search for a Course-Aligned Workshop and a Suitable Facilitator

workshops page, the content creator will find a + button, providing the avenue to upload a workshop.

Given that The Laaab strives for quality guidelines for workshops, the content creator is required to provide detailed explanations for both the user version and the facilitator version. Although filling out an extensive form could be a tedious experience for the user, we aimed to simplify the process as much as possible. However, this step is crucial to ensure the provision of quality guidelines for workshops.

Figure 8.10. Content Creator's Objective of Uploading a Workshop

The Facilitator with the goal of finding a workshop The facilitator must login to access the facilitator guidelines of the workshops. To find a workshop, the facilitator would navigate to the workshops page and utilize the filters to search for content or age groups relevant to her expertise. Similar to the teacher, selecting a workshop would constitute the most time-consuming part of her journey on the platform.

Upon finding a suitable workshop, she would download the facilitator guidelines. Following the facilitation of the workshop (an aspect not directly handled through our website), she would have the opportunity to receive feedback via The Laaab.

Information Architecture

The information architecture was devised to organize the structure of the The Laaab website, prioritizing key aspects for emphasis and ease of access. Remaining elements were positioned

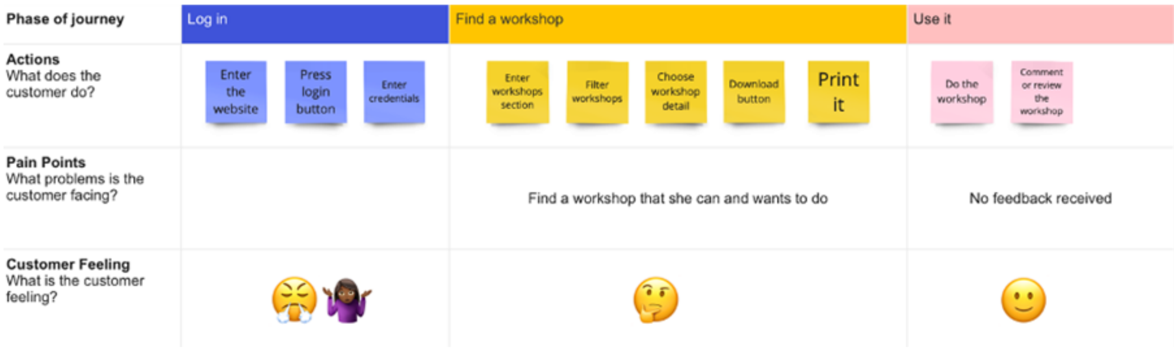


Figure 8.11. Facilitator that Aims to Find a Suitable Workshop

based on their relevance to core aspects and their significance. The homepage was crafted to convey the objective of The Laaab at first glance. Thus, it commences with a hero section that elucidates the aim via brief text, accompanied by a pertinent image or illustration. Following the hero section are categories of workshops, recent events, and an option to join the newsletter.

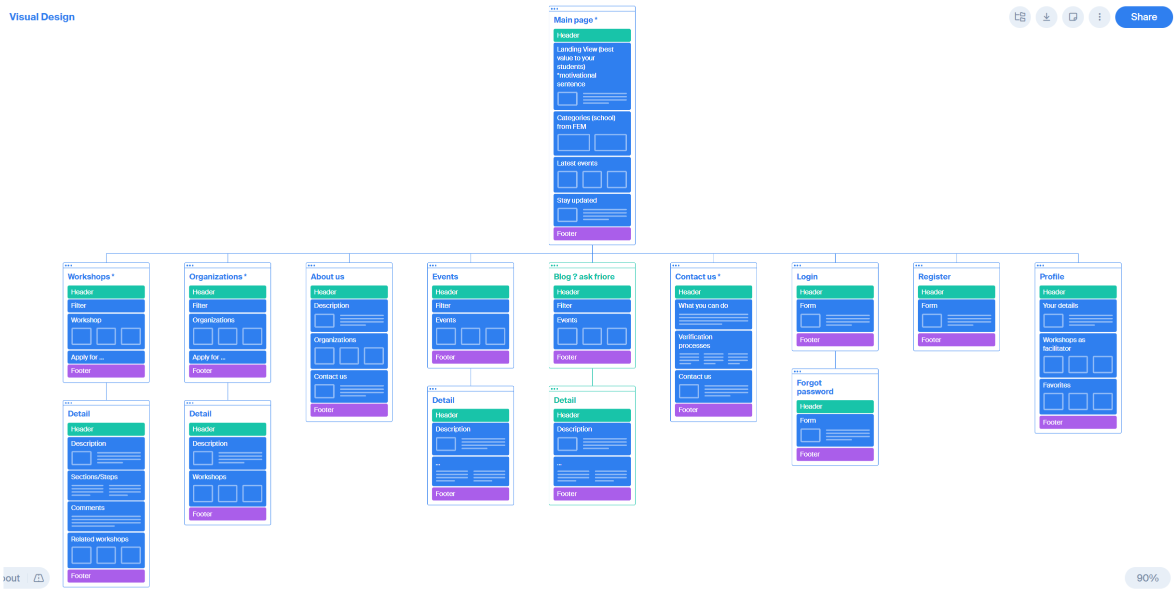


Figure 8.12. Information Architecture

The "Workshop" page was designed to feature cards of workshops, each displaying a brief description and a related image. Additionally, a filter section is included to help users search for workshops based on their needs. Upon selecting a workshop, users are directed to its page where they can access a detailed description, step-by-step explanations, comments from other users, and suggestions for related workshops.

The "Events" page is a public platform where users can view workshops offered by others and register for the ones that pique their interest. Mirroring the Workshops page, it features cards of events along with a filter option to narrow down choices based on users' preferences. Upon selecting an event, users are directed to its detailed page where they can find information about the topic, host, time, date, location, and a mechanism to subscribe to the event.

A major asset of The Laaab is its association with certified publishers from reputable institutions like universities and high schools. The Organizations page is crafted to underscore this quality. Here, users can browse cards representing all affiliated organizations, and upon selecting one, view its detailed page showcasing a description of the organization and the workshops it offers.

Additionally, a registration and login feature was integrated for users intending to publish content on the site. Post login, users can access a profile page displaying user details, published or facilitated workshops, and their favorite workshops.

Card Sorting

Card sorting is a UX research tool to understand how users organize the content in the website. After creating the site map, there was a need to test the structure of the sitemap to see how users would expect it to be and this was done with card sorting. 31 cards were chosen from the content of the website.

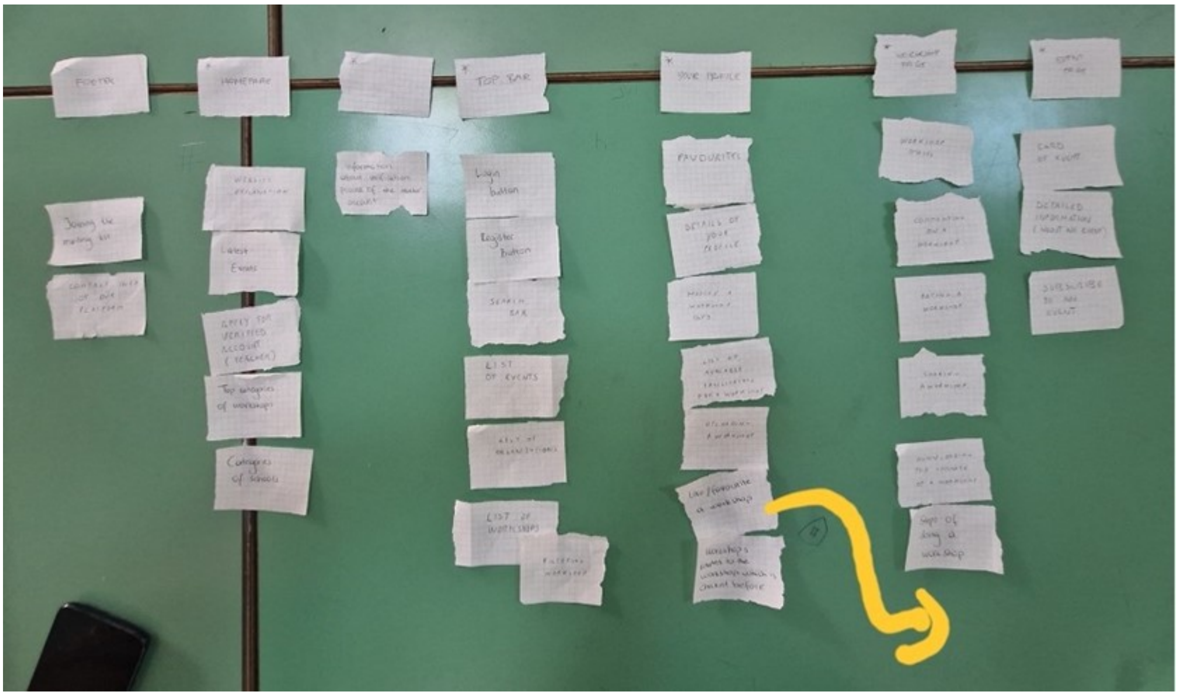


Figure 8.13. Card sorting

Cards with the page they were planned to be according to the team:

- **workshops**: list of workshops, applying for a verified account of a teacher, Home Page; latest events, top categories of workshops, joining the mailing list, login button, register button, categories of schools;
- **events**: list of events, detailed information about an event, cards of events, subscribing to an event;
- **workshop detail page**: steps of doing a workshop, workshops related to the workshop checked before, like/favorite a workshop, sharing a workshop, filtering workshop, commenting on a workshop, workshop images, modify a workshop information, downloading the template of a workshop, uploading a workshop, rating a workshop, list of facilitator available for a workshop ;

- **organizations**: list of organizations;
- **contact us**: website explanation, information about verification process of the teacher account, contact information of our platform (email address, social media);
- **profile page**: details of your profile, favorites;
- **search bar**.

Card sorting was performed on paper as opposed to digitally, as the tangible nature of paper was deemed to offer more flexibility for users to maneuver cards and alter decisions. The open card sorting method was employed, leaving the categorization and naming to the discretion of the participant.

The process commenced with a briefing on the method to the participant, clarifying that any uncertain cards could be set aside without forced grouping. Subsequently, the participant was handed the cards and tasked with categorizing and naming the groups.

Post card sorting, the participant elucidated her grouping rationale, affording the team deeper insight. During this debrief, it was noted that certain cards bore different meanings for the participant than intended by the team. Acknowledging her perspective proved beneficial in refining our information architecture.

While the outcome largely mirrored our initial sitemap arrangement, some disparities were noted and subsequently integrated into our sitemap, based on the insights gleaned from this exercise. The card sorting findings significantly informed the reorganization of the website's information architecture.

On the home page, akin to our initial setup, the participant grouped cards related to the website explanation, latest events, top workshop categories, top school categories, and applying for a verified account together. She also articulated that upon clicking "apply for a verified account", users would be directed to a page detailing the verification process. Initially, we envisioned housing this information on the "about us" page; however, post card sorting, we opted to align with the participant's approach. We transitioned the relevant information to a new "verification page", accessible via the "apply for a verified account" link.

The top bar is slated to feature login, register, and navigational links to workshops, events, and organizations. The workshop filtering option would be housed on a subsequent page, accessible after reaching the workshops section.

The profile page, as per our original design, would encapsulate profile details, created workshops, favorites, and options to amend created workshops. The participant suggested including workshops related to previously viewed ones on the profile page. Following a team discussion, we concurred that it would be more fitting to display such suggestions on the detailed pages of individual workshops, retaining our initial design in this aspect.

According to the participant, the workshop detail page would feature elements such as images, comments, ratings, share functionality, guideline downloads, steps, and like button, aligning with our original design.

Interestingly, the participant suggested placing contact information in the footer, negating the need for a dedicated contact us page.

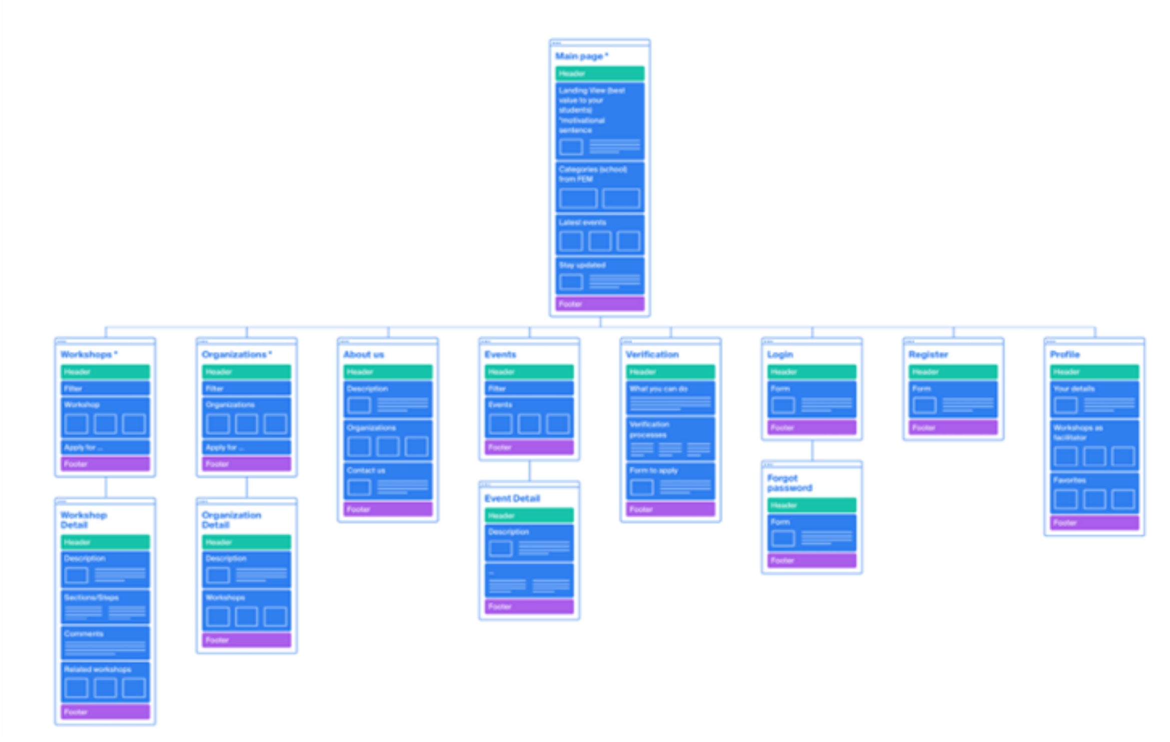


Figure 8.14. Information Architecture After Card Sorting

Wireframing

Drawing from insights obtained through customer journeys, card sorting, and the information architecture, we transitioned into the wireframe creation phase. Given the diverse design ideas within the team, initiating with paper wireframes proved to be a more flexible approach, facilitating easy modifications. Each team member crafted wireframes for four core pages: the home page, workshops page, organizations page, and contact us page.

