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Be an Engineer? I'm game!

Empower education to foster engineering

By

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Declaration

I hereby declare that, the contents and organization of this dissertation constitute my own original work and does not compromise in any way the rights of third parties, including those relating to the security of personal data.

Maria Giulia Ballatore
2024

* This dissertation is presented in partial fulfillment of the requirements for **Ph.D. degree** in the Graduate School of Politecnico di Torino (ScuDo).

I would like to dedicate this thesis to my family,
Paolo, Maria Elisabetta, and Giovanni,
your unwavering love, patience, and support
have been the bedrock upon which
this journey of research and discovery has thrived.

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"Osate, tutto cosa è possibile perché chi non osa non riceverà mai nulla"

– *Cerimonia di consegna della Laurea Honoris Causae* - Amilcare Merlo

"Io ti voglio bene e ne ringrazio Dio,
che mi dà la tenerezza, che mi dà la forza,
che mi dà la libertà che non ho io."

– *La ballata dell'amore vero* - Claudio Chieffo

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Abstract

Engineering Education Research is a rapidly evolving field focusing on understanding the effectiveness of teaching and learning strategies in engineering education. Research in this field aims to enhance the quality of engineering education and promote innovation in engineering education. In recent years, the Engineering Education community has been focused on increasing the diversity of students in engineering programs and developing pedagogical approaches that support the development of the competencies required by today's engineers. There is also an emphasis on creating sustainable Engineering Education practices that align with the needs of society and industry.

This research investigates the role of Engineering Education in a technical university. It starts with an overview of Engineering Education, the relation between technology and education, the science behind teaching, and finally, it analyzes the current Italian context. Then, it focuses on the different perspectives this research field involves: the student and lecturer sides. This is done through various research that has occurred at Politecnico di Torino in recent years.

The findings of this research underscore several critical aspects. Firstly, it demonstrates that the active engagement of an Engineering Education Researcher (EER) can bring about transformative changes in long-established engineering higher education institutions, effectively modernizing and improving their practices.

The research demonstrates that integrating preparatory study methods into engineering education can significantly enhance the learning experience and outcomes for students. This analysis underscores that engineering education can play a vital role in improving spatial abilities and reducing the gender gap in the STEM field. The study highlights the essential role of lecturer training in enhancing the efficiency of engineering education. Training programs tailored to educators can lead to more effective teaching methods and better student learning outcomes. Lastly, this dis-

sertation highlights the significant impact of technology in engineering education. The integration of technological tools and the implementation of effective impact evaluation methods contribute to the continuous improvement and innovation of engineering education practices.

In conclusion, this research not only reveals the capacity of EERs to catalyze positive changes in higher education institutions but also underscores the importance of lecturer training and technology in shaping the future of engineering education. It suggests further research directions in this area, emphasizing the importance of continuous innovation and inclusivity in engineering education practices.

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1

Introduction

"In learning, you will teach, and in teaching, you will learn."

– Phil Collins

1.1 Context

In Italy, approximately 150,000 students graduate with a master's degree every year, and 20% of them are engineers. However, the definition of an engineer can vary widely, prompting us to ask how people are trained to become engineers, or more precisely, how engineers are trained. This fundamental query unveils a complex and multifaceted landscape that necessitates a deeper understanding.

Engineering, as a discipline, is marked by remarkable diversity in its practice and applications. Consequently, the training of engineers must be adaptable, rigorous, and responsive to the evolving needs of society and industry. It is within this intricate framework that the field of Engineering Education (EE) emerges as a vital catalyst for change and improvement.

EE is a dynamic and multidisciplinary research domain dedicated to enhancing the quality of teaching and learning strategies in engineering. Its scope transcends traditional educational boundaries, encompassing all levels of instruction, from kindergarten to higher education. This field is characterized by a profound commitment to three core principles:

Diversity Recognizing the importance of a diverse engineering workforce, EE endeavors to broaden participation in engineering programs, ensuring that individuals from all backgrounds have the opportunity to pursue engineering careers.

Competency Development EE is devoted to nurturing the competencies and skills required by modern engineers, preparing them to tackle complex challenges and innovate effectively in their respective fields.

Sustainability Sustainability, both in the educational process itself and in its alignment with societal and industrial needs, is a central concern. EE seeks to create sustainable educational practices that resonate with the evolving demands of the world.

Politecnico di Torino (Polito), a distinguished Italian technical university, has played a pivotal role in shaping the landscape of EE in Italy. With an annual intake of approximately 5,000 engineering bachelor's students and around 8,000 bachelor and master graduates, Polito stands as a beacon of EE in the country. Notably, since the academic year 2010/11, the university adopted a pioneering approach by offering a common first-year curriculum for all incoming students, regardless of their chosen major. This innovative approach allowed students to build a strong foundational knowledge base before specializing in their chosen fields.

The commitment to student-centered education at Polito was further underscored from 2012 onwards. These years were dedicated to enhancing teaching quality and implementing actions aimed at supporting students in their educational journey. It is during this period that the author of this dissertation, while pursuing her undergraduate studies at Polito and serving as a student representative in the Academic Senate, actively participated in the university's efforts to revise quality assurance procedures following the guideline provided by the Ministry of Education.

After completing her Master's degree in Electrical Engineering with a focus on Smart Grids at Politecnico di Milano, the author won, back to the Polito, a research scholarship. Her mission: to document the teaching and learning innovations that had been implemented during the 2012-2018 rectoral period at Polito. This engagement allowed her to establish connections with the EE community in Europe, setting the stage for future endeavors in the realm of EE Research.

In 2018, a new chapter unfolded at Polito with the birth of the TEACH research group - Teaching Engineering Avant-garde Challenge Host. Simultaneously, the author embarked on her Ph.D. journey as a part-time student at TU Dublin, affiliated with the CREATE research group, while also assuming the role of a research fellow at Polito. It was during this period that the idea of exploring the role and impact of Engineering Education Researchers (EERs) in the Italian context emerged organically.

The dissertation that follows chronicles the narrative that unfolded after these pivotal moments in the author's academic journey. It invites the reader to delve into the rich tapestry of EE Research within the Italian context, providing insights, discoveries, and a vision for the future.

1.2 Research objectives

In the realm of EE, the fusion of pedagogy and engineering creates a dynamic field where theory and practice converge. This unique blend of disciplines is instrumental in cultivating the essential skills required to navigate the complexities of modern engineering. It goes beyond mere academia; it is a transformative journey that molds novices into proficient engineers with a profound understanding of intricate challenges.

EE Research stands as a dynamic and evolving field, harmonizing theoretical insights with practical applications. It plays a pivotal role in fostering problem solvers who can tackle multifaceted issues, including those of ethical and societal significance. Interdisciplinarity is at the heart of EE Research, nurturing awareness, ethical values, and effective communication skills, all while recognizing engineers as integral societal stewards.

In the context of Italy, there exists a noticeable void in dedicated EE Research. While STEM education is gaining traction, EE often remains overshadowed. This gap is particularly striking given Italy's rich heritage in engineering, which underscores the need for dedicated research efforts. The absence of such initiatives impedes the overall development of STEM education in the country. This stands in contrast to other countries such as the US where EE research departments have been firmly established for several years now. This disparity emphasizes the necessity for

Italy to further cultivate its EE Research landscape to keep pace with international advancements in the field.

Filling this void is of paramount importance. It not only elevates STEM education but also ensures that engineering, a cornerstone of progress, receives the attention it rightfully deserves. Globally, there is a growing body of research contributions in EE, but practical insights specific to Italy's educators, students, and engineers are conspicuously lacking.

This dissertation endeavors to address this pressing issue by contributing to the strengthening of EE Research in Italy. Its mission is to shape education and engineering practices, equipping educators with evidence-based methodologies, enriching student experiences, and ultimately cultivating a proficient engineering workforce capable of tackling the complex challenges of the modern world.

In summary, this research serves as a bridge to close Italy's educational gap, thereby enhancing EE. It transforms both educational and engineering practices, benefiting not only students but also society at large.

1.2.1 Main research question and objectives

In the dynamic field of EE, where pedagogy and engineering intertwine, the central question guiding this research is:

What role does an Engineering Education Researcher (EER) play within an esteemed Italian technical university like Polito, and how does their work positively impact both students' understanding and lecturers' roles?

This inquiry revolves around two primary objectives. Firstly, it aims to delve into the multifaceted role of an EER within the unique academic context of Polito. This involves a comprehensive exploration of the various dimensions and responsibilities that define the EER's role in this esteemed institution.

Secondly, this research strives to provide a compelling narrative of the tangible benefits that an EER can bring to the educational ecosystem at Polito. It endeavors to illustrate how the work of an EER can enhance students' comprehension of engineering concepts and simultaneously contribute to the refinement of lecturers' teaching practices.

Beyond the immediate context of Polito, this study holds profound implications for both the field of EE and the broader educational landscape in Italy. It unfolds in two significant dimensions.

Firstly, within the realm of educational enhancement, the research aims to contribute to the continuous improvement of EE. It draws from existing literature while adapting it to the specific Italian context. By doing so, it seeks to elevate the overall quality of the learning experiences offered to students, thus nurturing a more proficient cadre of engineers for the future.

Secondly, it emphasizes the vital role that research plays in shaping pedagogical practices. By spotlighting the pivotal role of an EER, the research underscores the intrinsic value of rigorous inquiry in the educational domain. This, in turn, supports lecturers in their ongoing professional development, fostering a culture of continuous improvement in teaching.

As for the anticipated outcomes, the study aims to provide concrete evidence of the positive impact an EER can have within PoliTo. It will furnish empirical data that demonstrates how the work of an EER can resonate throughout the educational landscape, not merely as an abstract concept but as a tangible force for change.

Furthermore, this research aims to inform educational practices by showcasing effective strategies and interventions. By doing so, it seeks to benefit both students, who will receive a more enriching educational experience, and lecturers, who will be equipped with valuable insights to enhance their teaching methods.

In conclusion, this investigation serves as an illuminating exploration into the invaluable contributions of an EER within the Italian technical university context. It aspires to set a precedent and serve as a guiding framework for future endeavors aimed at the enhancement of EE, not only within the confines of Polito but as a beacon of inspiration for the entire educational landscape of Italy.

1.2.2 Methodological framework

The methodology employed in this research is designed to systematically gather and analyze data from a diverse range of EE research projects and initiatives conducted within the academic context. This mixed investigation approach encompasses both quantitative and qualitative data, providing a holistic and inclusive representation of EE research activities at PoliTo. The methodology is structured to offer a comprehensive understanding of the multifaceted influence of EE research within the university, including innovative teaching methods and the development of educational technology.

The foundation of this research lies in the systematic collection of data from various projects and initiatives involving the EER at PoliTo. These projects serve as practical manifestations of the possible actions of EER, covering a wide spectrum of activities from novel teaching methods to advancements in educational technology. This comprehensive approach ensures that the research accounts for the diversity and richness of EE research within the university.

Qualitative data analysis techniques form the core of this methodology. A rigorous examination of both quantitative and qualitative data from each subproject is undertaken to derive meaningful and contextually rich conclusions regarding the impact of EER activities. Thematic analysis and content analysis will be applied to uncover recurring patterns, emergent themes, and nuanced narratives from the perspectives of both students and lecturers.

The analysis extends beyond surface-level observations, delving into the underlying factors, perspectives, and experiences that shape the impact of EER on education and pedagogy. By employing thematic and content analysis, the research aims to provide a nuanced understanding of the intricate dynamics at play within EE research initiatives.

This methodological framework facilitates not only the assessment of the current landscape of EE research at PoliTo but also offers valuable insights into the potential for future enhancements in having the support of the EER. It provides a solid foundation for deriving contextually relevant and practically applicable conclusions from the diverse array of projects under consideration.

In addition to the overarching mixed investigation approach, each project within the study follows an independent methodology tailored to its specific objectives. Projects like Matabì, SMaILE, SAperI, and DaybyDay adhere to the Randomized Control Trial (RCT) method, ensuring a robust and controlled evaluation of their impact. Other projects, such as the Open Educational Practices (OEP) initiative, utilize semi-epistemological interviews to gather in-depth qualitative insights. See table 1.1 for the detailed list.

Project	Methodology in short
Matabì	RCT
SMaILE app	RCT + Focus group
SMaILE teachers' course	Qualitative survey
SAperI	RCT
CIAO!	Statistical analysis
TIL	Descriptive and statistical analysis
Progetto per Giovani Talenti (Honor School)	Descriptive and statistical analysis
We are HERe	Descriptive analysis, qualitative survey and focus group
TEACH-POT	Descriptive analysis and qualitative survey
OEP	Semi-ephistemological inteviews
DayByDay	RCT
Math Games without frontiers	Descriptive analysis and qualitative survey
STEMM Games	Descriptive analysis and qualitative survey
IDEA ThinkLab	Descriptive analysis and qualitative survey
GYM Call	Descriptive analysis and qualitative survey
REAL Remote Lab	Statistical analysis + students' survey
PBL FAS	Statistical analysis + students' survey
Online Solutions	Descriptive analysis
W-STEM	Mixed approach
WeReLaTe	Mixed approach
Med-Mobility	Mixed approach

Table 1.1 Methodology adopted for each project

This dual-layered methodology, consisting of a general mixed investigation approach and project-specific methodologies, enhances the depth and breadth of the research, allowing for a nuanced exploration of EER within PoliTo.

The implementation of this research methodology involves a carefully planned timeline to manage the intricacies of conducting multiple projects concurrently. A graphical representation (Fig. 1.1) of this timeline is provided, offering readers a visual guide to the temporal evolution of each subproject. This timeline serves as a roadmap, illustrating the parallel development and interconnected nature of various research run by the EER. Each project is accompanied by a cross-reference to the specific subsection in this dissertation where it is discussed.

1.3 Dissertation structure

Now that we have established the context and outlined the primary research objectives, it is important to provide a roadmap of the structure that this dissertation will follow. This section offers a brief overview of how the subsequent chapters are organized to systematically address the research questions and objectives.

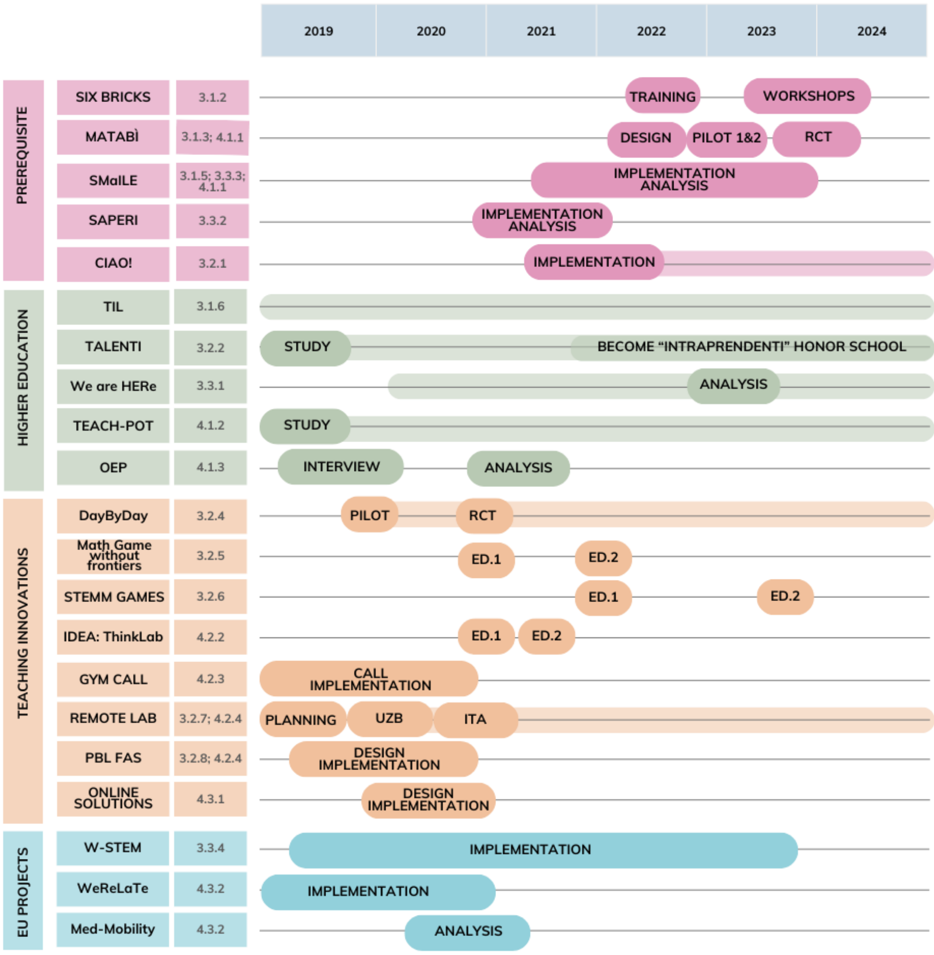


Fig. 1.1 Projects' timeline

Chapter 2: Background Information and Theory

In the second chapter, we embark on a comprehensive exploration of the background information and theoretical foundations that underpin this research. We begin by delving into the landscape of EE Research. This involves defining the field, identifying its various subfields, and understanding its broader context.

We then pivot to the role of technology in education, specifically in the context of EE. Here, we investigate how technology is integrated into engineering pedagogy and the impact it has on student learning.

The chapter further delves into the cognitive and behavioral theories that inform teaching practices, shedding light on the science behind effective instruction. It also examines the role of spatial ability in EE, a factor that significantly influences students' success.

Finally, we provide insights into the Italian educational landscape, offering an overview of the country's educational system, its focus on STEM fields, and the significance of Polito as a renowned institution for technical education.

Chapter 3: Nurturing STEM Pathways: Fostering Learning and Diversity

Chapter 3 embarks on a journey through the various stages of STEM education. It begins with a preparatory study that highlights the importance of early exposure to STEM concepts. We explore initiatives such as SixBricks and Matabì, which enhance understanding through hands-on activities, and delve into the potential of game apps in middle and high school contexts.

Moving into higher education, this chapter explores programs like CIAO! and the Talenti Project, which aim to create inclusive and stimulating learning environments. It also discusses innovative approaches such as reverse inclusion and the role of laboratory activities in comprehensive understanding.

A significant portion of this chapter is dedicated to addressing gender perspectives in EE. We examine recruitment and retention strategies through projects like "We Are HERe" and explore initiatives like SAperI that tackle gender gaps using spatial ability as a lens.

Chapter 4: Enhancing Engineering Education from the Lecturer's Perspective

Chapter 4 shifts the focus to the perspective of educators. It explores training opportunities and professional development, highlighting the importance of reinforcing engineering prerequisites in K-12 education and faculty development for higher education lecturers. It also delves into the concept of Open Educational Practices (OEP) and their potential benefits.

The chapter then delves into various course approaches and methodologies, emphasizing the role of Instructional System Design (ISD). It showcases examples like ThinkLab, TEACH-GYM, and innovations in course delivery.

Lastly, we explore global perspectives in EE, discussing how institutions adapt to educational challenges, embrace online solutions, and foster international mobility, training, and networking opportunities.

Chapter 5: Discussion

In Chapter 5, we embark on a comprehensive discussion that serves as the culmination of our research journey. This critical chapter delves deep into the key findings and insights garnered from the preparatory aspects, technological applications, and training strategies explored in Chapters 3 and 4. It is within this section that we synthesize the wealth of knowledge acquired, providing a holistic perspective on the transformative role of technology in EE. Through rigorous analysis and reflection, we draw meaningful conclusions that contribute to the advancement of educational practices at Polito and beyond, shaping the future of EE.

Chapter 6: Conclusion

Finally, in this concluding chapter, we provide a concise summary of the primary findings and notable contributions stemming from this comprehensive research endeavor. Alongside this, we conscientiously address the limitations encountered in our study to ensure a well-rounded perspective.

Moreover, we emphasize the pivotal insights garnered throughout this research and propose compelling avenues for future investigations within the realm of EE, specifically within the Italian educational landscape. Our goal is to guide and inspire further exploration and development in this evolving field.

2

Background information and theory

"You can't connect the dots looking forward; you can only connect them looking backwards. So you have to trust that the dots will somehow connect in your future."

– Steve Jobs

2.1 Exploring the Landscape of Engineering Education Research

This pivotal subsection of the chapter "Background Information and Theory" shall unravel the intricate tapestry of Engineering Education, unveiling its essence, significance, and multifaceted dimensions with the precision and depth requisite of a scholarly dissertation.

2.1.1 Definition

At the confluence of pedagogy and engineering, the intellectual terrain of Engineering Education (EE) unfolds: a dynamic realm wherein the amalgamation of educational theory and pragmatic engineering practice imparts transformative pedagogical endeavors. The overarching aspiration of EE resides in the systematic cultivation of knowledge, skills, and attitudes requisite for individuals to navigate the intricate labyrinth of contemporary engineering landscapes. This is not a mere academic pursuit; it is an orchestrated odyssey that propels aspirants from the realms of novices to the echelons of proficient engineers, armed not solely with technical dexterity, but also endowed with a profound understanding of the intricate mosaic of engineering challenges.

Central to the ethos of this educational paradigm is the delicate fusion of theoretical foundations and experiential engagement: an intricate symbiosis that empowers learners to transcend the boundaries of formulae and equations. Beyond the realm of technical competence, EE nurtures a cognitive transformation, wherein learners evolve to become adept problem solvers who adeptly navigate the ethical, societal, and environmental complexities inherent to their professional endeavors.

Yet, EE, in its expansive essence, extends beyond the realm of cognitive enrichment; it resonates as an interdisciplinary endeavor that kindles a holistic metamorphosis. It imparts, not merely cognitive prowess, but also nurtures metacognitive awareness, fosters ethical discernment, and hones the art of effective communication. The intricate tapestry of EE encapsulates the intrinsic understanding that engineers are not mere architects of technical innovation, but stewards of societal advancement, bearing the weight of profound ethical and cultural implications. A compendium of scholarly works collectively affirms the dynamic evolution of EE Research as an interdisciplinary, international, and nascent field that remains in the process of crystallizing its identity and scope.

Bernhard's insightful exposition in 2015 resonates with the assertion that EE Research, in essence, can be aptly regarded as an extension of engineering research, offering engineers a distinctive avenue to contribute through their acumen in design, technology, and materiality [1]. This underscores the potential of engineers to become influential contributors in the realm of educational inquiry, shaping the contours of EE research through their profound understanding of engineering systems and their transformative impact on society.

However, Jesiek, Newswander and Borrego's discerning observation in 2009 underscores the lingering ambiguities within the identity of EE research[2]. A lack of precise delineation about the field's objectives and aspirations persists, warranting the concerted efforts of stakeholders to elucidate and articulate the overarching goals that animate EE research. Such clarity, Jesiek posits, shall engender a more cohesive trajectory for the field's evolution, facilitating informed discourse and strategic development.

Finelli and Rasoulifar's discerning perspective, articulated in 2014, resonates with the proposition that a standardized taxonomy and organizational framework are indispensable for navigating the intricate terrain of EE research [3]. An organized lexicon and structure would catalyze a more interconnected research community, fostering symbiotic collaborations among researchers and facilitating wider accessibility to research outcomes. This, in turn, could yield manifold advantages, including heightened visibility of research initiatives and a more robust network of scholarly exchange.

Building upon this intellectual foundation, Borrego and Bernhard's pronouncement in 2011 reinforces the pivotal role of EE research in augmenting the preparation and training of engineers to confront formidable engineering challenges [4]. EE research, she contends, is an instrumental instrumentality in amassing the competences necessary for tackling the intricate web of technological, societal, and environmental complexities that characterize contemporary engineering landscapes.

Thus, a constellation of seminal perspectives from Fordyce [5], Bordogna, Fromm and Ernst [6], Fomunyam [7], and Viegas, Marques and Alves [8] coalesce to accentuate the diverse facets inherent to the definition of EE. While Fordyce eloquently illuminates the development of cognitive faculties, Bordogna Fromm and Ernst's proposition advocates for a holistic integration of knowledge and human potential. Fomunyam's discourse within the milieu of the Fourth Industrial Revolution underscores the transformative power of innovative technologies. Viegas , Marques and Alves, on the other hand, amplifies the imperative of EE to synchronize with the dynamic rhythms of the engineering business realm, thereby advocating for a pedagogical landscape adaptable to emerging technologies and societal demands.

In summation, EE research, as a burgeoning and globally linked domain, stands as an instrumental vanguard of the broader EE landscape. EE research, characterized by its interdisciplinary nature and resonant international impact, serves as a crucible for the fusion of educational research methods with engineering pedagogy. By acknowledging the distinctive contributions engineers offer to this evolving field, addressing the ongoing ambiguity surrounding its identity, fostering organized communication among scholars, and embracing the inexorable interplay of education, technology, and societal evolution, EE research charts a promising trajectory towards enriching the educational milieu of engineering disciplines.

2.1.2 Fields

The field of EE research encompasses a tapestry of interconnected domains that collectively converge to forge a comprehensive and nuanced understanding of the educational dynamics intrinsic to engineering disciplines. The taxonomy developed by Finelli, Borrego, and Rasoulifar in 2015, and further refined until September 2021, unfurls a plethora of fields, each characterized by distinct dimensions, foci, and research avenues [9]. This taxonomy is a testament to the expansiveness of EE research and the diverse lenses through which it is studied.