The wireframing process commenced with a thorough understanding of the content and essential components for each page. Subsequently, we explored websites bearing a similar purpose or structural resemblance to ours, albeit serving different purposes, to glean inspiration and insights for our wireframe designs. Some of the websites that were inspected are: https://www.splacer.co, https://fem.digital, https://www.instructables.com, https://www.thingiverse.com, https://www.ehow.com, https://www.hackster.io/workshops,https://www.brickslab.it.

From the outset, The Laaab was conceptualized to cater to two primary user types: those seeking workshop inspiration for engaging others, and those with the capability to publish new content. The former, anticipated to be a larger user base, necessitated a website design that succinctly elucidated its objective and highlighted key actions right on the home page. While a brief explanation and illustrative depiction of the website's aim were pre-planned, to amplify this message, a "search for workshops" section was integrated into the home page. Additionally, to enable users immediate access to workshops, multiple navigational options leading to the workshops page were provided, replacing the initial category-based approach.

Figure 8.15. TheLaaab Design

Emphasizing the pivotal role of contributing organizations, a segment dedicated to showcasing these entities was also incorporated into the home page.

A desire for uniformity led to the decision of mirroring the structure of the organizations and workshops pages. Varied ideas surrounding the design and quantity of cards on these pages sparked discussions. Eventually, it was resolved that the cards would predominantly feature images along with brief information, and a total of 12 cards would be displayed on both pages.

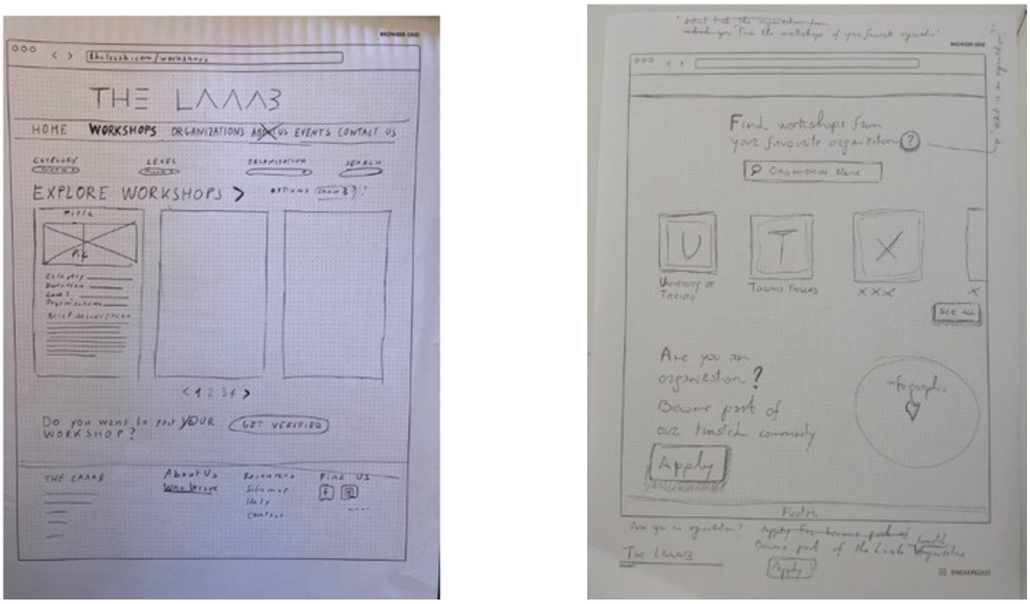


Figure 8.16. Wireframes

The initial design for the Contact Us page encompassed a contact form, an elucidation of The Laaab website's functionalities, and the publisher verification process. This layout was initially translated onto paper wireframes. However, post-card sorting insights, particularly the participant's inclination towards housing verification information on a separate page and placing contact information in the footer, prompted re-evaluations. This alignment with the participant's perspective led to the decision of omitting the Contact Us page altogether. Instead, a Contact Us section was integrated into the About Us page, and contact details were positioned in the footer, mirroring the participant's arrangement. Consequently, in the digital wireframes crafted on Adobe, the About Us page was developed in lieu of the erstwhile Contact Us page.

8.4 Design

We started working on our prototype by creating a sound design system.

8.4.1 Design System

Typography As previously mentioned, Lato was selected as our exclusive font due to its linear sans-serif nature, harmonizing impeccably with the logo. We established our default font size at `16px` (h7), equivalent to 1rem, and employed a Major Third scale (1.250) to derive six additional font sizes. The regular font weight was retained for all textual elements except for the two heading styles, which were set to bold. This preference for regular weight was driven by its neutrality and superior grapheme readability.

The bold styling for headings was adopted as it imbues a degree of expressiveness and effectively captures attention, aligning with the primary function of titles.

Layout Grid We adopted a 12-columns layout grid with an initial gutter of `64px` for better page organization, later modifying the gutter to `20px` post-presentation on professor's advice. The choice of 12 columns, divisible by 2, 3, 4, and 6, afforded flexible object placement. Instead of a vertical baseline rhythm, we set margins with a unit of 16px, utilizing its multiples as per page content requirements.

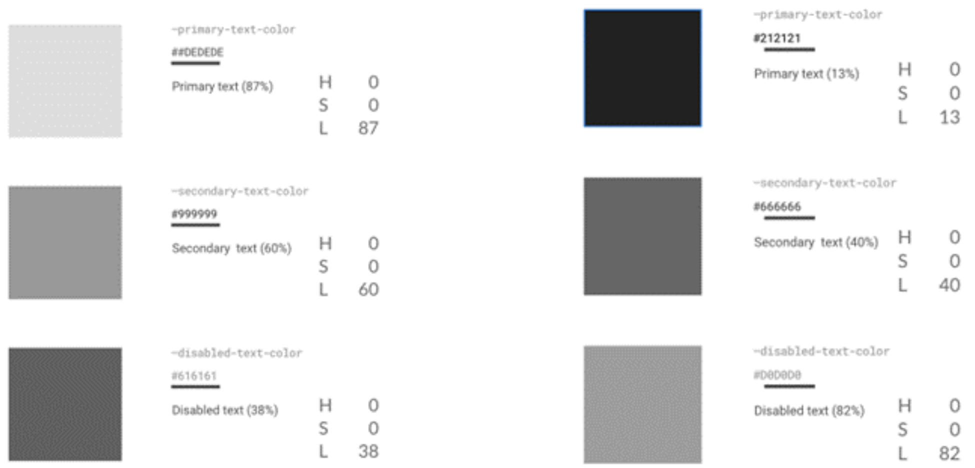
Color system We selected white as our background color for all pages. Since the aim of the website is to allow users to perform tasks in an easy and straightforward way, we chose white as it emphasizes clarity and removes visual obstacles and clutter. We opted, therefore, for a minimalistic design, and hues were added carefully to emphasize other important parts of the design.

We began with an adaptation of the *Shimmering Sunset Palette* by Pantone. We then added a darker and a lighter color for each of the three main colors.

Figure 8.17. TheLaaab Colour System

We utilized these colors for background shapes, buttons, and cards, according to the division of the content.

For “greys”, we selected six shades for text, background, and lines: two for the main text, two for the secondary text, and two for the deactivated text, with one of each pair to be used on lighter backgrounds and the other for darker backgrounds.



(a) (b)

Figure 8.18. TheLaaab Gray Scale

Header and footer The header was designed to be as simple and clean as possible: we therefore kept a white background and used only a dark color for text and contour. For consistency, we kept the same style of the header in the footer.

(a) TheLaaab Header

(b) TheLaaab Footer.

Figure 8.19. TheLaaab Header and Footer

Buttons We designed three types of buttons. All buttons have rounded angles to be consistent with all the design and visual elements that we inserted into the prototype. The primary buttons are those that occur the most and that are used by the user to perform a main task or to navigate into the website.

We used our main colors for the buttons and their darker version for the hover. Then we have filters which are placed in the selection bar of each page and their background matches the background color.

As a third type of button we have those with a white background and dark contour when in the hover state. These comprehend the "see all", "search", "see more", "apply" and "reply" buttons.

Cards Cards are visual elements that comprehend a picture and a text. We created three different cards for workshops, organizations and events using the page's color. These cards act as components and by clicking on them you are redirected either to the specific organization page or to the workshop page. We used them to create carousels on the home page.

Navigation The prototype navigation system is designed to be as easy as possible: we have the navigation bar with the logo acting as the "homepage" button, and all the other buttons redirecting the user to the corresponding page.

The Home page The home page presents a small description of the platform and an "explore" button that allows the user to be taken to the "workshops" page to start discovering workshops. Without scrolling down one can see the colored bar in which it is possible to set filters to find a workshop, so it instantly recognises that there must be content down.

Three carousels dominate the page, workshops, events and organizations respectively. The order is chosen according to a hierarchy of importance that sees workshop as the most important content of the page.

By interacting with the carousels one can be taken to either the specific workshop, event or organization pages if they click on one card or to the general pages if they click on the "see all" button. A form containing the possibility to subscribe to the website newsletter is put as the last element of the page, followed by the footer.

Workshops and Organizations pages Both the Workshop and Organizations pages are designed in the same way, with the only difference being the main color used (red shade and blue shade respectively). Upon accessing the page, the user is presented with a description of the page, the same filter bar present in the home page, and then a grid made of cards that are clickable.

By clicking on each card one is redirected directly to that card's specific page, whether it is an organization or a workshop detail page. There is the possibility to see more cards by clicking the "See All" button. The possibility of becoming a contributor is present in both pages: this allows a creator to publish their own workshop and an organization to become part of the platform's trusted community.

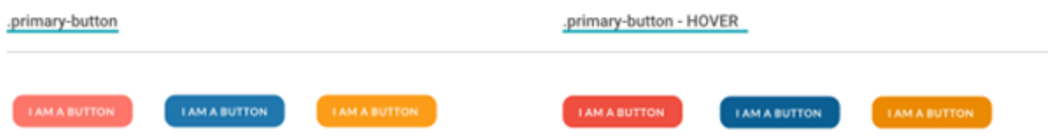


Figure 8.20. TheLaaab Buttons

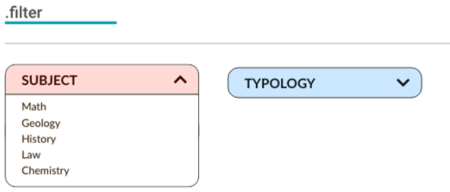


Figure 8.21. TheLaaab Filter

Figure 8.22. TheLaaab Buttons Search

Workshop Details page By clicking on one workshop card the user is redirected to the workshop detail page. In this page the user can see all the information regarding a workshop, see the list of supplies that are needed, share it, like it and most importantly download it.

In the page, after a brief description of the workshop, the steps that make up the workshop are presented. We also added a comment section and a "related workshop" section at the bottom of the page.

About Us page The about us page contains a description of the platform, a preview of some of the partner organizations and the possibility to get in touch with the managers of the platform.

User Interface and Mockup We briefly show the results of the two main mock-ups of our pages.