Within the taxonomy, we navigate through the intricacies of EE research, encountering a spectrum of fields that cast light upon different facets of EE. Organized with meticulous precision, these fields reveal the multifaceted endeavors that researchers and educators undertake to propel the evolution of engineering pedagogy. From assessment methodologies to instructional design, from diversity considerations to outcomes assessment, each field is a thread woven into the intricate fabric of EE research. This taxonomy serves as a guiding compass for researchers, educators, and practitioners, offering a systematic framework to navigate the expansive landscape of EE research.

Within this scholarly framework, we discern a hierarchical arrangement that encapsulates an extensive spectrum of subjects, ranging from assessment methodologies to diversity considerations, from instructional methods to professional practice. This taxonomy, like a symphony with myriad instruments, harmonizes the symphony of EE research into distinct thematic movements.

Assessment Within this branch, the quest for gauging the effectiveness of EE unfolds. It intricately weaves together methodologies for organizational assessment, student performance evaluation, and program efficacy measurement. As educational virtuosos, we navigate the intricacies of assessment tools, from traditional grading systems to innovative approaches like concept inventories, aligning our pedagogical endeavors with the pursuit of educational excellence. Through assessment, we cultivate a culture of continuous improvement, ensuring that the educational experience resonates with maximum impact. As stewards of educational quality, we analyze data to refine our symphony of instruction.

Design Like skilled artisans, we delve into the realm of design, where the alchemy of creativity converges with methodical processes. This branch unwraps the art of ideation, the precision of modeling, and the significance of problem definition. Comprising design practice, design projects, and the very process of design thinking, this domain is the crucible where creativity converges with methodology. It delves into ideation, modeling, problem definition, and the transformative journey from concept to reality. In design, we synthesize imagination with pragmatism to craft innovative educational experiences. We design the score that guides learners on their educational journey.

Diversity In an era emphasizing inclusivity and cultural consciousness, this domain sheds light on diversity concerns. Ranging from gender and race to underrepresentation and workplace diversity, it grapples with the multifaceted dimensions of bias, equity, and inclusivity within EE. With an unwavering commitment to inclusivity, we meticulously examine bias, equity, and the cultivation of learning environments where every voice resonates with equal significance. Through addressing diversity, we ensure that education becomes a beacon of equitable opportunity. We celebrate diversity as harmonious notes in the grand symphony of learning.

Educational Level Across the arc of learning, we journey through diverse educational levels, from the foundational stages to advanced frontiers. Each chapter of education reveals distinctive pedagogical nuances, and we, the pedagogical voyagers, adapt our approaches to suit the evolving needs and aspirations of learners at each educational juncture. Through educational levels, we cater our educational symphony to meet the developmental crescendo of our learners. We adjust our orchestration to match the changing rhythms of student growth.

Educational Setting Like explorers of pedagogy, we traverse the terrain of educational settings. Within classrooms, laboratories, and virtual domains, we decipher the alchemy of effective learning environments. These settings become our canvases, on which we paint the symphony of knowledge transmission and skill acquisition. Through optimizing educational settings, we create immersive spaces where learning is not just a process, but an experience. We curate the ambiance that harmonizes learning and inspiration.

Educational Technology Amidst the digital renaissance, we step into the realm of educational technology. Here, we decipher the fusion of learning and technology, exploring digital tools, online platforms, and gamified learning experiences. As technology's symphonists, we compose the digital notes that resonate within the orchestration of EE. Through educational technology, we amplify the reach and impact of our educational symphony. We harness technology as a conductor's baton, guiding the tempo of modern education.

Instruction At the heart of education lies instruction, and this field dissects it comprehensively. From conceptual learning and faculty roles to instructional methods and professional development, it illuminates the strategies that facilitate the transmission of knowledge and the cultivation of skills. We don the educator's mantle, shaping the cognitive landscape of learners, and orchestrate the process by which knowledge finds its harmonious resonance within their minds. In instruction, we guide the ensemble of learning, setting the pace and rhythm that propels students toward mastery.

Outcomes The ultimate goals of education crystallize within this domain. Communication skills, critical thinking, creativity, and ethical competence are among the outcomes that are meticulously examined. It also probes into the professional practice and career trajectories that EE engenders. As sculptors of educational impact, we mold students into proficient engineers, preparing them for the symphony of professional practice. We assess the resonance of educational notes as they reverberate through the corridors of industry and academia.

Professional Practice As stewards of the bridge between education and practice, we step into the domain of professional preparation. Here, we delve into the nexus of industry and academia, exploring internships, cooperative education, and the cultivation of professional acumen that resonates through real-world engineering pursuits. Through professional practice, we align the educational symphony with the rhythm of industry demands, ensuring that graduates are ready to play their part in the engineering orchestra.

Recruitment and Retention This branch unfurls as a saga of student progression. Ensuring the continuous influx of talent into EE and the persistence of learners through their educational journey are the focal points of this field. From academic support and advising to recruitment strategies and student development, it explores the mechanisms that foster student success. Through recruitment and retention, we ensure that the symphony of learners remains harmonious, nurturing every note from the moment they join the chorus to the day they graduate.

Related Fields Our scholarly compass extends to the interdisciplinary intersections where EE converges with related domains. Through this branch, we explore the symbiotic relationships that nurture cross-disciplinary understanding and innovation, enriching the educational landscape. In related fields, we cultivate bridges that extend the reach of our educational symphony, allowing echoes of EE to resound in diverse disciplines.

Research Approaches This domain provides the methodological toolkit that underpins EE research. From data collection methods like surveys and interviews to research ethics and theoretical frameworks, it equips researchers with the tools needed to investigate the complexities of EE. Through research approaches, we explore the symphony of empirical investigation. We wield methodological instruments to compose research scores that unravel the mysteries of effective pedagogy.

Theoretical Frameworks Like philosophers of pedagogy, we immerse ourselves in the realm of ideas and frameworks. Here, we explore the philosophical underpinnings that shape our understanding of education. From cognitive theories to critical perspectives, we embrace diverse lenses that illuminate the intricacies of the educational tapestry. Through theoretical frameworks, we compose the theoretical harmonies that underlie our educational symphony. We harmonize philosophical contemplation with empirical exploration.

Teams In this symphony of collaboration, we embrace the collaborative ethos intrinsic to engineering. We dissect the dynamics of teamwork, spanning multidisciplinary interactions and the symphony of collective creation. As conductors of collaborative learning, we nurture the harmonious blend of competencies mirroring the ensemble of engineering practice. Through teams, we orchestrate the harmonious collaboration that resonates within the educational symphony. We conduct the ensemble of expertise, blending diverse talents into a unified masterpiece.

This taxonomy transcends mere categorization; it orchestrates a symphony of interdisciplinary exploration. Each field resonates as a distinct melody, harmonizing collectively to enrich our comprehension of EE research's multifaceted panorama. This taxonomy stands as an invaluable guidepost for scholars, educators, and practitioners, facilitating their navigation through the labyrinthine avenues of EE and inspiring a harmonious symphony of research and pedagogical innovation.

As we delve into the intricate taxonomy of fields within EE research, it becomes evident that each field is a distinct note in the symphony of pedagogical innovation and scholarly exploration. These fields, meticulously organized and characterized by their unique dimensions and foci, offer a comprehensive framework to navigate the multifaceted landscape of EE. However, the melody of EE research is not confined solely to these fields; rather, it resonates within a broader context that draws from the insights of scholars who have journeyed through the intricate terrain of education, engineering, and research methodology. These scholars enrich our understanding of the dynamic and interdisciplinary nature of EE research, underscore the rigor demanded by its methodologies, and illuminate the diverse knowledge artifacts that contribute to its advancement. As we transition into the 'Context' subsection, it becomes imperative to explore these scholarly contributions, for they lay the foundation upon which the taxonomy of fields thrives: a harmonious interplay between theory and practice, innovation and tradition, and collaborative endeavors that illuminate the path toward educational excellence.

2.1.3 Context

The significance of the taxonomy of fields within EE research is deeply rooted in a multifaceted context that draws from the insights of scholars navigating the intricate landscape of education, engineering, and research methodology. This convergence of perspectives illuminates the dynamic and interdisciplinary nature of EE research, as well as the rigorous methodologies and diverse knowledge artifacts that underpin its advancement.

Amidst this contextual backdrop, Fortenberry [10] underscores the need for focused methodologies akin to those embraced in the biomedical community, emphasizing tailored research methods as essential in the context of EE. This resonates with the intricate nature of EE, where optimizing pedagogy demands methodological precision akin to the intricate research practices in fields like medicine.

Delving further, Allendoerfer et al. [11] navigates the journey of becoming an interdisciplinary scholar within EE research. The discourse emphasizes the integral role of community in scholars' trajectories, highlighting the collaborative ethos that characterizes the field. This sentiment finds harmony with the taxonomy's acknowledgment of interdisciplinary synergy and collaborative endeavors, illustrating how shared insights and collective exploration enrich scholars' pathways.

Shifting focus to fundamental questions about engineering learning, Streveler and Smith [12] directs our attention to the transformative potential of EE research. The shift from curriculum development to probing the core of EE aligns with the thematic movements within the taxonomy, accentuating the importance of exploring pedagogical paradigms and strategies to enhance learning outcomes.

Turning to the exploration by Johri et al. [13] of knowledge artifacts within EE research, we witness an echo of the taxonomy's commitment to diverse perspectives. The discourse on knowledge circulation, maintenance, and creation resonates through the interdisciplinary intersections embedded within the taxonomy's fields. Johri's observations regarding the transition to open access online publications mirror EE research's capacity to foster accessible and collaborative knowledge dissemination.

These scholarly voices harmonize to create a contextual symphony for EE research. Madhavan et al. [14] employs data mining techniques to uncover the intricate network topology within EE research, portraying it as a vibrant community of practice. Meanwhile, Nawaz et al. [15] defines EE research through a keyword-based scheme, illustrating how scholarly exploration shapes the evolution of the field's scope. Douglas and Purzer [16] casts light on the pivotal role of assessment strategies, resonating with the taxonomy's emphasis on assessment as a core thread within the educational tapestry.

Lohmann [17] emphasizes the global dimension of EE research's growth, underscoring its role in fostering global engineering excellence. This aligns with the taxonomy's recognition of educational settings and contexts, where international perspectives enrich the symphony of pedagogical innovation.

Collectively, these scholarly voices interweave to amplify the broader context of EE research: a dynamic, interdisciplinary realm where rigorous methodologies, collaborative ethos, and diverse knowledge artifacts converge to elevate EE. As the taxonomy of fields harmonizes with these insights, it becomes evident that EE research is not a collection of isolated domains, but a vibrant and evolving symphony poised to shape the future of education and engineering practice.

In synthesizing the insights shared by these esteemed scholars, a harmonious symphony of overarching themes emerges, painting a vivid portrait of EE research as a dynamic and evolving interdisciplinary field. Different scholars [10, 11] call for methodological precision emphasising on the collaborative ethos, resonating through the shared journey of interdisciplinary scholars. While others shift of focus from curriculum development to probing educational paradigms illustrating EE research's transformative potential [12, 13].

As Madhavan et al.[14] and Finelli et al. [9] uncovers the intricate network topology of EE research, and Nawaz et al. [15] defines its scope, they collectively weave the narrative of EE research as a vibrant community of practice. These scholars' voices harmonize to underscore EE research's role in nurturing global engineering excellence and responding to the evolving demands of technology and society.

Through this synthesis, a resounding truth emerges: EE research transcends mere categorization; it becomes a symphony of collaborative exploration, harmoniously embracing interdisciplinary perspectives to enrich EE. The dynamic interplay of methodological rigor, collaborative ethos, and diverse knowledge artifacts not only amplifies EE research's potential but also solidifies its role in shaping the future of education and engineering practice. This intricate narrative of scholars' insights resonates harmoniously with the taxonomy of fields within EE research. As these voices intertwine, they paint a vivid panorama that underscores EE research's dynamic and evolving nature. This interplay between diverse viewpoints and thematic domains illuminates the collaborative and interdisciplinary essence of EE research: a field where the taxonomy's threads intricately interweave, enriching our understanding of education, engineering, and their symbiotic resonance.

2.2 Technology & Education

Advancements in technology have ushered in transformative changes in education, shaping how knowledge is disseminated, acquired, and applied. As we step into this section, we embark on an exploration of the intricate interplay between technology and education within the context of EE research. Through the lenses of "Technology in Education" and "Education in Technology," we delve into the dynamic relationship that underpins the evolution of engineering pedagogy.

In this section, we traverse the landscape where technology and education converge, investigating how they coalesce to reshape the learning journey of budding engineers. With each subsection, we unearth the multifaceted dimensions that contribute to this dynamic interplay. From the perceptions of students towards technology's role in education to the transformative potential of digital platforms and adaptive learning technologies, we illuminate the transformative potential that technology bears. Furthermore, we navigate the realms of virtual reality, gamification, and industry collaboration, unveiling how they mold learning experiences and shape graduates into technology-driven innovators.