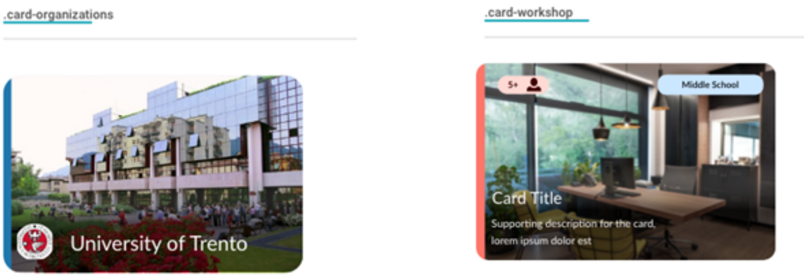


Figure 8.23. TheLaaab Cards

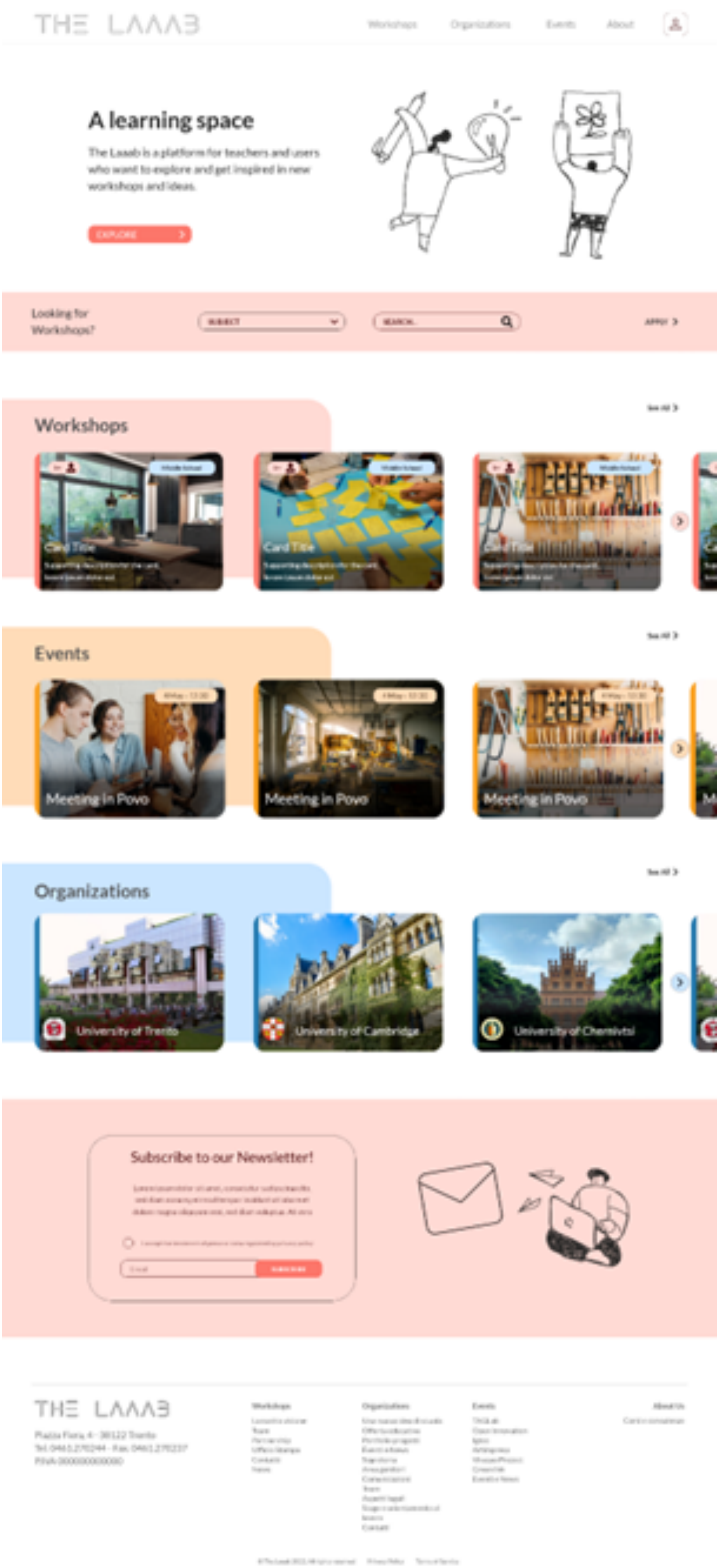


Figure 8.24. TheLaaab Home Page

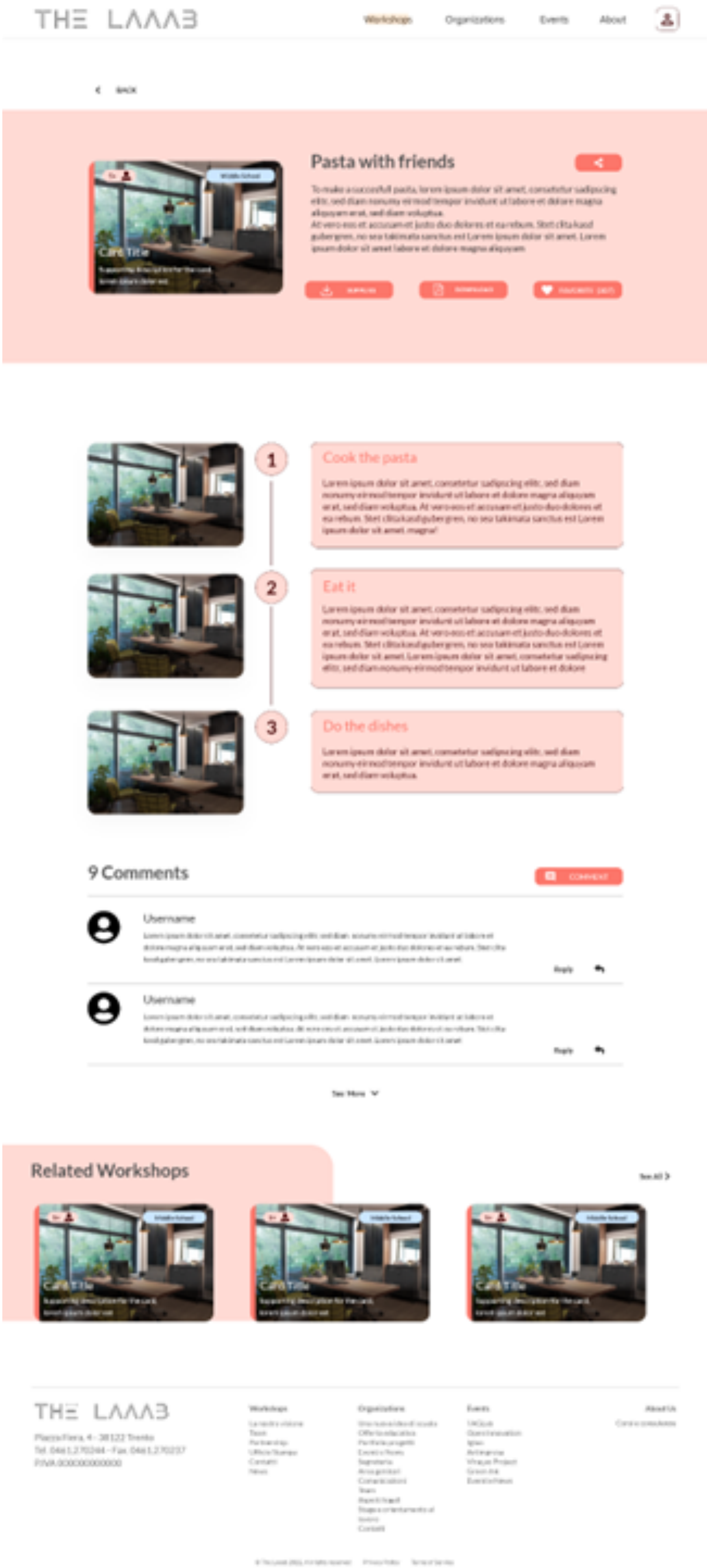


Figure 8.25. TheLaaab Workshop detail

8.4.2 Changes

We received constructive feedback following the presentation of the mock-up, prompting us to conduct a comprehensive review and enhancement of our design. Subsequently, we implemented several changes that have significantly refined the mock-up's presentation:

- we eliminated the use of blurred blobs positioned behind the landing text in the upper sections of each page. This step was taken to ensure a cohesive design aesthetic across all elements;
- we reverted oblique elements to a horizontal orientation, aligning them with the horizontal card layout to enhance overall visual harmony;
- to address concerns about excessive white space, we carefully decreased some of the margins in the upper portions of each page;
- in pursuit of a harmonized visual language, we replaced certain secondary buttons with either tertiary or primary buttons. This adjustment unified button interactions by adhering to the platform's defined "colors" and "outlined" styles;
- acting upon feedback, we resize the column gutter from 64 to 20 pixels. While this necessitated adjustments to various page elements given their reliance on the previous column width, some elements no longer rigidly adhere to the column alignment. This deviation was purposeful and introduced a more balanced composition, as advised by the designer's feedback to allow for instances where elements "break the column layout". Margins were introduced strategically to ensure a visually pleasing and well-spaced arrangement. This modification notably enhanced the spacing between cards, affording them a more visually breathable environment.

These changes collectively signify our commitment to iterative design refinement, driven by insightful criticism and aimed at delivering a more coherent, user-centric, and visually pleasing experience.

8.5 Features

The platform is planned to include a wide range of features to meet the needs of teachers and professors, listed below.

Management for organizations Teachers and professors can create and manage organizations within the platform, making it easy to share and collaborate on content (not available in the Alpha version). An organization, like a university, can have content published from many teachers that are part of it. Once an organization is created, users may be added to it by the creator, making it easier for users to find resources by having unique official sources for workshops. Organizations may apply from a form opened from the bottom part of the "organizations" page.

Events The platform includes a special section for events (not available in the Alpha version). These may be public events, organized and hosted by organizations, and private events, that

Figure 8.26. Organization Section

require a registration process for users that want to take part in them. Events may be a way for universities to promote their workshops and make people connect in a growing context. They appear and can be searched from the "Events" page.

Workshops, activities, and lessons The platform provides a simple way for teachers and professors to create and share educational content. Workshops are the main focus and an integral part of The Laaab. They provide all the necessary information divided in specific tasks. Tasks can be described textually or visually through images.

In addition, every workshop specifies many other details like:

- tools, materials, softwares used, and so on;
- educational objectives and required skills;
- number of suggested participants;
- time needed for preparation and execution.

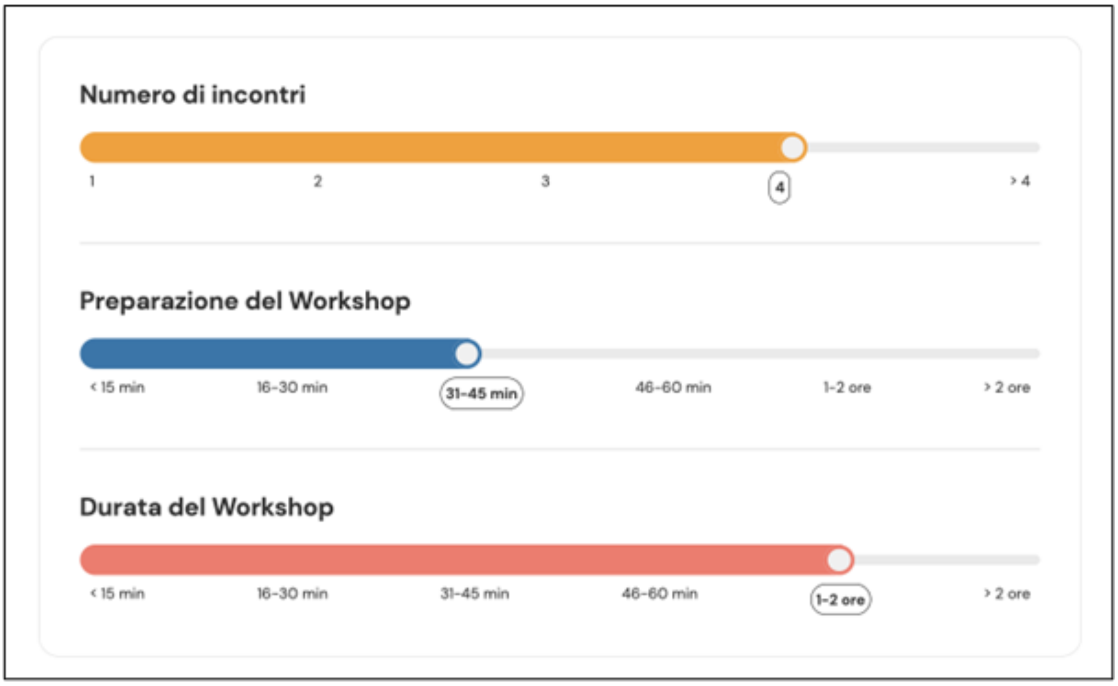


Figure 8.27. Workshop Details

Each user can create workshops for the organizations that it is part of, just by providing all the details on how to execute a workshop. They will appear in the home page and the workshops page.

Workshops will, in the future, be also categorized by subject: it will provide an even easier way for users to find the searched educational content.

8.6 Development

The platform was developed using several different technologies, including:

- **NextJS**: a framework for building web applications with React;
- **DaisyUI**: a UI library for React, providing a set of pre-built components for use in the platform;
- **Firebase**: a backend as a service platform, allowing for easy integration of database, authentication and hosting functionality.

Such combinations was choosen for several reasons. First, NextJS is a powerful framework for building web applications with React. It offers many features and optimizations that can improve performance, SEO, and development experience. For example, NextJS provides server-side rendering out of the box, which can improve page load times and SEO by serving a pre-rendered version of the page to users. It also supports automatic code splitting, which can help reduce the initial load time of a page by only loading the code that is needed. Additionally, NextJS includes built-in optimizations, such as automatic image optimization, that can improve performance without requiring extra work from developers.

Second, DaisyUI is a UI library for React that provides pre-built components and styles that can be used to create a consistent and visually appealing user interface quickly and easily. By providing pre-built components and styles, DaisyUI can help ensure that the user interface is consistent and follows best practices. Using pre-built components can also save development time and reduce the likelihood of errors. Furthermore, DaisyUI is highly customizable, allowing developers to modify the styles to match their specific needs and branding.

Finally, Firebase is a backend as a service platform that provides a range of features, including authentication, real-time database, cloud storage, and hosting. Firebase is designed to be easily integrated with front-end frameworks like React and provides SDKs for a range of platforms. Firebase's real-time database allows for real-time synchronization between clients, making it easy to build collaborative applications. Firebase also provides built-in authentication functionality, allowing developers to quickly add login and sign-up functionality to their application without having to implement their own backend. Additionally, Firebase provides hosting functionality, allowing developers to easily deploy their application to a scalable and secure cloud infrastructure.

In summary, The Laaab has chosen to use NextJS, DaisyUI, and Firebase for their platform because of the many features and benefits that these technologies provide, including improved performance, development experience, user interface consistency, real-time collaboration, and scalability.

8.7 User testing

8.7.1 Validation Day

Ensuring the usability and effectiveness of the The Laaab platform was of paramount importance. To this end, a comprehensive testing phase was undertaken, involving experts from the U-FAB network, a consortium of academic FabLabs from across Italy. The participation of 17 members from this network provided a diverse and representative sample to evaluate the platform's functionality and user experience.

A validation day was meticulously planned to evaluate the platform's workshop creation process. Drawing upon the collective expertise of FabLab practitioners from the U-FAB network, the validation day aimed to ascertain the platform's viability in real-world usage scenarios. The participants were guided through two core tasks: creating user accounts and designing workshops. The key focus areas were the intuitiveness of these processes, the platform's responsiveness, and its overall user-friendliness.

The diverse range of FabLab experts assembled for the validation day was instrumental in assessing the platform's robustness across various contexts and user perspectives. Each participant engaged in the tasks with minimal guidance, simulating real-world usage scenarios. The absence of detailed instructions aimed to mimic the scenario where new users approach the platform without prior knowledge, thus reflecting its ease of adoption.