As we delve deeper, we also unveil the ethical considerations that are an intrinsic part of technological evolution, ensuring responsible innovation that serves humanity. The transition from "Technology in Engineering Education" to "Education in Technology" is not merely a shift in nomenclature; it marks a pivotal juncture that encapsulates the intricate interplay between these two worlds. This exploration is not limited to theoretical discourse; it resonates with the mission of institutions like Polito, shaping graduates who are not only adept at utilizing technology but also pioneering its evolution.

Together, the subsequent subsections weave a narrative that illustrates the symbiotic dance between technology and education, shedding light on their transformative potential within the realm of engineering pedagogy.

2.2.1 Technology in Engineering Education

In this subsection, we delve into the intersection of technology and EE, a pivotal area of exploration in the context of our overarching research focus on investigating the role of EE at Polito. As we probe into the university's role, technology emerges as a central enabler, shaping the educational landscape and transforming pedagogical practices. Here, our aim is to comprehend how technology is perceived by engineering students, the array of technologies they employ, and the pedagogical implications of technology integration in the educational process, aligning with your dissertation's exploration.

Perception of Technology

The perceptions of engineering students toward technology in their education form a foundational aspect of this discourse. As elucidated by Johri et al. [18], contemporary engineering students, often belonging to the millennial generation, exhibit extensive engagement with technology. Johri highlights the prevalence of mobile devices, transcending the boundaries of traditional desktop computing and signifying a paradigm shift in technology's role for learning. Mativo, Womble and Jones's investigation [19] underscores the alignment between engineering and technology courses and the personal lives of high school students, thus highlighting the perceived relevance of these courses.

Furthermore, Koretsky and Magana's insights [20] into the potential benefits of technology-mediated learning experiences underscore the significance of technology as an enhancer of both learning and engagement. The research by Friedman and Kajder [21] accentuates the proficiency of aspiring educators in merging technical skills, pedagogical content knowledge, and motivation, culminating in the effective integration of technology within instructional contexts. Collectively, these studies illuminate the constructive perceptions held by engineering students regarding technology's pivotal role in their educational journey.

The perceptions of engineering students toward technology in their education form a foundational aspect of this discourse. In the context of your investigation into the role of EE at Polito, the alignment between contemporary engineering students' engagement with technology as highlighted by Johri et al.[18], resonates significantly. These insights underscore the relevance of technology's pivotal role within the institution's educational journey.

Technological Landscape

The utilization of technology within EE is a dynamic landscape, encompassing a spectrum of tools and platforms that contribute to enhanced learning outcomes. Khan and Chiang's exploration [22] showcases the affinity of students for utilizing smartphones and social media to bolster their learning endeavors. Meanwhile, MacLaren, Singamemni and Wilson's inquiry [23] into digital pen-enabled technologies demonstrates the versatility of tools that bridge the digital and analog realms, facilitating innovative modes of learning.

Li's comprehensive review [24] delves into a panoply of information technologies, propounding their efficacy in supporting diverse learning models across EE. The exhaustive assessment conducted by Hernandez-de-Menendez and Morales-Menendez [25] encapsulates the state-of-the-art technologies adopted by leading universities, divulging trends and practices that can reshape the pedagogical landscape. These studies collectively expound the diverse array of technologies available to engineering students, underscoring the imperative for educators to cultivate awareness and adeptness in harnessing these tools to enrich the learning experience.

Navigating the diverse landscape of technology within EE aligns harmoniously with our examination of the technological challenges and opportunities faced by Polito. By weaving studies such as Khan and Chiang's exploration of smartphones and social media [22] and Hernandez-de-Menendez and Morales-Menendez's comprehensive review of technological tools [25] into the narrative, we can draw parallels between the findings and Polito's own technological endeavors, offering a nuanced understanding of technology's role.

Enhancing Accessibility through Digital Platforms

The integration of digital platforms and online resources has emerged as a pivotal avenue for enhancing the accessibility of engineering educational content for learners with diverse backgrounds and abilities. González et al.'s insights [26] illuminate the enriching potential of digital video resources within e-learning engineering courses, widening the horizons of accessibility. Ray's exploration [27] expounds on online content repositories and authoring tools, epitomizing the democratization of innovative curricula for an extensive learner demographic. Bourne, Harris and Mayadas's visionary outlook [28] contemplates the future trajectory of EE, poised as a global phenomenon facilitated by the integration of online learning paradigms. Violante and Vezzetti's comprehensive proposal [29] for an e-learning platform underscores the quintessence of appropriate pedagogical principles and advanced information technologies. Collectively, these studies articulate the transformative potential of digital platforms in ensuring equitable access to EE.

The integration of digital platforms and online resources, which fosters inclusivity and accessibility, mirrors our broader exploration of the role of EE at Polito in catering to diverse learners. The resonance between the enriched accessibility discussed in González et al.'s work [26] and Polito's commitment to an inclusive educational environment adds depth to our discourse. By aligning the findings with the institution's initiatives, we will establish a concrete connection between theory and practice.

Pedagogical Implications of Virtual Reality and Augmented Reality

The realm of virtual reality (VR) and augmented reality (AR) within EE is a frontier imbued with pedagogical implications of profound significance. Cibulka and Giannoumis's discerning analysis [30] underscores the transformative potential of VR and AR in fostering visualization skills, motivating learners, and nurturing competencies relevant to the contemporary labor market. Lanzo et al.'s empirical exploration [31] further substantiates the benefits accrued from VR and AR, enhancing both cognitive understanding and practical skills. Omar, Mokhtar and Abdullah's inquiry [32] unravels the remedial capacities of VR and AR, offering solutions to pedagogical shortcomings inherent in conventional approaches. While promising, Sulbaran and Baker [33] and Lanzo et al. [31] remind us of the imperative to diligently investigate, develop, and assess these immersive technologies. Cumulatively, these studies resonate with the notion that VR and AR hold transformative promise in augmenting conceptual understanding and practical skill development within the realm of EE.

The examination of the pedagogical implications of VR and AR intertwines seamlessly with our consideration of how technology can augment conceptual understanding and practical skill. As we explore the transformative potential expounded by Cibulka and Giannoumis [30] and the skill enhancement elucidated by Lanzo et al. [31], we can establish a coherent narrative that aligns VR and AR's transformative promise with specific educational goals.

Facilitating Teamwork through Online Collaborative Tools

The integration of online collaborative tools and platforms emerges as a promising avenue for cultivating teamwork and communication skills among engineering students navigating virtual learning environments. Chaijum's findings [34] spotlight the efficacy of social media in fostering brainstorming and enhancing teamwork. Marra et al.'s elucidation [35] affirms the positive correlation between online collaboration environments and improved learning outcomes, echoing the influence of digital interaction on skill development. Requena-Carrión et al.'s integrated approach [36] unveils a holistic strategy that synthesizes project-based learning and peer assessment, nurturing not only teamwork but also refined communication skills. Turhan, Akman, and Hacaloglu's empirical analysis [37] unveils the proficiency of collaborative tools like Google Docs in augmenting various dimensions of learning, from efficiency to satisfaction. In unison, these studies underscore the potential of online collaborative tools to mold adept and collaborative engineers, poised for success in virtual learning landscapes.

The integration of online collaborative tools aligns with our broader investigation into effective teamwork and communication at Polito. The insights derived from studies like Chaijum's [34] resonate with Polito's endeavor to cultivate collaboration among students. By interweaving these insights, will can discuss a cohesive narrative that resonates with the institution's educational strategies.

Engagement and Motivation through Gamification

Gamification, an innovative approach rooted in game mechanics, emerges as a potent strategy for instilling motivation and fostering participation among engineering students engaged in online courses. Kho at al.'s exploration [38] underscores the transformative potential of gamified learning models in enhancing engagement and enjoyment among engineering students. Barata et al.'s empirical insights [39] unravel the positive correlation between gamification and proactive behaviors, ultimately enhancing the motivation and attendance of students. Gamarra et al.'s findings [40] resonate with the prevailing theme of gamification, accentuating its capacity to galvanize motivation and participation within the engineering educational landscape. Collectively, these studies illuminate the burgeoning role of gamification, heralding a paradigm shift in how EE harnesses motivational dynamics to amplify learning experiences.

The exploration of gamification techniques in enhancing engagement and motivation echoes ourexploration of effective pedagogical strategies at Polito. The resonance between the positive outcomes revealed by Kho et al. [38] and the institution's pedagogical aspirations reinforces the alignment between research and practice. By weaving these insights into our discussion, we contextualize the relevance of gamification within the institution's educational framework.

Personalized Learning through Adaptive Learning Technologies

The realm of adaptive learning technologies stands as a transformative arena for personalizing EE, catering to the distinctive learning styles and paces of individual learners. Galeev et al.'s innovative proposition [41] aligns with the zeitgeist of personalized education, proposing algorithms to customize educational systems, acknowledging the diversity of learning approaches. Panicker et al.'s comprehensive system [42] stands as a testament to adaptive learning's potential, tailoring questions to individual understanding levels while furnishing actionable insights to instructors. Walkington and Sherman's empirical research [43] unearths the efficacy of personalized instruction, interweaving learners' interests to amplify learning outcomes. Clark and Kaw's assessment [44] corroborates the effectiveness of adaptive lessons, particularly in numerical methods courses, shedding light on the transformative potential of personalized learning pathways. Cumulatively, these studies converge to underscore adaptive learning technologies' transformative power in sculpting bespoke educational journeys within the domain of EE.

The realm of adaptive learning technologies stands as a transformative arena for personalizing EE, catering to the distinctive learning styles and paces of individual learners. The alignment between Galeev et al.'s innovative proposition [41] and Polito's commitment to a personalized education experience enriches the discourse. By connecting these studies to Polito's broader objectives, we can highlight the potential for adaptive learning technologies to tailor education at the institution.

Remote Laboratories and Simulations: Challenges and Opportunities

The assimilation of remote laboratories and simulations into engineering curricula engenders both challenges and opportunities, transforming the landscape of hands-on learning and experimentation. Fábregas et al.'s insights [45] encapsulate the liberating potential of remote laboratories, enabling experimentation from disparate locations, transcending temporal constraints. Parkhomenko et al.'s reflection [46] underscores the pivotal role of remote laboratories in internationalization and inclusivity, aligning with the ethos of EE's democratization. The inquiry of Nikolic et al. [47] underscores the evaluative challenges posed by remote laboratories, necessitating a shift toward comprehensive assessment paradigms. Sauter et al.'s empirical analysis [48] extols the immersive potential of remote labs through realism-enhancing elements, augmenting student engagement. In parallel, Abdel-Salam, Kauffman and Crossman's comparison [49] attests to the adaptability of remote laboratories, revealing their equivalence in outcomes to conventional hands-on approaches. Imbrie and Raghavan's innovation [50] reinforces remote labs' viability, elucidating their potential for equitable access to experimental setups. Collectively, these studies reflect the nuanced equilibrium between challenges and opportunities presented by remote laboratories and simulations, charting a trajectory of transformative potential.

The examination of remote laboratories and simulations aligns harmoniously with our exploration of innovative strategies to enhance hands-on learning experiences at Polito. The multifaceted challenges and opportunities posed by remote labs, as illuminated by a range of studies, resonate with the institution's endeavors to augment practical learning. By weaving these insights into our dissertation, we try to link the theoretical discourse with the practical implications of remote labs at Polito.

Ethical Dimensions of Emerging Technologies

The integration of emerging technologies, particularly artificial intelligence (AI) and machine learning (ML), within EE's fabric begets a spectrum of ethical considerations, underscoring the imperative for responsible deployment. The ethical dimensions highlighted in these studies resonate profoundly with your investigation into the responsible and ethical deployment of technology at Polito. The utilization of AI and ML technologies in EE presents ethical challenges that demand careful attention. These considerations primarily revolve around issues of bias, privacy, transparency, and the ethical use of data.

Tiwari's deliberation [51] underscores the symbiotic relationship between research and ethicality, advocating for comprehensive research to anticipate AI's ethical implications, aligning with your emphasis on research-driven approaches. Anuyahong, Rattanapong and Patcha's blueprint [52] aligns with Polito's principles of responsible technology use, establishing guidelines that resonate with the institution's commitment to ethical and unbiased technology integration. Furthermore, de Vries's discourse [53] accentuates the ethical considerations essential to the advancement of emerging technologies, mirroring our exploration of the delicate balance between technological progress and ethical responsibility. Klimova, Pikhart and Kacetl's discerning analysis [54] amplifies the ethical consciousness vital to technology's integration, aligning with our dissertation's focus on supporting the plurality of students while upholding ethical integrity.

In symphony, these studies echo the significance of imbuing ethical considerations into the forefront of technology's integration, ensuring an ethically enriched educational landscape for budding engineers. As AI and ML continue to shape EE, the responsible and ethical deployment of these technologies remains a pivotal concern, demanding ongoing dialogue and conscientious practices.

In summation, the intersection of technology and EE embodies a transformative realm where perceptions, utilizations, and impacts coalesce to redefine the educational narrative. By fostering accessibility, engagement, and inclusivity while navigating ethical considerations, technology emerges as an indelible tool that steers EE toward new horizons. The subsequent sections of this dissertation will continue to unravel the layers of this intricate interplay, excavating the profound implications for both educators and learners alike.

2.2.2 Education in technology

Transitioning from our exploration of "Technology in Engineering Education," we now shift our focus to the domain of "Education in Technology." This transition is not merely a shift in nomenclature but a pivotal juncture that encapsulates the intricate interplay between the two worlds. As we delve into the multifaceted nature of education in technology, we embark on a journey that traverses the very essence of technical universities. Their role in molding graduates into adept navigators of technology's dual trajectory: proficient in utilizing existing technologies while pioneering the evolution of new ones.

In an era characterized by the convergence of knowledge and innovation, the imperative to equip graduates with both the proficiency to harness existing technologies and the ingenuity to propel technological frontiers takes center stage. As technical universities navigate the dynamic landscape defined by rapid advancements and paradigm shifts, their mission becomes all the more poignant: to cultivate professionals who are not only adept at utilizing technology but also skilled at shaping its evolution. This distinct mission embodies the dualistic essence of technical universities: an intricate tapestry woven with threads of technology use and technology development. As the cornerstone of engineering institutions, this subsection elucidates the multifaceted nature of education in technology, delving into its core tenets through the lens of overarching missions, innovative pedagogical paradigms, ethical considerations, interdisciplinary synergies, and the symbiotic dance between academia and industry. By unraveling the intricacies of skill and innovation, this discourse aims to mold graduates into adept navigators of technology's dual trajectory; effectively using it while pioneering its evolution.

Fostering Skill and Vision

Central to the mission of technical universities is not merely the impartation of technical skills, but the holistic transformation of students into multifaceted professionals. This transformation equips graduates with advanced industrial management acumen and the coveted soft skills demanded by industries [55]. Such a mission necessitates a symbiotic relationship between academia and industry, where collaboration ensures the relevance of research to real-world demands. Cultivating specialized experts requires an intellectual ecosystem underpinned by modularity and diverse learning approaches, ensuring graduates are well-prepared for specialized roles [56]. Embracing systemic planning and a stakeholder-inclusive approach further emphasizes the commitment of technical universities, exemplified by Polito, to seamless technology integration [57]. Simultaneously, strategies for senior management recalibration emerge, harmonizing academic, research, and management dimensions [58].

Within the vast expanse of education in technology, the overarching mission of technical universities resonates clearly: to equip graduates with not only the technical skills to employ existing technologies but also the visionary acumen to drive technological evolution. This distinct mission exemplifies the symbiotic relationship between academia and industry, where collaboration ensures that the research being conducted is not just an academic exercise but a response to real-world demands. The graduate attributes of the accrediting bodies must also be met. Some of these could be used to support your argument. This mission necessitates a pedagogical ecosystem that is modular, adaptive, and diverse, empowering graduates to excel in specialized roles while embracing interdisciplinary synergies. This consideration of graduate attributes aligns with the broader goal of preparing students to meet industry standards and expectations while fostering their ability to contribute to technological advancements in a meaningful way.

Striking the Balance: Practical Skills and Innovative Thinking

Within the corridors of technical universities, an intricate equilibrium is pursued: a balance between imparting practical skills and nurturing innovative thinking. Barak and Goffer [59] underscores the necessity for systematic techniques that stimulate innovation and critical problem-solving within technology education. Venugopal and Davuluri [60] advocates for a holistic training framework that nurtures students' nascent innovative ideas into tangible breakthroughs. As technical universities transition into technology generators [61], pedagogical innovation takes center stage, with methods such as the CDIO-approach and interdisciplinary integration gaining prominence in refining students' prowess [62, 63].

The delicate equilibrium that underpins education in technology is one that fosters the synthesis of practical skills and innovative thinking. While practical skills are essential, the cultivation of innovative thinking is equally crucial in an ever-evolving technological landscape. Pedagogical innovation, such as the CDIO-approach and interdisciplinary integration, has gained prominence in refining students' prowess, ensuring that they are prepared to tackle the dynamic challenges of the modern world.

Pioneering Pedagogical Paradigms: Technology Use and Development

The educational odyssey unfolds through diverse pedagogical strategies, tailored either to technology use or technology development. The teacher and lecturer's acumen and experiences play a pivotal role in shaping technology-integrated pedagogy [64]. A spectrum of instructional approaches, from self-paced modules to interdisciplinary methodologies, serves as scaffolds for imparting technology education [65]. The distinction between novice and experienced educators propels the evolution of technological integration [66]. Focusing on essential knowledge is underscored by Winn [67], while Tsanev [68] outlines a methodological model for training students in technology pedagogy. Having explored the pedagogical strategies in education for both technology use and development, we proceed to unravel the ethical dimensions that permeate this realm.

Ethical Dimensions

Embedded within the fabric of education in technology lies a profound ethical dimension. As technology's power to shape societies grows, ethical considerations become a moral compass that guides responsible innovation. Technical universities, like Polito, recognize that preparing students for the digital age involves more than just technical knowledge. It demands an ethical awareness that navigates the intricate web of ethical quandaries inherent in technology use and development. Notably, the scholars posit that the entwinement of ethics and technology education transcends the realm of academic discourse, embodying a moral obligation that underpins the very essence of responsible innovation [69, 70].

Within the esteemed precincts of institutions such as Polito, the discourse on ethics reverberates resoundingly, echoing through the corridors of academia as students grapple with the intricate web of ethical quandaries inseparably linked to technology's use and development. It is within this crucible of higher learning that the theoretical contemplation of ethics seamlessly converges into a realm of actionable pedagogy. Here, students are not merely passive recipients of ethical principles; instead, they become active agents of ethical decision-making, equipped to navigate the complex landscape of real-world ethical dilemmas [71, 72].

In an era where technology's influence extends far beyond the confines of innovation labs and classrooms, technical universities shoulder a profound responsibility: a responsibility to cultivate not only technical prowess but also an ethical consciousness that permeates every facet of technological advancement. Scholars such as Himmelreich [73] argue that acknowledging the ethical awareness necessary for preparing students for the digital age transcends the conventional boundaries of education. It is an acknowledgment that the impact of technology reverberates through society, shaping the very contours of human existence. Thus, the ethical dimensions within education in technology stand not as isolated fragments of consideration but as an interconnected tapestry that threads its way through the entire spectrum of technological learning [74].

Then, the realm of ethical dimensions in technological education is one that demands profound contemplation and decisive action. As ethical considerations guide the evolution of technology, technical universities like Polito stand as bastions of responsible innovation, nurturing graduates who are not only adept in the technical domain but also steadfast in their ethical resolve. The engagement with ethics is not a passive endeavor confined to lecture halls; it is an active and dynamic pedagogical pursuit, equipping learners to navigate the intricate ethical landscape of our technology-driven world [69].

Collaborative Endeavors: Industry Integration and Real-world Relevance

Central to the narrative of education in technology is the collaborative synergy between academia and industry. The partnership between these two realms bridges theory and application, ensuring that graduates are not only equipped with theoretical knowledge but also possess the practical acumen demanded by industries. This collaboration blurs the lines between academic learning and real-world technology development, creating an ecosystem where innovation and application converge seamlessly.

The symbiotic alliance between academia and industry emerges as a pivotal force, melding theoretical foundations with practical application. Technical universities, exemplified by Polito, adeptly navigate this intersection, acknowledging that technology's realm extends beyond academia's ivory towers to the industrial landscape. Collaborations with industrial partners blur the lines between academic learning and real-world technology development, creating fertile ground for knowledge exchange, research synergy, and skills alignment. Buniyamin, Zakaria and Mohamad [55] echoes this, asserting that the overarching mission resonates in graduates possessing technical prowess, industrial acumen, and coveted soft skills. Sabitov et al. [56] adds to this perspective, emphasizing the creation of an integrated intellectual system for training specialists based on modularity, learning variability, multidisciplinary teachers, and participation of leading teachers in industry-specific research and development. Tseng, Huang and Chen [75] further underscores the importance of collaboration, highlighting the role of financial support from governments and industries in resource allocation and technological innovation within universities.

Zavbi and Vukasinovic [76] introduces the concept of academia-industry collaboration as a means to foster technical and professional competencies in new product development, contributing to the bridge between academic learning and real-world technology development. Hoc and Trong [77] reviews the collaboration between universities and industries, offering insights into the motivations and barriers within the national innovation system of Vietnam. These collaborations are essential for promoting technology transfer and economic development. Overall, the collaborative efforts between technical universities and industries serve as catalysts for promoting real-world relevance, knowledge exchange, and the convergence of innovation and application.

Harnessing Interdisciplinarity: Navigating Complex Challenges

The importance of interdisciplinary education cannot be overstated. Graduates must possess the ability to navigate complex challenges that often span multiple domains. The interdisciplinary ethos fosters a mindset that transcends disciplinary boundaries, enabling graduates to tackle intricate problems with a holistic perspective.

In a technology-rich landscape where challenges seldom manifest in isolation, the need for holistic perspectives is paramount. Technical universities recognize that graduates' efficacy in tackling intricate contemporary problems relies on an interdisciplinary mindset. As Collins et al. [78] articulates, interdisciplinary education guides students toward a convergence of diverse insights. Within this milieu, engineering's harmonious confluence with other disciplines fosters a synergetic mindset. This interdisciplinary ethos resonates with Azimbayeva [61], amplifying both technological competence and the creative agility needed to navigate multifaceted challenges. By embracing this ethos, technical universities, including Polito, catalyze graduates capable of transcending disciplinary boundaries to forge innovative solutions, embracing complexity and charting novel courses.

In the intricate tapestry of education in technology, we have explored the multifaceted facets that shape graduates into adept navigators of technology's dual trajectory: equipping them with the prowess to harness technology effectively and pioneer its evolution. From fostering skill and vision to striking the delicate balance between practical skills and innovative thinking, from ethical considerations that guide responsible innovation to the collaborative endeavors that bridge academia and industry, and finally, to the transformative role of interdisciplinary education in tackling complex challenges, we have unearthed the foundational pillars of this dynamic domain. The subsequent sections of this dissertation will delve deeper into each dimension, weaving a narrative that illuminates their interconnectedness and their transformative potential in molding graduates for a technology-driven future.

In culmination, the exploration of "Technology & Education" unveils a tapestry woven with intricate threads of innovation, ethics, collaboration, and interdisciplinary synergy. We have journeyed through the transformative impact of technology on education, revealing how it empowers learners, shapes pedagogical paradigms, and fosters holistic growth. From the immersive potential of virtual reality to the motivational dynamics of gamification, each facet signifies a stepping stone towards molding graduates into adept navigators of technology's dual trajectory. The ethical dimensions that underpin technological advancement stand as a guiding compass, ensuring that innovation remains responsible and humane. The symbiotic alliance between academia and industry echoes as a resounding force that blurs the lines between academia's ivory towers and real-world technological landscapes. The interdisciplinary ethos resonates as a mindset that transcends disciplinary boundaries, equipping graduates to tackle complex challenges with a holistic perspective. As we conclude this exploration, we stand at the precipice of a new educational era: one where technology and education are interwoven, propelling the evolution of engineering pedagogy and preparing graduates to shape the future of technology.

2.3 Science behind teaching

The convergence of cognitive neuroscience and pedagogy forms an intricate tapestry, woven with the threads of cognitive processes and neuroeducational insights. This synthesis offers a transformative perspective, shedding light on the inner workings of the human mind and their profound implications for effective teaching. As the educational landscape evolves, the significance of understanding how attention, perception, memory consolidation, brain plasticity, learning modalities, and metacognition interplay within the cognitive canvas becomes paramount. This exploration delves into the symphony of cognitive processes and neuroeducational insights, unraveling the intricate orchestration that guides students on their educational journey. By navigating the domains of attention, perception, and memory consolidation, and unveiling the dynamic interaction between brain plasticity, learning modalities, and metacognition, educators are poised to craft pedagogical experiences that resonate harmoniously with the intricate rhythms of the human mind. As we embark on this intellectual odyssey, the intersection of cognitive neuroscience and pedagogy unfolds as a transformative nexus, ushering EE into an era of enriched learning experiences and innovative instructional practices.

2.3.1 Cognitive Processes and Neuroeducational Insights in Engineering Education

The burgeoning field of neuroscience has cast a transformative light on the landscape of pedagogy, offering invaluable insights into the intricate workings of the human mind and its implications for instructional practices within EE. Within this intricate cognitive landscape, attention serves as the sentinel of sensory inputs, guiding the mind's focus toward relevant information. Perception, in turn, transforms these inputs into meaningful constructs that shape understanding. As the journey through cognition unfolds, memory consolidation solidifies the acquired knowledge, engraving it into the cognitive canvas for enduring retention. This subsection embarks on a transformative odyssey through the realms of attention, perception, and memory consolidation, shedding light on their profound impact on the pedagogical tapestry of EE. As we traverse this cognitive terrain, we uncover the nuanced interconnections that shape the cognitive landscape of learning in this domain.