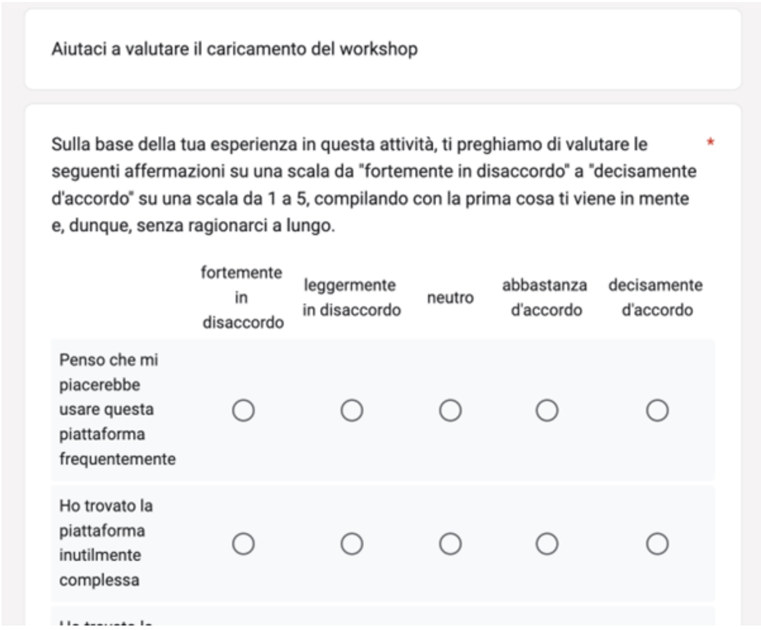
Throughout the validation day, one designated member of the team was available to aid users encountering difficulties. This support system was established to gauge the platform's self-sufficiency and identify areas of improvement where users encountered hurdles. The feedback and observations collected during this process were crucial in refining the platform and addressing user pain points.

As anticipated, the validation day revealed both external challenges and platform-related issues. Certain technical hurdles arose due to external factors, while others were identified as genuine bugs within the platform. These insights were invaluable in streamlining the user experience and bolstering the platform's reliability.

The validation day conducted with the participation of U-FAB network members was a pivotal step in ensuring the user-centric design and functionality of the The Laaab platform. The engagement of experts from the academic FabLab community provided an authentic testing environment, illuminating strengths and areas of improvement. This collaborative effort between academia and practical application underscores the significance of user-driven design and its potential to shape effective technological solutions.

8.8 Questionnaire & Results

A questionnaire was prepared to ask specific questions about the platform itself, the idea behind it and the usage of it. A Google Form page was prepared (only in italian) as it can seen in Figure 8.28.



Aiutaci a valutare il caricamento del workshop

Sulla base della tua esperienza in questa attività, ti preghiamo di valutare le seguenti affermazioni su una scala da "fortemente in disaccordo" a "decisamente d'accordo" su una scala da 1 a 5, compilando con la prima cosa ti viene in mente e, dunque, senza ragionarci a lungo. *

	fortemente in disaccordo	leggermente in disaccordo	neutro	abbastanza d'accordo	decisamente d'accordo
Penso che mi piacerebbe usare questa piattaforma frequentemente	○	○	○	○	○
Ho trovato la piattaforma inutilmente complessa	○	○	○	○	○

Figure 8.28. User Feedbacks

Users were instructed with the following initial line: “Based on your experience in this activity, please rate the following statements on a scale from ‘strongly disagree’ to ‘strongly agree,’ on a scale from 1 a 5, filling in with the first thing that comes to mind and without giving it too much thought.”

A total of 17 answers were collected.

8.9 Insights from Expert Validation: Shaping Platform Features and User Experience

We acknowledge that a single day of testing may not be sufficient to fully assess a platform’s capabilities and user experience. Indeed, the development of the The Laaab platform will be an integral part of future studies and enhancements. Nevertheless, the expert participants from the U-FAB network provided invaluable insights into the usability and potential improvements of the The Laaab platform following the validation day. Analysis of their feedback and observations unearthed several key themes that shed light on user perceptions, preferences, and recommendations.

Ease of Use and Value Proposition The consensus among the expert participants was that the platform exhibited a high degree of user-friendliness. The intuitive nature of the workshop creation process was highlighted, indicating that users could readily navigate the platform's features and functionalities. Furthermore, the fundamental concept underlying the platform was regarded as exceptionally beneficial, reaffirming the value it brings to the FabLab community.

Workshop Categories and Enriched Interaction A prevalent suggestion from the expert participants was to introduce a categorization system for workshops. This enhancement was seen as a means to streamline workshop discovery and enhance user engagement by allowing individuals to locate content relevant to their interests more efficiently. Moreover, the potential for further developing features that encourage sharing and interaction among workshops garnered significant attention. This aligns with the participants' recognition of the collaborative essence inherent in FabLab culture.

Frequency of Use and Incentives It was observed that while the platform was well-received, there were reservations regarding its frequency of use. Some participants expressed the belief that the platform might not be utilized as extensively as intended. Considering this observation, the experts suggested introducing incentives or reasons that motivate users to regularly engage with the platform. This recommendation underlines the significance of embedding features that encourage ongoing participation.

Educational Resources and Tutorials Experts underscored the importance of including educational resources and tutorials within the platform. While the workshop creation process was deemed intuitive, the consensus was that supplementary guidance in the form of tutorials and informative content could further empower users to make the most of the platform's capabilities.

The insights gleaned from the validation day bear testament to the invaluable role that user input plays in refining and optimizing the The Laaab platform. The convergence of expertise from the U-FAB network experts served as a litmus test, confirming the platform's strengths and illuminating areas ripe for improvement. The collaborative interplay between academic theory and practical application is showcased by the resonance between the expert observations and the platform's trajectory.

In essence, the observations from the validation day offer a road map for fine-tuning the The Laaab platform to better serve the FabLab community. These insights not only validate the platform's current direction but also offer a springboard for its continued evolution.

8.10 Future Developments and Conclusions

As the digital landscape continues to evolve, The Laaab platform is poised for dynamic growth, driven by emerging technologies and evolving user needs. One exciting avenue for future development lies in harnessing the power of machine learning and artificial intelligence algorithms to elevate the platform's recommendation system. By analyzing user behaviours and preferences, these algorithms can offer personalized and pertinent suggestions for workshops and educational materials. This advancement could leverage data from user interactions, feedback, as well as external sources like social media and search histories.

Furthermore, The Laaab envisions incorporating virtual and augmented reality technologies to amplify the user experience, immersing learners in interactive workshops and simulations. This would facilitate exploration of novel concepts in a captivating and lasting manner. Executing these enhancements mandates a collaborative and agile development approach, characterized by ongoing iteration and refinement. An adept team of developers and designers, fervently dedicated to education, will be essential. Importantly, ongoing user feedback integration will ensure that the platform remains aligned with users' evolving requirements.

With an unwavering commitment to innovation and user-centric design, The Laaab is poised to ascend as a preeminent platform for educational content and workshops, poised to reshape the educational landscape.

The development of The Laaab education platform aimed to furnish educators with a seamless, efficacious tool to craft and share educational content. Drawing inspiration from platforms like Instructables, The Laaab boasts a user-friendly interface, organizational management features, University Workshops, and a diverse array of educational content. Through meticulous planning, design, and implementation, the platform underwent testing, receiving positive feedback from potential users who recognized its potential as a transformative tool for educators.

To forge ahead, The Laaab must accentuate interactions while preserving its current user-friendly essence. This entails a deeper commitment to refinement and evolution. With an ever-present focus on simplicity and user satisfaction, The Laaab is poised to evolve into an indispensable resource for educators seeking innovative ways to disseminate educational content.

9 Conclusions

Embarking on this journey, we delved into foundational literature, exploring the evolution from 21st-century skills to the maker and tinkering worlds and their integration into education. Moving from theory to practice, we started with an explorative study to gauge youth perceptions in our region. This process spurred the creation of a holistic framework, extending beyond traditional STEAM confines, gravitating towards an expansive pedagogical outlook.

While academic research often brings a mix of successes and learning opportunities, our three-year expedition has been transformative. As a team, we have expanded our horizons, engaging with diverse individuals, fostering communities of practice, and even orchestrating innovative initiatives like the pink ApeLab outreach. This dynamic exploration has further catalyzed comprehensive and interdisciplinary discussions within the education sector.

Given the breadth of our investigations, offering a monolithic conclusion would be reductive. This final chapter then seeks to weave together the threads of inquiry laid out at the beginning of this exploration.

In this research work, we have undertaken a thorough examination of various activities that, not only corroborate established notions found within the literature (Chapter 2), but also aim to fortify them. From a methodological standpoint, our work reinforces pedagogical principles (Chapter 4) and highlights the advantageous outcomes of implementing innovative educational activities.

The substantive contribution of this dissertation lies in its "integrated" approach — melding the domains of academia and the third sector, capitalizing on the strengths of each, and, crucially, uniting realms that traditionally seldom intersect.

Our intent to foster cross-disciplinary contamination stands at the forefront of this endeavor. By bridging the gap between researchers across diverse fields and between academia and the broader world — often distant from conventional dissemination channels — we propose a model that holds the potential for significant, far-reaching benefits. This model, characterized by its inclusivity and its ability to engage with citizens typically remote from academic outreach, represents a paradigm that we believe can yield fruitful and impactful educational advancements.

We embarked on a journey through three interconnected areas: educational models and methodologies, the extension of university missions beyond traditional borders, and the measurement of impact. Each area addressed a critical aspect of the evolution and effectiveness of university FabLabs. This synthesis not only revisits our original research questions (RQs) (Section 2.5.1) but also presents the conclusions and contributions to the field, encapsulating the findings in the broader context of educational innovation and societal impact.

Our initial reaserch questions were:

Educational Models and Methodologies

> **RQ1**: *What are the types of educational processes embedded in the design of a university FabLabs and its activities?*

Extending University Education Beyond its Walls

> **RQ2a**: *How can we transfer outside the formal and institutional barrier the educational model and knowledge produced in our university labs?*
>
> **RQ2b**: *What are the educational methodologies and approaches that are best suited for integrating activities inside and outside a university?*

Measuring Impact

> **RQ3**: *How do we measure the impact of our activities?*

In the following subsections we present more insights about our findings.

9.1 Educational models and methodologies

At the heart of our first inquiry (RQ1) was the aim to understand the educational processes within university FabLabs. Our research demonstrated that FabLabs are more than mere spaces for technical creativity; they are breeding grounds for 21st-century skills, fostering innovative thinking and adaptability. Our findings, which are mainly described in the architecture we designed for our environment (discussed in Chapter 4) and in its implementation towards our students (presented in Chapter 5, revealed that FabLabs:

1. Enhance learning through hands-on experiences that deepen existing academic skills and knowledge.
2. Propel invention and design through accelerated creative cycles that prompt students to become not just consumers but creators.
3. Foster collaborative learning environments where long-term projects encourage peer-to-peer learning and collective problem-solving.

In addition to these three foundational aspects, a necessity for a plurality of competences has emerged. This encompasses both technical and non-technical skill sets, along with some reflections on such methodologies.

9.1.1 Integrating the non-technical

This dissertation proposes that the integration of non-technical aspects into the computing curriculum is not merely an innovative idea but a fundamental necessity–a sentiment echoed by a symphony of voices ranging from individual scholars [54] to comprehensive educational frameworks [4, 55, 128]. Our inquiry corroborates this narrative, shining a light on the oft-neglected humanistic facets within STEAM education. Through a deliberate reconceptualization of non-technical elements, we aim to foster a STEAM paradigm imbued with a deeply human-centric ethos. The 2020 pandemic served as an unforeseen catalyst in this regard, highlighting the shortcomings of purely top-down educational methodologies and underscoring the importance of grassroots, inclusive approaches that consider the multifaceted nature of our societal challenges.

In transitioning away from the rigid structures of traditional engineering education, we champion a move towards a fluid, interdisciplinary paradigm that gracefully melds the quantitative rigors of engineering with the qualitative insights of social sciences. This blend not only amplifies the potential for innovation but also enriches the educational tapestry with a diversity of perspectives and methods that respect the complexity of human needs and the societal roles of technology.

Within the scope of our work, the embracement of this interdisciplinary approach has proven to be profoundly beneficial, particularly as documented in Chapter 5 and Chapter 6, which detail the student-centric and school-focused activities we have undertaken. It has become increasingly clear that when education transcends the purely technical and positions the individual at the forefront–with their amalgam of skills, passions, aspirations, and insecurities–a richer and more nuanced educational experience unfolds. Our conviction is firm in the principle that every individual's unique contributions are invaluable. The varied experiences and perspectives of all those who have engaged with our Fablab have not only enriched the learning environment, but also challenged and redefined established educational dynamics. Our Fablab is conceptualized not just as a confluence of high-tech tools and machinery but as a vibrant hub where resources are fundamentally human-centric—where individuals are empowered to share their expertise and perspectives, thus creating a collaborative ecosystem that values diversity and fosters innovation.

Technology and tools are increasingly seen not merely as functional for other activities, but as essential enablers for achieving one's goals. Gaining proficiency in these techniques and resources empowers individuals, leading to their autonomy. The learning process, characterized by its trials and triumphs, is further enriched by the act of constructing and creating. The opportunity to showcase one's work to others not only fosters a sense of accomplishment but also cements the individual's place within a community.

9.1.2 Methodological insights

The concept of replicability of the UniTrento FabLab model poses a pivotal question within our investigation–one that bears significant implications for the expansion of the constructionist community. Acknowledging that our lab is not an isolated venture but part of a broader narrative of constructionist spaces within academic settings, we face challenges that are likely familiar to similar initiatives [227]. It is our conviction that these shared experiences warrant a rigorous literary debate [110]. Our reflective analysis of the FabLab's foundational model and methodologies has naturally led to contemplation on the factors that underpin its replicability. It becomes clear that the replicable nature of our success is not merely a byproduct of the originating founders' dynamism and passion [199].

This introspection is essential in determining which elements can be emulated across different contexts, to not only replicate, but also to sustain the vibrant spirit that is the hallmark of our constructionist laboratory. Drawing from our extensive experiences within and beyond the academic setting (Chapter 5, Chapter 6, Chapter 7), and informed by the pertinent literature (Chapter 2), we are poised to emphasize a specific list of key points that warrant particular attention.

Some aspects are linked to Section 4.4; however, their integrated approach in this manner represents a novel development.