Attention: The Gateway of Perception

The cognitive process of attention stands as the gateway through which the human mind filters and selects information from the sensory barrage that envelops us. In the context of EE, attention takes on a pivotal role in orchestrating the acquisition of knowledge. Understanding the theory of attention, its fundamental nature and modulatory mechanisms, unveils insights into how attentional mechanisms influence the cognitive processes of engineering students within educational settings. Moreover, this comprehension offers a profound avenue for optimizing instructional strategies, thereby fostering enhanced learning outcomes.

Attention, often referred to as the "gateway of perception," is a cognitive process that governs the selection, allocation, and enhancement of sensory inputs for processing. At its core lies the intricate interplay between bottom-up stimuli-driven processes and top-down goal-directed control. In the context of education, attention becomes a cognitive asset through which students navigate the influx of information within engineering classrooms.

Scholars such as Keller et al. [79] delve into the nuances of attention within educational contexts, proposing frameworks that illuminate how attention can be harnessed to design effective active-learning strategies. The work of Olney et al. [80] sheds light on the transformative potential of attentional manipulation through task structure alteration, a concept that catalyzes increased learning by optimizing attentional resources.

Within the lecture halls and laboratories of engineering classrooms, students engage in the intricate act of selective attention. The question emerges: How do students allocate their cognitive resources to focus on pertinent information while filtering out distractions? A deeper exploration unveils the interplay between top-down cognitive control and bottom-up saliency mechanisms, as students prioritize concepts, equations, and visual representations that align with their learning objectives.

Therefore, in EE, a symbiotic relationship between attentional mechanisms and instructional strategies emerges. The research conducted by Rapp [81] introduces the concept of attention-aware systems, technology-driven platforms that dynamically adapt interfaces and content to align with users' focus on vital material. This highlights how an understanding of attention can reshape educational technology, enhancing student engagement and knowledge absorption.

Chandler and Sweller's exploration [82] of the split-attention effect underscores the significance of cognitive load in instructional design. By integrating text and diagrams physically, educators can circumvent cognitive overload, facilitating seamless information processing. Collectively, these sources suggest that the integration of attentional insights into pedagogical design can potentiate instructional strategies, fostering an enriched learning environment for engineering students.

The role of attention extends beyond the theoretical realm, resonating with the cognitive landscape of engineering students. Ulker et al.'s study [83] unveils the positive correlation between heightened attention and meditation with improved learning outcomes among engineering students, accentuating attention's pivotal role in knowledge assimilation.

Hsing, Bairaktarova and Lau's investigation [84] into the spatial problem-solving tasks of engineering students, utilizing eye gaze analysis, unravels the intricate interplay between attention and spatial cognition. Furthermore, Hames and Baker' work [85] highlights the interrelationship between learning styles, cognitive performance, and attentional dynamics among engineering students.

Importantly, Alias, Akasah and Kesot [86] accentuates the affective dimension of learning within EE, wherein attitudes, self-efficacy, and emotional engagement interface with cognitive processes, ultimately shaping students' attentional focus and cognitive outcomes.

Moreover, the dimension of divided attention beckons us to inquire into the capacity of engineering students to multitask effectively, juggling the absorption of theoretical principles while manipulating intricate mathematical derivations. How does cognitive load theory come into play here [87]? This facet delves into the constraints of working memory and the cognitive penalties incurred when students navigate multiple cognitive demands. Impelluso [88] used cognitive load theory to redesign a computer programming class for mechanical engineering students, resulting in improved learning and reduced dropout rates.

In synthesis, the mosaic of scholarly voices resoundingly underscores the profound role of attentional mechanisms in shaping the cognitive tapestry of engineering students. By deciphering the intricate interplay between attention and cognition, educators can craft instructional strategies that synchronize harmoniously with attentional dynamics, thereby elevating the landscape of EE into an era of enriched learning experiences and optimized pedagogical practices.

As we navigate the intricate interplay between attention and cognitive processes, the exploration now extends to the realm of perception, where the cognitive tapestry continues to unfold, revealing how engineering students construct meaning from their sensory encounters.

Perception: The Canvas of Cognition

Perception, an intricate cognitive tapestry, shapes how engineering students construct meaning from the sensory inputs that surround them. In the context of EE, the phenomenon of perceptual biases assumes significance.

Perceptual biases, influenced by cognitive schemas and prior experiences, can inadvertently color students' interpretations of complex engineering diagrams, graphs, and spatial representations. How do these biases affect comprehension and problem-solving abilities? The exploration of this realm unveils the cognitive strategies educators can employ to ameliorate misconceptions and facilitate accurate perceptual interpretations.

Perception, a fundamental cognitive construct, empowers individuals to interpret sensory inputs and construct meaningful mental representations. The theory of perception illuminates how individuals organize, recognize, and categorize stimuli from their surroundings, shaping the cognitive terrain within which engineering concepts are explored.

Scholars such as Nelius et al. [89] reveal the impact of perceptual biases on engineering design, demonstrating how confirmation bias can inadvertently lead to the acceptance of inaccurate problem causes. Ball, Evans and Dennis's model of design processes [90] introduces a "satisficing" procedure that reflects initial solution concepts: a manifestation of perceptual tendencies that favor efficiency over exhaustive optimization.

Amidst the academic corridors of EE, perceptual biases and cognitive schemas wield a profound influence on the interpretation of complex concepts. Van Dantzig et al.'s research [91] supports the intertwining of perceptual and conceptual systems, highlighting the intricate relationship that shapes how individuals perceive and process information.

Offert and Bell's exploration [92] delves into machine vision's inherent biases, demonstrating how perceptual topology affects interpretability. Montfort et al.'s findings [93] resonate, indicating how students may inappropriately generalize causal relationships, impacting their comprehension of diverse engineering content.

Furthermore, Zhou's discourse [94] delves into cognitive biases within technical communication, unveiling how perceptual dynamics influence how technical communicators and users navigate past experiences, stimuli, decisions, and social contexts.

Encompassing a multitude of perspectives, the scholarship collectively emphasizes that an awareness of perceptual dynamics can wield transformative influence on instructional strategies within EE. Hardré and Kollmann's study [95] underscores the evolution of learners' preferences, suggesting that as competence deepens, the selection of less familiar tasks fosters growth.

Reisslein and Moreno's insights [96] foreground the significance of instructional design in pre-college EE, urging the incorporation of diverse representations and problem-solving designs. Shafqat and Saqlain's correlation [97] between learning styles and information scanning accentuates the importance of tailoring teaching methodologies to individual proclivities.

Integrating these insights, Ng et al.'s review [98] underscores the potency of instructional design principles in enriching learning experiences across EE.

In synthesis, the symphony of scholarly voices resounds, illuminating the integral role of perceptual biases and cognitive schemas in shaping the interpretative panorama of complex engineering concepts. By weaving an understanding of perceptual dynamics into the fabric of instructional strategies, EE transcends boundaries, fostering a learning milieu where cognition, perception, and pedagogy converge harmoniously.

As our exploration of the cognitive intricacies of perception draws to a close, we venture deeper into the cognitive landscape, where memory consolidation stands ready to engrave the intricate tapestry of engineering knowledge into enduring understanding.

Memory Consolidation: Engraving the Cognitive Landscape

Memory, the cornerstone of learning, is a complex cognitive construct that involves encoding, storage, and retrieval. Within EE, memory consolidation emerges as a linchpin in the acquisition of enduring knowledge. The exploration of memory consolidation within pedagogical frameworks prompts us to probe into the mechanisms of synaptic plasticity and long.term potentiation, the neural underpinnings of memory storage. How can educators harness these insights to optimize the spacing and repetition of learning material, fostering durable memories that withstand the test of time?

Memory serves as the repository of acquired knowledge and experiences, encompassing not only long-term memory but also the critical domain of working memory. Working memory, a fundamental concept widely accepted within cognitive psychology and education, plays a pivotal role in the learning process. It is characterized by its limited capacity and susceptibility to overload, particularly when learners are exposed to a barrage of information. In essence, working memory is dominant when individuals are learning new concepts that have not yet been committed to long-term memory. The model of working memory, as proposed by Baddeley [99], has gained prominence in understanding this cognitive facet.

In scholarly discourse, Bego et al. [100] and Hopkins et al. [101] accentuate the potency of retrieval practice and spaced learning: methods that enhance memory consolidation. Their findings resonate with the educational realm, showcasing how these strategies augment performance in engineering mathematics classrooms. Barbosa et al.'s exploration [102] reveals how memory processes within project-based organizations differ from traditional settings, further emphasizing the impact of memory consolidation on knowledge retention that crosses organizational boundaries.

In EE, the awareness of memory consolidation's role emerges as a transformative force that informs pedagogical approaches. Cowan et al.'s perspective [103] underscores the dynamic role of post-encoding consolidation, facilitating the selective stabilization of experiences into enduring memories that fuel adaptive learning.

Roediger and Butler's insights [104] underscore the catalytic role of retrieval practice in long-term retention. The potency of this strategy lies in its ability to enhance mnemonic recall, enabling the flexible transfer of knowledge across diverse contexts. Storm, Bjork and Storm's deliberations [105] highlight the nuanced nature of optimizing retrieval practice, factoring in the vulnerability of information to forgetting: an essential consideration in designing effective pedagogical sequences.

In unity, Khajah, Lindsey and Mozer's heuristics [106] offer a practical compass for optimizing review performance, aligning with memory consolidation principles to foster enduring knowledge acquisition.

Furthermore, the question arises: How do educational technologies (virtual simulations, interactive modules, and immersive environments) interface with memory consolidation processes? This aspect delves into the interplay between cognitive psychology and technological innovation, offering a nuanced perspective on the integration of digital tools in EE.

The papers suggest that educational technologies can have both positive and negative effects on memory consolidation processes. Puddifoot and O'Donnell[107] argues that the over-reliance on verbatim information storage technologies may hinder the formation of abstractions and insights from newly learned information. However, Larsen [108] suggests that retrieval practice, which involves repeated acts of retrieval, can improve long-term retention of information. Marsh and Butler[109] describes three theoretical principles from cognitive science that have implications for educational practice, including introducing desirable difficulties during learning and processing information to extract meaning. Finally, Reber and Rothen[110] argues that educational app-development needs to be informed by the cognitive neurosciences of learning and memory, and that focusing on retrieval practice can be an efficient way to boost learning outcomes.

Collectively, the symphony of scholarly voices harmonizes to reveal the profound role of memory consolidation in shaping the pedagogical landscape. McGaugh's retrospective [111] unveils a century's progress in comprehending the temporal dimensions of enduring memories, highlighting the temporal dynamics that impact learning.

Fandakova and Bunge's interconnection [112] between memory research and educational practice underscores the reciprocal synergy, nurturing the bridge between laboratory insights and classroom strategies. Sander et al.'s model [113] introduces a dual-component framework of memory development, underscoring the intricate interplay between associative and strategic components: foundational aspects in educational contexts.

In synthesis, the kaleidoscope of scholarship collectively articulates that an understanding of memory consolidation, including the critical role of working memory, serves as a guiding beacon for refining pedagogical strategies within EE. As educators align instructional methodologies with memory dynamics, the realm of learning transforms into an enriched environment where enduring knowledge flourishes, and the mastery of complex engineering concepts becomes a resounding testament to the harmonious interplay between memory and pedagogy.

In weaving the intricate threads of attention, perception, and memory consolidation, this exploration has shed light on the cognitive architecture that underpins the learning odyssey of engineering students. Yet, the true power of these insights lies in their translation into tangible pedagogical design, where theory seamlessly transforms into practice. Sanchez Rojo's perspective [114] invites us to craft a pedagogy of attention: a pedagogy that intertwines psychological and philosophical dimensions to optimize knowledge absorption and retention. As we delve into the realm of visual perception, Nückles' exploration [115] beckons us to harness technology such as eye-tracking, catalyzing evidence-based pedagogical principles that enhance instructional strategies. Styles [116] unifies attention, perception, and memory within a cognitive framework, reminding us of the seamless interplay among these cognitive pillars.

Guided by these scholarly voices, we are compelled to intertwine attentional dynamics, perceptual understanding, and memory consolidation into the fabric of instructional design. By capitalizing on the malleability of attention, educators can orchestrate learning experiences that captivate the mind, aligning content with students' cognitive proclivities. Infusing the pedagogical journey with an understanding of perceptual biases, educators can tailor explanations and representations, nurturing a comprehensive grasp of intricate engineering concepts. Moreover, as memory consolidation, including working memory, stands poised to etch knowledge into enduring memory, educators can strategically space learning episodes, enabling students to retrieve and apply complex concepts with confidence.

In weaving these principles into pedagogical design, EE ventures into an era marked by evidence-based excellence. By honoring attention, perception, and memory, including working memory, as pillars of cognitive engagement, educators craft environments where students thrive intellectually and holistically. In doing so, the realm of EE advances, enriched by the harmonious symphony of cognition and pedagogy.

Neuroeducational Insights

The burgeoning field of neuroeducation bridges the gap between cognitive neuroscience and pedagogy, channeling neuroscientific findings into actionable strategies for effective teaching.

The neural canvas upon which learning modalities are painted invites us to explore the theoretical underpinnings that shape the brain's response to diverse educational avenues. Within this intricately woven tapestry, the symphony of scholars resonates, revealing that the human brain's intricate architecture is poised to respond to diverse learning modalities through a symphony of multimodal-multisensory interactions, modular organization, brain states, and effective connectivity. In this realm, the brain and learning modality engage in a symphonic duet that promises to elevate the pedagogical landscape to a crescendo of enriched learning experiences.

At the heart of this intricate neural dance lies the concept of multimodal-multisensory interactions. Drawing from James, Vinci-Booher and Munoz-Rubke's perspective [117], the brain becomes a receptive symposium, engaging with the world through multisensory processing, where sensory inputs intertwine to facilitate learning interactions. This perspective echoes the work of Bassett et al.[118], who harmonizes this idea with modular organization: a concept that carves the neural landscape into interconnected modules. In his exploration, modular structure emerges as a beacon of predictive prowess, as the brain's flexibility within these modules emerges as a harbinger of learning magnitude in future endeavors. The symphony of multimodal-multisensory interactions invites educators to compose teaching strategies attuned to the neural rhythms of diverse learners.

Ritter et al.[119] casts a nocturnal spotlight on the brain's dynamic states, where sleep emerges as an essential actor in the symphony of learning. Brain states, particularly during sleep, compose a harmonious melody that orchestrates memory consolidation. These oscillatory movements, akin to musical notes, emerge as pivotal orchestrators of plasticity and cross-brain communication. Meanwhile, Büchel, Coull and Friston's work [120] paints a canvas of effective connectivity: neural pathways that intertwine to underlie associative learning. Within these neural passages, the symphony of connections between cortical systems specialized for distinct functions forms the bedrock of associative learning. The convergence of these perspectives harmonizes into a profound revelation: the human brain's response to learning modalities is not a solo act but a harmonious symphony of interactions.

Green and Bavelier [121] guides us through the intricate choreography of training regimens, revealing strategies that guide the acquisition of knowledge, preparing learners for flexible application across diverse contexts. This symphonic ensemble of studies orchestrates a profound revelation: the human brain's response to learning modalities is not a solo act but a harmonious symphony of interactions that invite pedagogues to compose teaching strategies attuned to the neural rhythms of diverse learners. In this realm, the brain and learning modality engage in a symphonic duet that promises to elevate the pedagogical landscape to a crescendo of enriched learning experiences.

The captivating phenomenon of neuroplasticity beckons us to peer into the intricate neural mechanisms that underlie the brain's astonishing ability to adapt and reshape itself in response to the influx of new information and experiences. This extraordinary capacity, often referred to as brain plasticity, illuminates a tapestry of molecular and neural processes, where the interplay between biochemical interactions, synaptic dynamics, and inhibitory mechanisms interweaves to create the symphony of adaptive learning. The symphony of plasticity offers educators the opportunity to shape pedagogical interventions that harness the brain's adaptive potential.

Gulyaeva's insight [122] guides us into the biochemical orchestration of synaptic plasticity, where the dynamic dance of molecules within synapses is the cornerstone of neural adaptability. This molecular ballet sets the stage for the transformative power of neuroplasticity. Schaefer et al.'s discourse [123] further enriches this symphony, spotlighting synaptic plasticity's role in shaping neural circuits and behaviors. Long-term potentiation and depression emerge as instrumental cadences in this melody, fostering associative memory and motor learning. The symphony of plasticity invites educators and researchers alike to explore ways in which the brain's innate plasticity can be harnessed to create pedagogical interventions that optimize learning experiences.

Metacognition, the cognitive beacon guiding self-awareness and self-regulation in learning, beckons us to embark on a journey through the neural terrain where cognition and reflection intertwine. This intricate interplay illuminates the symbiotic relationship between metacognitive strategies and the orchestration of self-regulated learning, unraveling the neural symphony that empowers students to chart their educational voyages with autonomy and mastery. Metacognition's symphony guides students towards autonomy in their learning journey.

Metacognitive strategies, those profound self-awareness tools, find their neural counterpart in executive control processes that choreograph attention, conflict resolution, error correction, inhibitory mechanisms, and emotional regulation [124]. The discourse presented by Mitsea and Drigas [125] sheds light on the strategic dance of executive functions, self-monitoring, and adaptation that comprise the metacognitive toolkit. Palincsar's lens [126] focuses on metacognitive instruction's architectural blueprint: how students are taught to weave the threads of planning, implementation, and evaluation into strategic tapestries that shape learning and problem-solving approaches. The symphony of metacognition bridges the cognitive and neural domains, casting a spotlight on the power of self-awareness in fostering the autonomy and mastery that define the educational voyage.

In culmination, the exploration into neuroeducational insights has illuminated the harmonious interplay between cognitive neuroscience and pedagogy. As we traverse the neural symphonies that guide learning modalities, brain plasticity, and metacognition, a profound orchestration unfolds. The neural canvas, intricate and dynamic, resonates with the symphony of multimodal-multisensory interactions, modular organizations, brain states, and effective connectivity, inviting educators to compose pedagogical harmonies that resonate with diverse learners. The symphony of plasticity, conducted by the intricate ballet of molecular processes and neural dynamics, beckons us to leverage the brain's adaptive potential for tailored interventions. Finally, the symphony of metacognition, directed by executive control processes, empowers students to chart their educational voyage with autonomy and mastery. This symphonic exploration is more than a harmonious convergence of disciplines; it is a call to orchestrate evidence-based pedagogies that dance in harmony with the intricate rhythms of the human mind, propelling EE into a new era of enriched learning experiences and transformative growth.

In closing, the symphony of cognitive processes and neuroeducational insights resonates as an intricate score, orchestrating the convergence of cognitive neuroscience and pedagogy within the realm of EE. As we navigate the intricate pathways of attention, perception, and memory consolidation, and immerse ourselves in the profound interplay between brain plasticity, learning modalities, and metacognition, a harmonious melody emerges. This symphony beckons educators, researchers, and practitioners to join hands in composing a pedagogical opus that harnesses the intricate rhythms of the human mind, guiding students towards a crescendo of enriched learning experiences and a profound mastery of the engineering landscape. With attention as the conductor, perception as the canvas, and memory consolidation as the engraver, the educational odyssey becomes a transformative journey where theory harmoniously converges with practice. As we collectively embrace the symphony of cognitive processes and neuroeducational insights, the stage is set for EE to ascend to new heights of excellence, ushering in an era of empowered learners and innovative educators.

2.3.2 Behavioural theory

The foundational tenets of behaviorist theories have wielded a profound influence on educational contexts, offering a lens through which the intricacies of learning behaviors and motivation can be comprehended. Behaviorist principles provide a framework for understanding how external stimuli and responses shape cognitive processes and drive learning outcomes within the realm of EE. This section delves into the core elements of behaviorist theory and their relevance to educational practices, highlighting the interplay between operant conditioning, reinforcement, and behavior modification in engineering pedagogy.

Operant conditioning stands as a pinnacle in behaviorist theory, unraveling the intricate interplay between actions and their consequences in the learning process. The seminal work of Skinner [127] laid the cornerstone for operant conditioning, elucidating how the reinforcement of desired behaviors and the extinction of undesirable ones can meticulously mold the trajectory of learning. Building on this foundation different scholars applied it in different fields. For example, Leeder [128] extends the discourse, rendering insights into the practical implications of operant conditioning in sport coaching practice, emphasizing its value in shaping athlete behaviors for optimal performance.

The orchestration of operant conditioning principles within the landscape of EE is an endeavor marked by strategic intent. Educational practitioners, analogous to skillful conductors, craft a symphony of positive reinforcement techniques to harmonize with the cognitive symposium of engineering students. Immediate feedback on complex problem-solving endeavors or collaborative projects emerges as a beacon of positive reinforcement, enkindling intrinsic motivation through the flame of accomplishment. Chen [129], for instance, adds a comprehensive layer to the discourse, weaving the intricacies of reinforcement, shaping, and schedules of reinforcement into the rich tapestry of behavior principles.

Yet, the symphony of operant conditioning is not monophonic. Negative reinforcement, when judiciously employed, transforms into a powerful instrument to alleviate learning anxieties and foster resilience. Jablonsky and DeVries [130] casts a broader net, extending operant conditioning's realm into the realm of management theory, thereby shaping a predictive model grounded in reinforcement contingencies. This interplay of positive and negative reinforcement within educational contexts serves as a dynamic scaffold, one that intertwines with the very fabric of students' cognitive landscapes.

Engineering classrooms emerge as the crucible within which operant conditioning is artfully harnessed to sculpt learning behaviors. This artistry of pedagogical design traces a path beyond mere instructional mechanics, delving into the intricate dance of positive and negative reinforcements. The integration of operant conditioning principles metamorphoses learning environments into sanctuaries for coveted behaviors, akin to a painter adorning a canvas with strokes of motivation and engagement.

The literature reveals a symposium of voices that accentuate the transformative power of operant conditioning within educational domains. Aziz et al. [131] casts a spotlight on the era of online learning during the COVID-19 pandemic, unveiling how stimulus and student reactions converge to shape behaviors in a virtual learning landscape. Peter and Nord [132] elucidates operant conditioning's nuances in marketing, unveiling how misinterpretations have cast shadows on its role within behavioral learning theory. These echoes of exploration resound in resonance with the canvas of EE, where operant conditioning threads its narrative through the very fabric of course design.

The realm of intrinsic motivation, a beacon of effective learning behaviors, emerges as an axis where operant conditioning's principles interlace with cognitive landscapes. The delicate balance between positive and negative reinforcement emerges as a fulcrum upon which educators pivot to navigate the spectrum from extrinsic rewards to intrinsic motivation. Istiqomariyah, Sutomo and Fatmawati [133] magnifies this symphony, unfurling how teachers draw upon stimulus and reinforcement to shape student behaviors and assess learning within thematic domains.

The discourse finds resonance in Chyung, Moll and Berg's [134] revelations that align intrinsic goal orientation and e-learning practices in fostering effective learning. In a similar vein, Young [135] illuminates the transformative power of application-oriented experiences led by enthusiastic faculty, nurturing intrinsic motivation through interaction, feedback, and clearly defined learning goals. The application of operant conditioning principles emerges as the transformative tool that strikes equilibrium between rewards and the cultivation of intrinsic motivation, transcending pedagogical realms.

Behavior modification emerges as a formidable catalyst, reshaping the dynamics of learning within educational and organizational contexts. Richardson [136] espouses the utility of behavior modification techniques to impart active self-management strategies, bridging cognitive and behavioral dimensions in addressing life's challenges. The literature echoes with myriad voices, converging to illuminate behavior modification's potential to instigate metamorphosis.

In the realm of EE, behavior modification weaves its tendrils to shape learning dynamics. The theories of learning that form the cornerstone of learning processes are revisited through the lens of behavior modification, as elucidated by Chebet and Rotich [137]. The interplay of learning, forgetting, unlearning, and relearning, the pulse of learning organizations, is distilled by Rupčić [138], revealing the intricate dance of behavioral adaptations. Within the contours of engineering classrooms, behavior modification resonates as an impetus that catalyzes learning dynamics, fusing cognition and behavior into a symphonic union.

Educators stand as architects, sculptors of learning environments, poised to strategically intervene and shape behaviors that resonate with desired learning outcomes. Ryan, Halsey and Matthews [139] and Dunlap adn Kern [140] cast a spotlight on modifying the classroom environment to nurture positive behavior, advocating for functional behavioral assessment as a guiding beacon. This discourse reverberates in EE, where educators wield a palette of strategies to weave a tapestry of positive behaviors.

Little and Akin-Little [141] unearths a treasury of evidence-based positive strategies for behavioral interventions within educational domains, ranging from positive behavior support to group contingencies. Within the sphere of clinical education, Arlinghaus and Johnston [142] illuminates how clinicians can be conduits of behavior change, offering practical tools to foster transformation in patient behavior.

The integration of operant conditioning principles serves as the compass guiding the design of instructional strategies that resonate harmoniously with the cognitive landscapes of engineering students. Anwar [143] beckons educators to the realm of self-regulated learning theory and the Interactive-Constructive-Active-Passive (ICAP) framework, poised to inform the selection of instructional strategies. The affective dimension of learning, championed by Alias et al. [144], unveils a framework for infusing emotion within EE, elevating learning within the cognitive domain.