- **Fostering Exploration:** To stimulate an explorative mindset, educators and facilitators must create environments where individuals are free to play and explore. This is now extended to teachers, who, with their strong connections to students, can more readily identify and support shifts in mindset.
- **Personalized Meaningful Making:** Central to our philosophy is the powerful role of making — an act of creation that goes beyond mere demonstration to actively share one's work with the public. This process is intrinsically tied to the social dynamics of knowledge production and serves to empower the creators. Importantly, the notion of "meaningful" is deeply personal; it resonates with what is subjectively significant to each individual. In our lab, participants are encouraged to embark on projects that stem from their personal experiences and individual tastes. By fostering a space where personal narratives and preferences guide the creative process, we facilitate a form of making that is intimately meaningful to each creator.
- **The Act of Play and Skill Acquisition:** Encouraging play as a revolutionary act is instrumental in fostering a lifelong passion for exploration and learning within STEAM fields. It is through play that individuals find joy and agency, which in turn nurtures confidence and cultivates cultural relevancy. This enhanced connection to their work allows creators to reflect their identity, culture, and aspirations in what they produce. Moreover, play is a valuable medium through which individuals can develop new skills, bolster collaboration, and forge meaningful relationships. The notion of "hard fun" [214], which introduces challenges within the play, promotes agency and fosters a contextual understanding that is critical for both personal and professional growth.
- **Cultivating Spaces for Freedom, Opportunity, and Community Building:** Our ambition is to cultivate environments that promote the freedom to take part in playful discovery and to learn from a spectrum of experiences, ranging from successes to setbacks,

thereby enriching both individual and collective narratives. These environments act as harbors where individuals can find their “tribe”, places where a sense of belonging and collaborative growth are of utmost importance. Here, community building is a deliberate process, transforming personal journeys into empowering stories for others and providing a canvas for personal identity to flourish. Particularly, we engage individuals with technical backgrounds, who may lean towards introversion and for whom social interaction is not an innate strength. These environments not only acknowledge their technical skills but also elevate them, allowing their expertise to become a conduit for connection. It is within these nurturing spaces that they find peers with different competencies and backgrounds, yet with similar interests, fostering bonds with individuals they might never have encountered in other settings. The commonality of shared passions acts as a bridge, uniting diverse minds and catalyzing unlikely alliances. This creates a dynamic and supportive community, where the richness of diversity in expertise and experience is the cornerstone of strong, meaningful relationships.

- **Equipping, Connecting, and Supporting with Room for Experimentation:** Central to our ethos is arming individuals with the tools and knowledge that are not only reusable but also instrumental in bridging the divide between academic and non-academic worlds, thereby nurturing individuality in a supportive community setting. We provide a structured, yet flexible, environment that is rich with guidance and bolstered by support, allowing for the liberty and resources necessary for individuals to pursue their goals and address challenges. Integral to this environment is the freedom to act and to make mistakes; our spaces are deliberately designed to accommodate errors, both in economic and temporal terms. We believe that it is through making and learning from mistakes that one can advance and garner knowledge, and thus, it is essential to have the space and time to engage in this process. In parallel with fostering this freedom, we also emphasize the importance of responsibility among our participants. By encouraging them to view the space as partly their own, we inspire them to treat it with the same care and accountability they would apply to their personal belongings. This approach not only promotes a sense of ownership but also instills a mindset of stewardship towards the communal resources and environment.

- **Collective Action, Vulnerability, and Safe Environments:** The act of collective creation inherently invites vulnerability, as it involves exposing ideas and work to others. The methods employed in managing conflicts and the perception of feedback are pivotal in cultivating trust within the community. Creating a secure environment and promptly addressing these dynamics is crucial to ensuring a relaxed atmosphere within the laboratory. It is within such a space that individuals feel safe to share, experiment, and innovate without fear of undue criticism or conflict.

9.2 Redefining and extending the Third Mission

The concept of the Third Mission in academia is traditionally characterized by a university's commitment to engage with and contribute to the socio-economic fabric of its surrounding context. This engagement is traditionally manifested through the enhancement and transfer of knowledge [14]. Initially, our interpretation of this mission was ambitious but somewhat conventional: we aimed to extend the reach of our academic knowledge beyond the confines of the university. The intention was to disseminate information, to unveil the often-hidden wonders of science, and to ignite curiosity. Science, which is frequently perceived as distant and esoteric, was to be rendered more approachable and engaging, particularly to younger minds. Our ambition was to devise educational models that, rather than sensationalizing science, would encourage a deeper and more personal exploration of its realms.

As our endeavors progressed, however, a transformation in our understanding of the Third Mission unfolded. This evolution in perspective unveiled a more dynamic and reciprocal conception: one that not only disseminates knowledge but also actively engages in the co-production of innovation and understanding, thus supporting sustainable development [53]. Collaboration activities under this new vision enhance reciprocal learning processes, bringing to light the mutual nature of knowledge exchange.

It became evident that explicating the substance of the Third Mission is essential to highlight this bidirectional exchange. In this revised paradigm, the Third Mission is re-imagined as a conduit for shared innovation, where universities and external entities engage in a symbiotic relationship of knowledge co-creation. This bidirectional dimension places the new concept of the Third Mission squarely within the framework of an "engaged university". Moreover, alternative terminologies to the "Third Mission" have been contemplated and also reported in the latest Italian university summit about Third Mission [94], such as "Collaboration with Society", "Engagement with the Local Context/Territory" and "Social Participation". These terms imply a specific stance of the universities towards engaging other actors. Strategic planning is now centered around continuous dialogue within a reciprocal context; the term "collaboration" suggests an active and joint effort in this dialogue. The preposition "with" emphasizes the two-way interaction and the collaborative nature of these relationships. "Society" and "Context/Territory" encapsulate the collective of actors within the local environment. Through this lens, the university is not merely an isolated beacon of knowledge but a participatory member of a larger community, committed to nurturing an ecosystem where mutual growth is paramount.

In transitioning from our initial vision to this more nuanced approach, we have come to appreciate the Third Mission not as a unidirectional outreach but as a rich tapestry of interwoven initiatives that foster a deeper connection between the academic sphere and the broader societal fabric.

Our efforts to demystify and disseminate scientific knowledge, as can be seen specifically in Chapter 7, have shown promise in sparking curiosity and a desire for deeper understanding among broader audiences, particularly the youth. The Third Mission (RQ2a and RQ2b) of our research has been a clarion call for the expansion of university education beyond the traditional confines of academia, heralding a vision where education is a continuous, inclusive journey that reaches into the very heart of the community, and that should be co-created. This engagement transcends mere outreach, fostering a learning continuum that bridges academic knowledge with societal growth, defying both physical and social boundaries.

To achieve these ambitious objectives, we have mobilized an array of initiatives to deeply permeate the community fabric:

1. Initiating inclusive and innovative projects that meld university expertise with the vibrant needs and interests of the local milieu, we aimed for an organic integration that underpins both academic and communal development.
2. Delivering educational experiences that are not only accessible but deeply engaging and relevant to everyday life, we nurtured a culture of lifelong learning—explored in greater detail in Chapter 7.
3. Bridging theory and practice, our work with local schools became a touchstone for students to grasp the material's relevance to the wider world, as outlined in Chapter 6.
4. We have reimagined community activities to be more digestible and enthralling, with initiatives like "Apelab" and the mountain cabin "Fontana dei Gai", serving as testaments to our commitment to make complex ideas engaging and accessible, as can been seen in Chapter 7.
5. In a pivotal move, our collaboration with Glow, a non-profit organization, has extended our educational impact significantly, fostering dialogue between academia and the community at large.

9.2.1 Our model in the context of the expanded third mission

Embracing the expanded Third Mission, our model seeks to foster a dynamic ecosystem where academia and society converge through meaningful engagement and collaboration. This involves cultivating a community culture that cherishes unity and shared values while also recognizing and honoring the diversity of backgrounds, disciplines, and skills present within our community [199]. Our community extends beyond the immediate boundaries of the FabLab, encompassing dedicated staff, students actively involved in the lab, alumni who have transitioned to educators, professionals at Glow, and participants from associated external organizations. Creating channels for effective communication and collaboration is vital in nurturing this environment, one where transparency, trust, and mutual respect are paramount [124]. Through regular community events, workshops, and mentorship programs, we facilitate rich interaction, knowledge exchange, and skill enhancement among all members [234, 132]. Celebrating individual and collective achievements is a practice we uphold to strengthen the community's cohesion and the individuals' commitment to the collective vision [9].

In parallel to these internal initiatives, we recognize the indispensable role of external organizations in amplifying our impact and extending our educational outreach. The dual-model approach we have adopted allows us to forge and nurture relationships with a diverse range of partners. These include the foundational association with Glow, formed from within the university, and a vibrant network of collaborations with specialized entities across various sectors and regions. This boundary-spanning strategy is critical for mobilizing stakeholders, integrating resources, and cultivating a unified, powerful network [7, 226].

Maintaining the economic sustainability of these partnerships is of utmost importance for their longevity and success. A clear understanding and alignment of financial models, responsibilities, and revenue strategies between the FabLab and its partners is essential. This financial synergy ensures that these collaborations are maintained on stable and sustainable grounds. The resulting ecosystem is one where each entity, including the university, benefits from shared cooperation, aligned goals, and mutual growth.

By integrating this model with the Third Mission's principles of reciprocal engagement and shared innovation, we reinforce the university's role not just as an academic institution but as an active, engaged member of the broader societal and economic context.

9.3 Measuring impact

In response to our third research question regarding the evaluation of the FabLab's impact, we've considered various assessment methodologies. While we recognize the challenges in establishing concrete metrics for educational impact, our research has led us to a hybrid model of assessment that combines immediate and longitudinal measures to gauge the effectiveness of our initiatives.

1. **Immediate Measures**: we employ short-term metrics to capture immediate learning outcomes and participant engagement. These include evaluations of participant satisfaction, learning gains, and emotional responses immediately following an activity or a series of sessions. This can be found both in the contribution described in Chapter 5 and Chapter 6.

2. **Long-Term Impact**: the significance of longitudinal studies cannot be overstated. They serve as the cornerstone for evaluating the prolonged effect of educational initiatives on individual academic trajectories, career paths, and life choices. However, we acknowledge that our FabLab's relatively short existence poses a limitation to this approach.

3. **Evolution of Assessment Metrics**: our journey has evolved from focusing solely on "learning outcomes" to emphasizing "learning experiences". We've realized that impact can be multifaceted, encompassing not just the acquisition of knowledge but also the development of a sense of belonging, personal motivation, and empowerment to the whole community around.

To further elucidate on the methods of impact assessment and improvement of our practices, we engage in periodic surveys, interviews, and discussions with students, educators, and community members. Quantitative data such as attendance, participation rates, and project completions are meticulously tracked. We also conduct pre- and post-assessments to measure the growth in competencies and attitudes among participants, as can be seen in the contributions presented in the previous chapter Chapter 5.

Despite these efforts, a comprehensive measure of impact remains elusive. We rely on anecdotal evidence and stories that track the journey of individuals from their early engagement with the FabLab to their presence in our university classrooms. These narratives, while not statistically significant, are rich with insights into the individual experiences and success stories that define the essence of our impact.

In light of our research and expert consultations, we have come to understand that measuring the impact of the FabLab can transcend traditional metrics. The sense of achievement, personal empowerment, and the success stories, although they may not always be quantifiable, hold profound significance for individuals involved.

By fostering a constructionist approach to learning, we position ourselves as both contributors to and facilitators of larger educational movements. Our localized efforts complement the widespread educational revolutions, such as those initiated by Logo and Scratch [189, 169]. We do so by closely aligning with our community, enabling us to implement and amplify these educational breakthroughs effectively. The challenges of this approach are manifold, but the potential for tangible change within our community offers a compelling incentive to persist.

In the educational sphere, a significant emphasis has been placed on learning outcomes—concisely defined as statements encapsulating what a learner is knowledgeable of, understands, and is capable of performing after completing a learning process [45]. This trend, especially prevalent within vocational education and training, has also touched upon general schooling and higher education, albeit to a lesser extent. The focus on learning outcomes has profoundly shaped teaching methodologies, evaluation practices, and regulatory frameworks.

Conversely, the discourse on the evaluation of learning experiences is less robust, even though the concept of experiential learning is widely discussed [129]. Future efforts in the field are likely to focus more thoroughly on exploring this area and developing a robust framework for its effective assessment.

9.4 Open questions and future works

These multifaceted approaches have not only helped demystify scientific knowledge but have also ignited curiosity and a yearning for a deeper understanding across a broad spectrum of the population, particularly among the youth. Our work reaffirms the university's role as a beacon of knowledge, illuminating paths for communal enlightenment and individual empowerment.

Our pedagogical innovations are mirrored in our published works, though, as we have reiterated, encapsulating their full impact remains challenging.

The multidisciplinary cohesion of our team stands as a testament to our collaborative spirit.

We are poised to further diversify and fortify our team, ensuring our initiatives leave an enduring legacy. Our initial forays, driven by sheer passion, often saw us immersed in actions, with little time for reflection. Yet, over time, we have evolved, striving for systematic efforts and broader accessibility, as manifested in platforms like "TheLaaab" (Chapter 8).

Our forward-looking vision is clear: we aim to fortify our collective, nurturing the growing community of practice and consistently integrating a multidisciplinary lens.

Lastly, as we emphasize the universality of this educational model, we cannot overlook the pivotal role of diversity. Our innovative pedagogical approaches, coupled with adaptable toolkits, aim to promote inclusive and discerning technological engagements, working on inclusion and highlighting the strength of every individual as the ones of every discipline.

In our pursuit of educational innovation, we are charting a course for the future that emphasizes the development of comprehensive assessment tools and the strengthening of our educational community:

- **Develop robust evaluation frameworks**: as we delve into the intricate landscape of constructivist pedagogy and STEAM education, we recognize the imperative of rigorous assessment and evaluation. Our commitment lies in developing comprehensive evaluation frameworks that not only measure the effectiveness of our pedagogical approach but also provide valuable insights into its long-term impact. Moreover, we are dedicated to crafting assessment tools that transcend traditional learning outcomes to encompass the broader spectrum of learning experiences and the cultivation of community within our educational spaces. This entails not just a static evaluation model but an adaptive framework that can capture the dynamic and communal aspects of learning. By continually refining these frameworks, we aspire to offer educators and stakeholders tangible evidence of the benefits of our approach, enabling them to make informed decisions in the realm of education.
- **Expand TheLaaab**: we plan to expand the platform "TheLaaab", as discussed in Chapter 8, beyond its initial expert review round to engage a wider audience. By gathering diverse feedback, we aim to inform and enhance our approach, ensuring that our evaluation platform is as inclusive and informative as possible.
- **Strengthen Our Multidisciplinary Community**: The tapestry of our pedagogical philosophy is woven with the varied threads of insight from our multidisciplinary community. Moving forward, we are committed to nurturing this collaborative network, bringing together educators, researchers, and practitioners from an array of disciplines. Our vision is to cultivate a fertile ecosystem that supports the exchange of innovative ideas and ensures the sustainability, resonance, and impact of our educational initiatives on both local and global scales.
- **Analyze the FabLab's Organizational Model**: While we have established and delineated the structure of our FabLab, there is a pressing need to critically evaluate its organizational model. This analysis is pivotal in identifying the strengths that we can

leverage and the weaknesses that require attention. A thorough evaluation will guide us in refining our strategies, optimizing our operations, and ultimately, reinforcing the foundation of our educational framework.

- **Strengthen the Ecosystem**: The FabLab, poised at the heart of our endeavors, is anticipated to remain a central figure within an expanding ecosystem. Our vision is to fortify this network, where the FabLab may continue to serve as a nucleus around which a more comprehensive constellation of initiatives orbit. By enhancing this ecosystem, we aspire to create a synergistic environment that supports a broader scope of educational, communal, and developmental activities.

Through these endeavors, we aspire to illuminate the path of educational progress, ensuring that every learning experience is not only assessed but also cherished as a vital component of personal and community development.

9.5 Concluding reflections

In summary, this dissertation has contributed to the discourse on the role of university FabLabs as transformative educational environments. Through a multi-pronged investigation, it has offered insights into how these labs can shape educational paradigms, extend university influence, and measure the true value of educational innovation.

As we consider the implications of our findings, it is evident that university FabLabs could serve as microcosms for the larger educational landscape, reflecting a shift towards more dynamic, inclusive, and impactful learning models. In the spirit of continuous improvement, this research advocates for ongoing refinement of educational methodologies and impact assessment tools to keep pace with the evolving demands of society.

The journey does not conclude here. Rather, this dissertation is an invitation to further dialogue, research, and action as we collectively strive to enhance the educational experience and its resonance in the world beyond the university.

A Interviews tracks and focus group track

A.1 Semi-structured interview tracks

A.1.1 Non-expert students

Preliminary questions:

- What are you studying/have you studied in high school?
- What led you to make this choice?
- Have you studied computer science?
- If yes, on what occasion?
- Did you like it?
- If not, would you have liked to study it?
- Do you think studying computer science is useful?
- If yes, in what particular ways have you found it useful or do you think it could be useful?
- Do you feel comfortable using a computer?

Knowledge of coding and participation in events/lessons/seminars related to it:

- What comes to mind when I say the word "coding"?
- What kind of personal characteristics/inclinations do you associate with this term?
- What kind of person do you associate with coding?
- Do you feel coding is a topic that is close or distant from you? Why?
- Have you ever participated in coding-related activities (lessons/seminars)?
- Tell me about your experience. What did you learn from this activity?
- Do you think it was helpful?
- If I asked you to imagine a coding lesson, how would you describe it?
- Are you aware that coding has become a subject in primary school education?
- In your opinion, why is coding introduced into the curriculum of schools from primary level onwards?

A.1.2 Expert students

Preliminary questions:

- What did you study in high school?
- Were you interested in computer science?
- Why did you get into this field?
- What university path are you pursuing?
- What led you to make this choice?
- How did you get into the world of computer science?
- What area have you specialized in the most?
- Are you satisfied with the choice you made?
- Why?
- Let's imagine our life in 10 years. What will your job involve?
- Will coding be part of your professional life?

Knowledge of coding and its role in everyday life:

- Tell me what coding means to you.
- How would you define coding broadly?
- What do you think about the inclusion of coding in the curriculum of every educational path?
- Why should someone who doesn't plan to pursue a career directly related to coding know about it?
- Based on your experience, what kind of skills does coding help develop?
- How can these skills be useful in everyday life? (From your perspective and from the perspective of someone who doesn't intend to make coding their career).
- Can you think of a commonly known game (e.g., a board game) that you would associate with coding?

A.1.3 Teachers/trainers

Preliminary questions:

- What was your educational background?
- What led you to make these choices?
- What is your current professional role?
- Can you tell me about a typical day in your life?

Role of coding in the interviewee's life:

- What is coding to you?
- How did you get into the world of coding, and why?
- What role does coding play in your professional journey?
- What kind of skills does it help develop?
- How are these skills applicable in everyday life?
- What benefits will coding offer to children who will be adults in 2030?

- How would you evaluate school programs regarding this subject?
- What is the most challenging stereotype to overcome regarding coding?
- How would you organize lessons to introduce young people to coding?
- Are there preferred channels for learning coding outside of the school context?
- In your opinion, can the Latin taught to high school students be considered a form of coding? What is a commonly known game that you would associate with coding?
- Is there anything else you would like to add?

A.2 Focus group track

A.2.1 Welcome and brainstorming (15–20 minutes)

After introducing the research project and getting to know each other, to familiarize the participants with the topic of coding, a brainstorming activity will be proposed. This will allow the participants to reflect on the meaning of coding and facilitate a dialogue on the subject.

- The facilitator will divide the participants into three pairs, each consisting of an expert student and a non-expert student. Each pair will have a few minutes to come up with a shared definition of coding;
- Following this, there will be a general sharing of the definitions identified by the three pairs and the thought processes involved;
- Finally, together, we will come up with a single definition of coding.

A.2.2 Logic activity (30–45 minutes)

At this point, the six participants will be presented with seven puzzles that require different skills to be completed and are related to learning coding in a playful way and developing logical thinking through problem-solving activities. Specifically, each participant will be able to try:

- The Tower of Hanoi, which in its classic form consists of eight overlapping disks of decreasing sizes, with a hole in the center, placed on one of the three pegs fixed on a board. The eight disks, forming the tower, must then be moved to one of the other two free pegs, following a precise rule: only one disk can be moved at a time, and it is prohibited to place a larger disk on top of a smaller one.
- The well-known Rubik's Cube, which involves completing the faces with squares of the same color.
- Five other wooden puzzles that involve: skill in separating two objects tied by two strings; fitting rectangular pieces into a square container; a tower with three balls inserted, with a string attached to its end, with the goal of reversing the order of the balls without letting them fall off the string; separating two interlocked objects; and finally, a sphere made up of wooden pieces to be disassembled and reassembled in its original form.

Participants will be able to switch to another puzzle at any time. At the end of the activities, they will be invited to reflect on their different playful experiences in relation to coding.

A.2.3 Project proposal discussion (30–45 minutes)

Participants will be presented with a draft of the project proposal envisioned by the members of the research group, focusing on the aspect of a coding-themed Escape Room. They will be asked to engage in an open discussion, examining both the potential positive aspects and, even more importantly, the negative ones. In particular, they will discuss the feasibility of the activity in terms of logistics and its effectiveness in achieving the objectives that the initiative sets out to accomplish, considering innovation as well.

A.2.4 Debriefing (10 minutes)

With microphones turned off, there will be a moment of informal discussions between organizers and participants.

B Tables

Table B.1: Codes based on the conducted interviews.

Date	Activity	# participants
	November 2021	
16/11/2021	3D Printing Basics [1/2]	25
25/11/2021	3D Printing Basics [2/2]	18
25/11/2021	Laser Cutting & Vinyl Cutting [1/4]	25
30/11/2021	Introduction to Parametric 3D Design	13
	December 2021	
14/12/2021	Electronics Design Basics with KiCAD	17
	February 2022	
08/02/2022	Laser Cutting & Vinyl Cutting [1/3]	6
	September 2022	
19/09/2022	Laser Cutting & Vinyl Cutting [2/3]	15
20/09/2022	2.5D CNC Milling and Engraving with Fusion 360	8
27/09/2022	3D Printing Basics	15
	October 2022	
25/10/2022	Laser Cutting & Vinyl Cutting [3/3]	6
26/10/2022	3D Printing Basics	8
	November 2022	
14/11/2022	Workshop: Design your own USB keyboard [1/2]	35
15/11/2022	Workshop: Design your own USB keyboard [2/2]	30
30/11/2022	Sistema Moka, workshop introduttivo ad Arduino	23
20/11/2022	La creatività dei dati e l'ecosistema OpenStreetmap with Maurizio Napolitano	15
29/11/2022	I-produce – co-creation hackathon	38
30/11/2022	Sistema Moka, workshop introduttivo ad Arduino	23
	December 2022	
1/12/2022	Case di domani moqa system	10
5/12/2022	Case di domani moqa system	12
6/12/2022	Workshop: Introduction to parametric design	18
12/12/2022	Giudici competizione Trentino young scientist challenge	24

Continued on next page

Table B.1: Codes based on the conducted interviews. (Continued)

Date	Activity	# participants
February 2023		
03/02/2023	Trentino young scientist challenge Stampante 3D (due gruppi)	68
06/02/2023	OpenStreetmap per terremoto in Siria with Maurizio Napolitano	12
March 2023		
04/03/2023	Tech Party (esposizione)	128
09/03/2023	Reply challenge	56
13/03/2023	Workshop: Stampante 3D	25
13/03/2023	Stampante 3D, materiali ed economia circolare (due gruppi)	50
14/03/2023	Workshop: Laser cutting & vinyl cutting	32
15/03/2023	Workshop: 2.5 CNC Milling and engraving with Fusion 360	24
16/03/2023	Workshop: Customising textiles using embroidery machine	22
16/03/2023	Workshop addressable LEDs [1/4]	8
22/03/2023	Workshop Flutter [1/3]	30
23/03/2023	Workshop addressable LEDs [2/4]	8
25/03/2023	Hackathon: Arduino day	34
27/03/2023	Montaggio e tutoring stampanti 3D	16
29/03/2023	Workshop Flutter [2/3]	30
30/03/2023	Workshop addressable LEDs [3/4]	8
April 2023		
03/04/2023	Introduzione alla stampa 3D	20
04/04/2023	Presentazione Fablab	50
05/04/2023	Workshop Flutter [3/3]	20
13/04/2023	Workshop addressable LEDs [4/4]	8
20/04/2023	Hackathon: Fablab serra i produce	21
27/04/2023	Workshop LaTeX [1/5]	25

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Table B.1: Codes based on the conducted interviews. (Continued)

Date	Activity	# participants
	May 2023	
02/05/2023	Corso misure DeCecco (stampa 3D) [1/3]	62
04/05/2023	Workshop LaTeX [2/5]	23
09/05/2023	Corso misure DeCecco (elettronica) [2/3]	63
9-10/05/2023	Hackathon: Menz and gasser	96
11/05/2023	Workshop LaTeX [3/5]	24
16/05/2023	Corso misure DeCecco (stampa 3D) [3/3]	60
18/05/2023	Workshop LaTeX [4/5]	23
19/05/2023	Presentazione laboratorio e taglio laser	30
25/05/2023	Workshop LaTeX [5/5]	23
	June 2023	
07/06/2023	Festa della scienza	120
28/06/2023	DISI per *Orienta Estate* (visiting laboratory)	24

Table B.2: The list of questions and answers.

n.	Question	Answers
1	Penso che mi piacerebbe usare questa piattaforma frequentemente	strongly agree 0 slightly agree 1 neutral 0 slightly disagree 5 strongly disagree 11
2	Ho trovato la piattaforma inutilmente complessa	strongly agree 0 slightly agree 0 neutral 5 slightly disagree 3 strongly disagree 9
3	Ho trovato la piattaforma semplice da usare	strongly agree 4 slightly agree 10 neutral 2 slightly disagree 1 strongly disagree 0
4	Penso che avrei bisogno del supporto di una persona già in grado di utilizzare la piattaforma	strongly agree 1 slightly agree 2 neutral 1 slightly disagree 5 strongly disagree 8
5	Ho trovato le varie funzionalità della piattaforma ben integrate	strongly agree 0 slightly agree 8 neutral 6 slightly disagree 1 strongly disagree 0
6	Ho trovato incoerenze tra le varie funzionalità della piattaforma	strongly agree 0 slightly agree 4 neutral 3 slightly disagree 2 strongly disagree 8
7	Penso che la maggior parte delle persone possano imparare ad utilizzare la piattaforma facilmente	strongly agree 10 slightly agree 6 neutral 0 slightly disagree 0 strongly disagree 1
8	Ho trovato la piattaforma macchinosa da utilizzare	strongly agree 0 slightly agree 2 neutral 5 slightly disagree 1 strongly disagree 9

Continued on next page

Table B.2: The list of questions and answers. (Continued)

n.	Question	Answers
9	Mi sono sentito a mio agio nell'utilizzare la piattaforma	strongly agree: 5 slightly agree: 10 neutral: 2 slightly disagree: 0 strongly disagree: 0
10	Ho avuto bisogno di imparare molti processi prima di riuscire ad utilizzare al meglio la piattaforma	strongly agree: 0 slightly agree: 1 neutral: 0 slightly disagree: 5 strongly disagree: 11
11	Credo che l'attività sia intuitiva	strongly agree: 7 slightly agree: 9 neutral: 1 slightly disagree: 0 strongly disagree: 0
12	Mi sono annoiato/a svolgendo l'attività	strongly agree: 0 slightly agree: 0 neutral: 3 slightly disagree: 3 strongly disagree: 11
13	Userei la piattaforma per divulgare i workshop del mio laboratorio	strongly agree: 7 slightly agree: 7 neutral: 3 slightly disagree: 0 strongly disagree: 0
14	Raccomanderei la piattaforma ad altri	strongly agree: 10 slightly agree: 4 neutral: 3 slightly disagree: 0 strongly disagree: 0
15	Lascerei dei blocchi di testo standard per creare le schede dei workshop	strongly agree: 0 slightly agree: 2 neutral: 5 slightly disagree: 7 strongly disagree: 3
16	Quante volte al mese saresti in grado di caricare le attività del vostro lab?	Less than once a month: 7 Between once a week and once a month: 7 Between once a day and once a week: 2 Even every day if the materials were there: 1
17	Perché caricheresti i tuoi workshop sulla piattaforma?	• bene comune; • dare e ricevere; • divulgazione; • divulgazione e comunicazione; • per condividere le mie esperienze con altri; • per condividere, pubblicizzare e attendere dei commenti; • per divulgare il lavoro, e vedere come gli altri usano gli strumenti che abbiamo generato; • per divulgarli e condividerli con altri; • per gestire attività e divulgazione dei corsi; • per implementare conoscenza condivisa; • per rendere più facile la prenotazione; • per usarla come una vetrina per le mie attività; • sharing workshops.

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Table B.2: The list of questions and answers. (Continued)

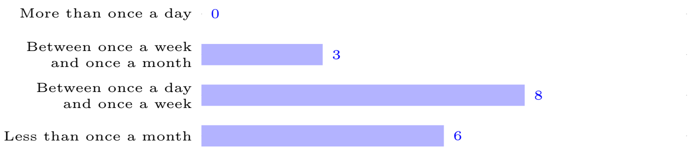
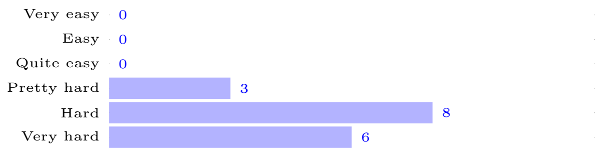
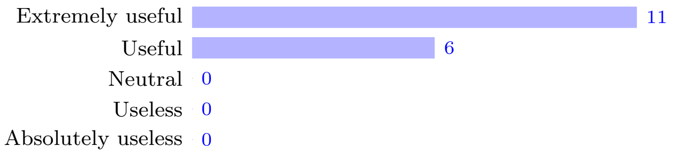
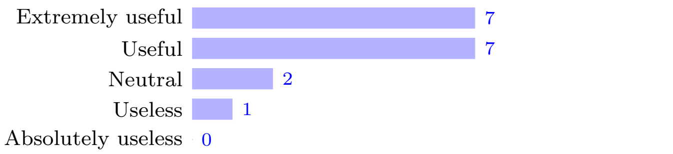
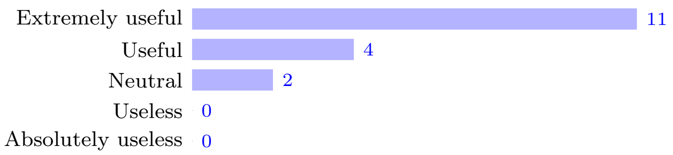
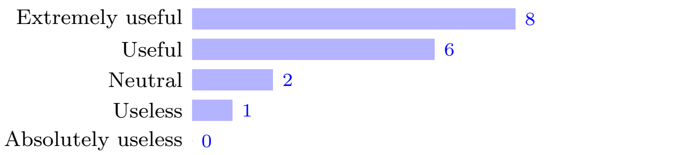
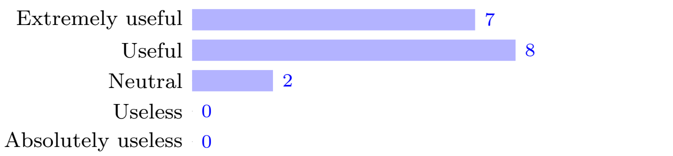
n.	Question	Answers
18	Quali potrebbero essere gli incentivi per decidere di caricare le attività sulla piattaforma?	• accesso a conoscenze preziose; • aiuto di altri fablab e usare esperienza di altri; • collaborazione, test in altri contesti, partecipazione; • dare senso alla rete u-fab per sharing e mettere in opera lo scopo; • feedback; • la possibilità di condivisione delle diverse attività; • la possibilità di replicazione e adattamento delle attività in altri contesti; • nessuno; • per favorire l'accesso in modo più ampio e condividerlo facilmente; • possibilità di individuare persone più interessate; • ricevere il feedback dei diversi user. . . anche avere tipo "favorite workshop" con il numero di caricamenti; • soldi; • trovare materiali utili e attività ben documentata; • visibilità come formatore.
19	Quante volte al mese consulteresti la piattaforma per visualizzare nuove attività di altri?	
20	Nel complesso, quanto è stato difficile il caricamento dell'attività?	
21	Avere un archivio di workshop	
22	Avere workshop raggruppati per età/fascia scolastica	
23	Avere workshop raggruppati per temi	
24	Ricevere suggerimenti su workshop interessanti da consultare	
25	Ricevere informazioni su interessi comuni tra te e profili/enti affini	

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Table B.2: The list of questions and answers. (Continued)

n.	Question	Answers
26	Leggere valutazioni su chi carica workshop	Extremely useful 7 Useful 7 Neutral 1 Useless 2 Absolutely useless 0
27	Poter lasciare feedback sui workshop scaricati	Extremely useful 10 Useful 5 Neutral 1 Useless 1 Absolutely useless 0
28	Avere uno storico dei cambiamenti apportati all'attività per riadattarla alle varie esigenze	Extremely useful 7 Useful 6 Neutral 3 Useless 1 Absolutely useless 0
29	Poter comunicare con gli/le initiator dei workshop	Extremely useful Useful 3 Neutral 1 Useless 0 Absolutely useless 0
30	Quanto utile sarebbe thelaaab per te?	Extremely useful 5 Useful 10 Neutral 1 Useless 0 Absolutely useless 1
31	Quanto utile sarebbe thelaaab per gli insegnanti/facilitatori/educatori che conosci?	Extremely useful 8 Useful 6 Neutral 3 Useless 0 Absolutely useless 0
32	Qual è stata la parte che ti è piaciuta di più o che credi possa avere più potenzialità?	• events!; • l'archivio dei workshop, e le schede; • in generale è una buona piattaforma; • la foto. e dovrebbe essere possibile caricare la propria versione; • la possibilità di aggiungere le immagini per ogni attività; • modalità di inserimento durata workshop ecc, incentivo alla compilazione; • tutta.
33	Qual è stata la parte che ti è piaciuta di meno o che credi possa avere meno potenzialità?	• about; • allineamento con modelli attività making, design, educativi; • magari sul about puo' essere piu informazioni per capire bene come funzione, per esempio un video animazione che mostra vari step per educatori/workshop conductors; • nessuna; • può essere utile una divisione tra attività complete e attività solo in vetrina.

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Table B.2: The list of questions and answers. (Continued)

n.	Question	Answers
34	Qual è stata la parte più difficile o meno chiara dell'attività?	• alcune diciture non intuitive; • da mobile, non è possibile premere invio per aggiungere i campi. Non è chiara la distinzione tra strumenti, macchine, materiali. Non mi è chiara neanche la distinzione tra iniziatore e facilitatore. Forse cambierei; • l'etichetta "aggiungi testo" con "aggiungi attività"; • iniziatore, facilitatore; • inserire Facilitatore e iniziatore; • l'organizzazione dei tempi non è chiara se la durata è per una singola seduta per l'intero Workshop; • login; • mi sarebbe piaciuto scegliere tra un elenco di keyword; • quando ho inserito i materiali, strumenti, macchine, quando aprivo seconda volta scompaiono.
35	Cosa cambieresti o faresti diversamente?	• avere un buon meccanismo di ricerca; • il modello scheda va implementato; • inserirei la possibilità di caricare video; • magari un video introduttivo per far vedere la modalità di uso per due tipi di user; • nella pagina per aggiungere un workshop, aggiungerei alcune sezioni aggiuntive, magari opzionali: un campo di testo libero, o semi-strutturato su consigli e indicazioni rispetto a possibili punti di debolezza o punti di forza del workshop; un campo per indicare la durata di ogni attività; indicazioni su come poter adattare le attività (es. Durata, attività opzionali); indicazioni su possibili partecipanti (età, interessi, abilità, bisogni speciali).
36	Commenti extra?	• è importante che gli utenti si sentano incentivati a caricare materiale; • potreste pensare a inserire dei pop up informativi (?) per ogni sezione del formulario, per far capire quali informazioni inserire e magari dare degli esempi: es. chi è l'iniziatore; • un video introduttivo.

C Projects abstracts

University strategic plan The specific objectives of the project are as follows:

a improvement of the MOQA monitoring and automation system, originally developed within the university, with the aim of optimizing the quality and energy consumption of university spaces.;

b monitoring and low-cost, plug-and-play automation of small and medium-sized university premises that are constantly occupied and particularly problematic in terms of indoor environmental quality and energy consumption, as indicated by the university's energy manager. The monitoring will not interfere with the electrical and heating systems or the spatial layout of the studied premises but will interface, if possible, with the existing instrumentation (sensors and devices);

c engagement of the university community through:

  c1. questionnaires and interviews;

  c2. collection of feedback data through smart wearable devices, following the approach already proposed in other international university environments (Cozie project);

  c3. raising awareness among the university community and the broader community through outreach and training activities.

U.O. Programmazione e Politiche del lavoro The present project considers STEAM education as one of the main pillars of the path towards gender equality, starting from COMPETENCIES, by strengthening and consolidating the guidance services network It aims to strengthen, in a unified framework and through collaboration among all educational entities – schools, training institutions, ITS foundations, and universities, as well as families and businesses – the educational and training offerings in STEM competencies. Combating gender stereotypes in educational and professional choices, promoting collaboration in caregiving responsibilities, and investing in STEM competencies are the key drivers for reducing gender inequalities and fostering sustainable development.

Lagorai, tesoro nascosto The project "Lagorai, Hidden Treasure" aims to promote awareness and knowledge of the mountainous territory of Val di Fiemme. It includes three events: a nighttime outing with camping to observe the stars and listen to local stories, a day at Malga Canzenagol with educational activities about local flora and fauna, and site improvement work, and an educational field trip to analyze the territory's changes due to climate change and understand how to live in it safely. The project involves various local partners with the goal of promoting inclusivity and sustainable practices.

The House of Tridentum The "The House of Tridentum" festival is an inclusive event, a two-day festival where our primary target audience, primarily the age group between 11 and 14 years old, but extendable to young people aged 15-18 and their families, will be at the center of various forms of expression and dialogue concerning their relational experiences, especially those related to family, friendship, and social interactions. During this festival, various workshop sessions will be offered, involving different languages and forms of expression (Art, Theater, and Storytelling). The project's focus and promoted activities will revolve around the theme of diversity and inclusion, as it aims to raise awareness among the new generations about acceptance and the importance of diversity. This will be achieved through work aimed at recognizing, using, understanding, and consciously managing one's own emotions and those of others. The festival is designed as a space where participants can freely express themselves, learning new ways of expression, building relationships, and connecting with others through the workshops offered. The activities promoted will enable participants to learn about the intersectional approach and, through the activities themselves, experience inclusivity.

Biblioteca nel bosco The project stems from the need to provide students in the area with a different approach to studying by creating a library in the Marzola forest, near the Fontana dei Gai cabin. The goal is to give young boys and girls the opportunity to learn outdoors, reconnecting with nature and the surrounding environment, thereby promoting their well-being. The period in which the project is intended to be realized is the first week of July and the last week of August, as it is considered the best time for young people to review before university exams, engage in the final moments of study together in groups, allowing them to review aloud in a space different from the usual libraries.

Giovani spazi creativi "Harpolab", promoted by the Il Funambolo association and supported by the "Young Creative Spaces" call from the Youth Policies of the Municipality of Trento, is located in Piazza Garzetti inside the Liberty-style building. Within the approximately 600 square meters available, there will be a screening room for art-house cinema, an editing room, an audio recording room, a small photo studio, a darkroom, and a laboratory for technological experimentation, as well as spaces for meetings, workshops, and exhibitions. The program includes film festivals, meetings, events, hybrid performances, exhibitions, presentations, debates, and in-depth discussions, as well as workshops and consultations. The aim of this new, multifaceted space dedicated to visual arts, resulting from collaboration between the association and the "G. Prati" Classical High School, with the participation of the Harpo and Glow associations and a wide network of partners, is to become a reference point for the youth and beyond. By positioning itself as a place open to experimentation, it will provide an opportunity for people to come together to explore the visual arts and new technologies, learning to decode their messages.

LIGNEO: Legno per l'Inclusione LIGNEO will develop new skills among teachers within ENAIP and provide support in creating a school community of practice to disseminate innovative experiential teaching methods focused on new technologies, sustainability, and inclusion. LIGNEO includes a training phase for teachers, a co-design and implementation phase with students for an educational pathway. Teachers will acquire new skills, an experimental method, and replicable teaching materials for the years ahead.

Russell Professional Development The national recovery and resilience plan (PNRR) have prompted reflection among teachers, a process that had already begun years ago, in order to experiment with new teaching approaches involving teachers, students, and communities. The question that many teachers ask themselves and their colleagues is: how can I motivate my students to learn and make teaching effective and efficient? This question is prompted by the heterogeneous composition of the classes at Russell High School. We believe that engaging in Steam-type learning activities is an opportunity not to be underestimated. Therefore, the teachers at Russell High School in Cles have thought about possible strategies to improve the learning and motivation of students from all tracks using the Steam methodology in collaboration with the University of Trento through *coaching* and *job shadowing* with lesson planning and dissemination.

Trento. Ieri, oggi, domani The discovery of the history of Trento, a land on the border and a gateway to Europe. A performance to learn about the history of the region through the art of theater. Students will be offered a brief training course, first on the history of Trento and then on acting techniques, and they will be provided with a script. Participants will learn acting techniques and delve into the history of the city from yesterday to today, with an eye on tomorrow, envisioning and hoping for the future Trento imagined by young people.

Sustainable Week Sustainability and environmental respect are primary and shared objectives for the development of our Trentino. The brain marathon (hackathon) will feature eight teams composed of students from different tracks at our 9 centers, along with teachers and professionals in sustainable areas, marketing, computer science, and graphics. The journey will give rise to ideas that will materialize into innovative, new, and original solutions to meet the challenge presented by the company in search of a sustainable solution for the well-being of the territory and its employees.

Donne & STE(A)M: dalla consapevolezza alla *mentorship* The project involves the training of university female students in the STEAM field with the aim of making them aware of their career opportunities while simultaneously serving as positive female role models for young people aged 6 to 26. After receiving specific training in project management, entrepreneurship, and communication, the participants will be engaged in a mentorship program for younger students, during which they will design and implement scientific outreach activities.

Che GENERE di diritti? WHAT KIND OF RIGHTS? is a training, knowledge, and creative reprocessing journey on the topic of rights and gender equality. Following an initial training phase conducted by Glow and Deina (project partners), two theater trainers, Federica Chiusole and Alessandra Evangelisti, will guide students from the Prati and Galilei high schools in creating a theatrical narrative on the topics discussed. The first part of the project, focusing on the history of rights, gender education, and active citizenship (10 hours in plenary), will be offered to teachers from both institutions. The second part involves a week of School-Work Alternation (50 hours of face-to-face learning) with a final performance.

Algoritmicamente: dal *problem solving* all'Informatica The objective of this experimentation is to introduce an innovative method for teaching Computer Science, approaching it as one does when teaching a foreign language and using active teaching methodologies such as peer education, cooperative learning, and project-based learning. Within the experimentation, Computer Science will be the focal point for proposing multidisciplinary activities, in line with the spirit of a high school curriculum that aims for a well-rounded education of the individual. We will start in the first year of class by offering problem-solving activities and developing computational thinking, and in the second year, we will introduce the PRIMM method for programming.

STEM:KIT - Capire la fisica con l'informatica This project aims to create a dialogue between two disciplinary areas that are typically taught separately, namely physical sciences and computer science. Interdisciplinary teaching paths have been developed that make use of new technologies related to low-cost sensors (such as Arduino and Micro:bit) and aim to promote a technical-scientific culture in the educational world. More specifically, these paths consist of custom-designed kits composed of hardware systems, sensors, and instrumentation, intended for the implementation of personal experiments using easily accessible and low-cost components. In addition to the kits, documentation is provided for teachers/trainers, as well as worksheets for students, illustrating the possibilities offered by the kits while simultaneously promoting personal exploration. One of the strengths of the project is to enable the introduction of computer science courses in educational contexts that often lack coding programs, which is now considered unacceptable in the digital context we experience daily.

Computational Thinking Academy for inclusion The aim of this project is to bring CT closer to the teachers and thereby bridging the gender gap. The project aims to provide role models, hand-on experience and encourage a growth mindset by creating environments where questions, discovery and even failure are treated as positive parts of the learning process. We show teachers how core characteristics of CT can be integrated into compulsory education. We provide concrete tools for an effective teacher training and explain how teachers can integrate CT in their own teaching practice as an innovative cross-curricular topic, with particular attention to the STEM discipline and gender equality.

Bel da Matti The project is born in memory of Elisa Deflorian, a teammate but above all a friend. The idea is to create a project around her memory that promotes community development and the involvement of young people in the world of sports and the mountains. This network of associations - but above all friends - has decided to organize a series of events to raise awareness and particularly involve girls in the world of sports and teamwork. To do this, we will use soccer as a tool, a sport she loved. "Bel da matti" this is the name of the project, originates from a hashtag she used to put in her posts. The project includes three phases. The first involves the participation of some female players and the coach of the Fiemme Women's Futsal team, who will conduct various training sessions with classes from middle and high schools in the area during physical education classes. In particular, we have already contacted middle and high schools in Cavalese, Tesero, and Predazzo, who have shown a willingness to host the initiative. There will be no distinction between boys and girls who participate in the intervention. It will begin with a discussion about the prejudices surrounding women's soccer and then move on to physical activity. The second phase of the project is designed for all girls who love soccer, who already play, or who are simply curious to try this sport, and it includes an open day outdoors at the Ziano field, Elisa's hometown. Following that, the third phase will involve the organization of a soccer 5-a-side tournament with both male and female teams. The tournament will be spread over two days: a qualifying round and a full day of matches. This second day will not only be a fun moment to come together and enjoy but will also serve as a stage for all the local associations involved in social engagement and activities for young people. They will be invited to set up booths to present their activities (such as the AVIS, for example, or the Alpine group, which has already offered to prepare lunch). On this day, the creation of a new association will be launched, which will in the future promote support for projects related to the recovery of spaces (such as old bivouacs) in the mountains in Val di Fiemme, always in memory of Elisa.

Case di Domani We are an 'indoor generation', spending an average of 90 percent of our time indoors (World Health Organization); in cars, at the office, and most importantly, at home, totaling around 22 hours a day. We do so unconsciously, living in sealed, poorly lit, and poorly ventilated environments, in other words, harmful to our health. A comfortable and healthy space requires energy to be such: the boiler that maintains the desired indoor temperature, the air conditioner that cools us on hot summer days, mechanical ventilation systems that ensure adequate air exchange all contribute to an increasingly intolerable environmental cost, which, however, is often only realized when looking at the monthly utility bill. Buildings, in fact, account for a significant portion of global emissions, occupying over 30% of final energy consumption in Europe, similarly to transportation (Eurostat). Faced with these facts, one may wonder, 'how much do we know about the buildings we live in?' We can probably reconstruct the interior spaces of our homes from memory with considerable accuracy – the rooms, objects, colors, walls, switches. But if we were asked to assess indoor air quality or talk about what hides within those walls, we wouldn't know how to respond. It is necessary to become aware of this and begin to change our habits. The idea behind the 'HOUSES OF TOMORROW' project arises in this context and is developed based on the doctoral research conducted by one of the group members, focusing on the creation of a low-cost and user-adaptable environmental monitoring system. Hence, the desire to initiate a path of awareness that helps young people better understand the behavior of their homes, making them more comfortable and energy-efficient. All of this is done with a constant eye on technology and the new paradigm of the 'smart building'.

SPACE BIO TINKERING The project involves the development of a series of tinkering activities aimed at boys and girls aged 8 to 13 to be carried out in the Prato Maranza garden and at the Arena Parco near Cassa Rurale di Povo. These activities aim to address the lack of interaction and interactivity typical of teamwork on experimental educational projects, which has been exacerbated by the last three years of the pandemic. The methodology, that of tinkering, an informal learning type based on creativity and collaboration, is well-suited for these purposes. The theme, that of space exploration, is nothing more than a pretext to stimulate the minds of young people to experiment with innovative solutions in the most pioneering fields of scientific research: engineering, biology, and biotechnology. The goal is to simulate solutions for extreme environments that can then be adapted to the challenges set by the sustainability objectives of the Agenda 2030. Furthermore, this project finds its place in the opportunity and necessity to provide the recipients and their families with the opportunity to spend quality time during the summer, meeting both recreational needs and fostering creativity development in a context of scientific themes.

PER sFIdarli DObbiamo impegnarci The project aims to offer, first and foremost, to the involved class, a 4th-grade class in the Administration, Finance, and Marketing program, and then to the rest of the student population, knowledge about local and national organizations, such as the Libera association and the Questo Trentino magazine, dedicated to defending legality and environmental heritage. It is believed that this commitment can also be undertaken by younger individuals through a path of awareness (what is happening?) and one of expression (what can I do? how? with what means?), in order to refine the participation strategies necessary to achieve the common goal.

PRONTI... ATTENTI... STEAM! 'Ready... set... STEAM!' aims to provide a professional growth opportunity for teachers and meaningful learning for students through the design and setup of a mobile STEAM educational laboratory within the I.C. Vigolo Vattaro. The initiative will be open to all classes and, periodically, to external participants as well. The experience will involve all school campuses, including the three Primary Schools and the Secondary School, in addition to various local organizations that will collaborate with the schools in the project's implementation.

Mathematics at play The project represents an initial implementation of a mathematics dissemination protocol that, through the PCTO/ASL mode, allows the examination projects presented for the 'Science Communication' course, led by Prof. M. Andretta, to materialize into actions of science communication in society. More specifically, this initial implementation has allowed for the creation of some proposals for mathematical games with educational and outreach objectives, which will be available in the future through donations and themed or scientific outreach events. One of the games created will also participate in the next edition of the 'Archimede Prize' competition. The project took place at the UniTrento FabLab and involved the participation of 19 students from various academic backgrounds, in order to cover different aspects of science communication (scientific, graphic, and technical): eight students from a scientific high school, seven students from an art high school, three students from the MADE-Manufacturing course, and one student from a classical high school. Meetings with the students were held weekly, totaling 39 hours, starting from February 1, 2022, until May 3, 2022. Each meeting included an initial training session on theoretical topics (science communication, history of mathematics, game design, educational aspects of the game) or technical topics (design with 3D printers and laser cutters) and a second session of individual and group activities aimed at refining and developing the games.

Science communicators - Training course for aspiring communicators and teachers 'Science Communicators' is a program for aspiring professionals in the field of science education and outreach. Often, university programs for educators focus on the so-called hard skills: disciplinary content, pedagogical theories, and teaching methodology. In these curricula, the development of soft skills necessary for this job context is neglected, and there is limited opportunity to apply what has been learned in diverse and real-world settings. The project aims to involve 12 master's students or recent graduates interested in science education and outreach in a training program focused on soft skills and career orientation. This program blends science journalism with non-verbal communication skills, and workplace safety is combined with the ability to use 'maker' machinery for the creation of scientific instruments. At the end of the training, participants will be engaged in internship activities at Level Up and involved in mixed experiences such as experiment design, teacher training, and educational/outreach workshops for schools and the general public.

ApeLab - laboratori di comunità Is it possible to take science beyond the usual institutional boundaries? Absolutely! GLOW, LEVEL Up, and Coder Dolomiti join forces to bring scientific workshops to the city parks, hosted on the 'ApeLab'. 'ApeLab' is a mobile FabLab, a small traveling experimental laboratory for social innovation serving the local community. It can activate formal and informal learning processes, creative and innovative co-design, and empowerment for those who use it. It's a meeting space that makes (almost) everything 'possible' thanks to the sharing of knowledge, skills, and machinery in the true spirit of FabLab. Guided by experts from GLOW, CoderDolomiti, and Level Up, technology becomes an accessible tool for everyone, capable of creating connections, innovative models, and developing ideas for the well-being of the community and the territory. All of this comes with dedicated scientific workshops. P.S.: Did we happen to mention that it's all set up on a pink Ape Car?

Rinforzi@moci 2 The project described below is based on the sharing of objectives and methods within an established network of local partners, including the Carpe Diem Association, a school (Trento 7 Comprehensive Institute), institutions (Territorial Welfare and Social Cohesion Service of the Municipality of Trento), and other third-sector organizations that have been operating in the area for years to support children and families (Progetto 92 Social Cooperative). Since 2016, the network has been operating within the Institute to support vulnerable students with the aim of strengthening personal autonomy and enhancing collaboration with families, also involving the Glow association for more specialized technical support. During the 2020/21 school year, the network implemented a synergistic and flexible system to support teachers, students, and families in a blended school and integrated learning context, working together to ensure that no one was excluded. The project involves the Primary Schools of ICTN7, which collectively enroll 787 students, 41 of whom have a certification under law 104/92, and around a hundred students with Special Educational Needs. The primary schools of the institute are divided into 4 campuses located in Gardolo, Meano, and Vigo Meano.

"hello world" — STEAM Workshops with Live Coding How has our relationship with performative art and technology changed in recent years? People go to the cinema to watch visual art and listen to pure sound design, they visit museums to see multimedia installations, travel to attend light festivals, and go to raves to dance to algorithms. Too fast? Let's take a step back and talk about what we believe to be one of the most innovative philosophies in the music scene in recent times: Algorave. The word is derived from the combination of "algorithm" and "rave". It represents a point of intersection between generative art and the rave scene because it is a moment of performance where music and visuals are generated through live coding, using code and algorithms. In other words, music is no longer composed just in notes but by writing code. During these events, the focal point for people is not the computer musician but the screen, as it displays the transparent process of writing the source code, allowing the audience not only to listen but to see the programming process unfold, unadulterated. This movement encompasses not only the playful aspect but also entire academic fields on the design and realization of these performances, aiming to be moments of sharing to break down stereotypes and preconceptions. "hello world" aims to bring this experience to the Trentino region, attempting to overturn every possible stereotype: from legal issues related to computer science and algorithms to those related to gender, age, or background, creating a moment of sharing, celebration, as well as education and dissemination. Drawing inspiration from similar experiences worldwide, including the international event LPM-Live Performers Meeting supported by the European Commission, "hello world" serves as a workshop, a place for exchange and cross-pollination, and a showcase for local entities working in the field of multimedia performance, including the academic research realm. "hello world" is an event that starts from the grassroots, leveraging the power of social networks to create a situation of beneficial collaboration for the development and spread of technology in performative art. On one hand, "hello world" aims to be a local meeting place for entities that experiment, operate, play, and are interested in using technology in performative art. On the other hand, the project aims to be a unique opportunity for enthusiasts and curious individuals to meet a selection of artists and experts working in multimedia and new technologies for performative art, ranging from research to the underground scene. Students will be actively involved in designing, proposing activities, and experimenting. The festival, intended for both 2022 and 2023, will span two days during which various moments of meeting, exchange, showcasing, and think tanks on the theme of multimedia and experimental performance will be organized. The project will include some performative moments, presentations, and enjoyment of multimedia and technological productions, alongside educational and didactic meetings aimed at communicating, sharing, and reflecting on theoretical and practical aspects related to audiovisual performance.

Rinforzi@moci The project aims to support teachers in providing the necessary skills to students in this particular and complex historical moment, collaborating with the local network of services to ensure that no one is left behind. This shared purpose and operational approach translate into genuine co-design of widespread support within school walls for the benefit of students and teachers. The project, in fact, intends to create a multidisciplinary team composed of professionals, the IT technician, the territorial educator, and the team of teachers involved in the project.

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