The confluence of affective and cognitive dimensions within engineering pedagogy is further accentuated by Lashari et al. [145], who showcases the positive behavioral engagement catalyzed by an integrated affective-cognitive teaching approach. Ng et al. [98] forays into instructional design, aligning the First Principles of Instruction (FPI) framework with cognitive and psychomotor skill acquisition. Together, these luminaries narrate a story of instructional design informed by operant conditioning principles, embarking on a journey that resonates in the hearts and minds of engineering students, fostering profound learning outcomes.

The realm of engagement, time management, and metacognitive skills emerges as a dance orchestrated by behavior modification strategies. Caratozzolo, Alvarez-Delgado and Hosseini [146] casts the spotlight on dialogue seminars and online discussion boards, nurturing critical thinking skills that stoke the flames of intellectual engagement. Cunningham et al. [147] beckons educators to the world of metacognitive skills, urging the cultivation of ownership over one's learning journey.

The symphony continues within EE, where Abu-aisheh et al. [148] champions problem-based learning and Learner Agent Object portfolios as vehicles to sustain engagement across lectures and semesters. Adams and Blair [149] offers a gem of insight, revealing the profound connection between perceived control of time and cumulative grade point averages, emphasizing time management's pivotal role. The literature converges, unveiling behavior modification as the agent of transformation, fostering student engagement, time management prowess, and metacognitive mastery within the landscape of learning.

Can be said that the quest for balance between rewards and intrinsic motivation emerges as an exquisite challenge. Rassuli [150] invites educators to embrace a bonus credit system, incentivizing extrinsically motivated students toward engagement in classroom learning. Bolkan, Goodboy and Griffin [151] dons the mantle of transformational leadership, catalyzing intrinsic motivation through intellectual stimulation, shaping deep and strategic learning approaches.

This discourse echoes within the domain of EE, where educators navigate the nuanced terrain of extrinsic rewards and intrinsic motivation. Cameron [152] cautions educators of rewards' contextual effects, underscoring the need for a judicious orchestration that aligns with the educational landscape. Brewer, Dunn and Olszewski [153] peers into the pitfalls of poorly-designed reward systems, cautioning against their detrimental impact. Cordova and Lepper [154] extols the virtues of contextualization, personalization, and choice, illuminating the path toward intrinsic motivation's sanctuary. In essence, the balance emerges as a canvas that educators paint upon, crafting a landscape where rewards and intrinsic motivation dance harmoniously, fostering the pursuit of knowledge and meaningful learning.

As we embark on a journey to understand and cultivate learning behaviors, the canvas of EE is enriched by these narratives, inviting educators to be the conductors of transformation within cognitive landscapes. The chapters that follow weave these principles into the fabric of educational practice, crafting a symphony of learning that resonates with the hearts and minds of engineering students.

2.3.3 Spatial ability: definition and role

Spatial ability is a multifaceted cognitive capacity that encompasses the capacity to understand and manipulate nonlinguistic, symbolic information related to the representation, transformation, generation, and recall of spatial relations among objects. Following the classification provided by Linn and Petersen [155], it involves several interrelated factors, each contributing to its overall definition.

Spatial Perception

One facet of spatial ability involves spatial or visuospatial perception. This entails the ability to perceive and understand spatial relationships among objects, particularly in terms of their orientation and composition. Individuals with strong spatial perception can effectively navigate unfamiliar environments and recognize spatial patterns in various contexts [156]. It encompasses several key components:

- **Spatial Relations:** This involves understanding how objects are positioned relative to each other in space. For example, it allows individuals to determine if one object is above, below, to the left, or to the right of another object.
- **Orientation:** Spatial perception helps individuals establish the orientation of objects or spatial arrangements. This is essential for tasks such as reading maps, interpreting diagrams, and navigating through unfamiliar environments.

- **Spatial Patterns:** It includes the ability to identify and analyze recurring spatial patterns or structures. This skill is crucial for recognizing regularities in data, which can be valuable in fields like engineering, where patterns in data may indicate machinery malfunctions.
- **Progressions:** Spatial perception extends to recognizing the progression of spatial elements. This can involve identifying how a series of objects or spatial components change or evolve in relation to each other.
- **Paper Folding:** Spatial perception also plays a role in tasks like paper folding, where individuals mentally manipulate two-dimensional shapes to visualize their transformation into three-dimensional forms.
- **Navigation Ability:** An important practical application of spatial perception is the capacity to navigate effectively in both familiar and unfamiliar environments. This includes understanding spatial landmarks, directions, and routes.

In summary, spatial perception is the cognitive capacity to understand and interpret spatial relationships, patterns, and orientations among objects in the environment. It is an essential skill in various contexts, from interpreting maps and diagrams to navigating physical spaces.

Spatial Visualization

Spatial visualization is a vital component that involves the mental manipulation of spatial information, particularly in complex and multifaceted ways. Individuals with strong spatial visualization skills can mentally represent, manipulate, and transform spatial objects and configurations [157]. This facet includes the following aspects:

- **Mental Manipulation:** Spatial visualization enables individuals to mentally manipulate objects or spatial arrangements. This can involve rotating objects in the mind's eye, altering their positions, or transforming their shapes without physically interacting with them.
- **Complex Spatial Configurations:** It allows individuals to work with intricate spatial structures, such as machinery, architectural designs, or abstract spatial

representations. This is especially valuable in engineering, architecture, and design fields.

- **Multi-Faceted Manipulation:** Spatial visualization involves the capacity to engage in multifaceted manipulation of spatial information. This means individuals can simultaneously consider various spatial elements and their interactions.
- **Abstract Spatial Thinking:** Individuals with strong spatial visualization skills can engage in abstract spatial thinking, allowing them to conceptualize and analyze spatial relationships that may not have a direct physical analog.
- **Three-Dimensional Thinking:** This aspect of spatial ability is often crucial for tasks that require thinking in three dimensions, such as understanding complex 3D structures or visualizing how objects interact in space.

Spatial visualization is instrumental in professions and disciplines where complex spatial thinking is required. Engineers, architects, designers, and scientists often rely on these skills to conceptualize, design, and solve problems in their respective fields.

Mental Rotation

Mental rotation is a specific cognitive skill within spatial ability that focuses on the ability to rapidly and mentally rotate two-dimensional (2D) or three-dimensional (3D) objects in the mind's eye. This skill allows individuals to visualize how objects or shapes would appear from different orientations without physically turning them. Key aspects of mental rotation include:

- **Rapid Rotation:** Mental rotation involves the quick and efficient mental manipulation of objects. Individuals proficient in mental rotation can mentally reorient objects in their minds without much effort.
- **2D and 3D Rotation:** Mental rotation applies to both 2D and 3D objects. For example, it can involve mentally rotating a flat image of an object (2D) or mentally rotating a three-dimensional object to visualize it from a different angle (3D).

- **Spatial Transformation:** It is closely linked to spatial transformation skills, as individuals mentally transform an object's spatial configuration by changing its orientation.
- **Problem-Solving:** Mental rotation is valuable in problem-solving tasks where understanding how objects relate to each other from different perspectives is essential.
- **Real-World Applications:** In professions like engineering and medicine, professionals frequently use mental rotation to mentally manipulate and understand complex machinery or anatomical structures from various angles.

Mental rotation is a core component of spatial ability with practical applications in fields that require spatial thinking and visualization. It enables individuals to mentally explore and understand spatial relationships and configurations without physical interaction.

Spatial ability plays a pivotal role in numerous domains, particularly within STEMM fields (Science, Technology, Engineering, Mathematics, and Medicine). Professionals in these fields rely heavily on their spatial abilities to understand and communicate complex mathematical and scientific concepts. For example, engineers frequently interpret graphs, discern intricate part-whole relationships within machines, and translate mathematical models into real-world applications. In medicine, surgeons need strong spatial abilities to develop cognitive images, while radiologists must interpret X-rays with varying orientations [158].

The link between spatial ability and success in STEMM studies and careers is well-established. Longitudinal studies spanning decades have consistently shown that individuals with higher SA are more likely to excel in STEMM fields [159–161].

Lubinski [162] and Wai, Lubinski and Benbow [160] have shown that spatial ability is not only relevant but crucial in identifying individuals with the potential to excel in STEM disciplines. In fact, they argue that incorporating spatial ability assessments into talent identification procedures can reveal a previously untapped pool of talent. This underscores the significance of recognizing spatial ability as a powerful source of individual differences in educational and occupational settings, particularly within STEM domains. Individuals with strong spatial skills are better equipped to understand and communicate complex mathematical and scientific concepts, making them more likely to excel in these disciplines.

Instead, Newcombe [156] highlights an opportunity for educators to adapt their teaching styles to emphasize spatial thinking and support students in developing these skills.

Crucially, spatial ability is not a fixed attribute; it is malleable and can be improved through training at any age [163, 164]. Furthermore, the benefits of spatial development endure for several months and are transferable to various tasks and settings [164]. For instance, training in mental rotation can indirectly enhance spatial perception skills [157].

However, it's essential to distinguish spatial ability from learning style preferences, such as visual, auditory, or kinesthetic learning. Spatial ability is an integral aspect of cognition that all individuals utilize in their daily lives, combining verbal, mathematical, and spatial thinking [165]. This underscores the notion that intelligence is not fixed; individuals can develop their intelligence, including their spatial abilities, through effort and hard work [163].

Newcombe [166] reviews research indicating that spatial thinking and STEM learning are intricately connected. Importantly, Newcombe emphasizes the malleability of spatial thinking, which opens the door to educational strategies aimed at improving spatial abilities. These strategies can take two forms: direct training of spatial skills and spatializing the curriculum. This underscores the potential for educators to intentionally incorporate spatial thinking into their teaching methods to enhance STEM learning.

Uttal and Cohen [167] argues that spatial skills serve as a crucial gateway to or barrier for entry into STEM fields. Developing spatial thinking through training and education may, therefore, increase the number of individuals pursuing STEM careers. Stieff et al. [168] reinforces this idea by highlighting the importance of representational competence, which includes spatial skills, in interpreting various external representations in STEM domains.

Xie et al. [169] provides a nuanced perspective on the relationship between spatial and mathematical ability. Their meta-analysis reveals that this relationship is not simply linear. Instead, logical reasoning appears to have a stronger association with spatial ability than numerical or arithmetic ability. This insight suggests that fostering logical reasoning skills alongside spatial abilities may be particularly beneficial in STEM education.

Despite the potential for improvement, there exists a gender gap in spatial ability, with males typically outperforming females on certain spatial tasks, notably in mental rotation [157, 155]. The origins of this gap are multifaceted, involving both environmental and biological factors [158]. However, it's crucial to emphasize that biological influences do not equate to immutability, and environmental factors do not preclude change. Education plays a pivotal role in mitigating this gender gap [157].

Hoffman, Gneezy and List [170] presents compelling evidence that the gender gap in spatial abilities can be influenced by nurture. In matrilineal societies, where nurturing roles are traditionally assigned to females, this gender gap disappears. This insight underscores the role of societal and environmental factors in shaping spatial abilities.

Wang and Carr [171] proposes a comprehensive model that delves into the nuances of gender differences in spatial ability. This model suggests that these differences can be attributed to variations in working memory capacity and strategy use. Such findings highlight the multifaceted nature of the gender-spatial ability relationship and the potential for cognitive factors to influence it.

Yuan et al. [172] conducted a comprehensive study that revealed gender disparities in both large-scale and small-scale spatial abilities, with larger disparities observed in the former. This distinction emphasizes that gender differences are not uniform across all spatial tasks, with some tasks exhibiting more pronounced disparities.

Reilly and Neumann [173] conducted a meta-analysis that yielded interesting insights. The study found that masculinity was associated with better performance in mental rotation tasks for both men and women. This suggests that gender roles and identities may play a role in shaping spatial abilities. Stumpf and Eliot [174] highlights the persistence of gender differences in spatial ability over time. Even when controlling for a general spatial ability factor, mental rotation tasks consistently exhibited substantial gender-related variance. This reaffirms the idea that gender differences in spatial ability are not easily explained by a single factor.

Chan [175] investigated the relationship between gender differences in spatial ability and spatial experience. Interestingly, the study found that gender differences favoring boys could not be fully attributed to differences in spatial experience. This implies that encouraging female students to gain more spatial experience could help bridge the gender gap in spatial ability, but other factors are also at play.

In summary, the interplay between nature and nurture, cognitive factors, age-related changes, task-specific disparities, and gender roles all contribute to the intricate landscape of gender differences in spatial ability. These differences are not uniform and may vary across different contexts and spatial tasks, highlighting the complexity of this subject.

Spatial Malleability, the capacity for spatial thinking to be developed and enhanced through training, presents a promising avenue for addressing disparities and bolstering STEM education. Uttal et al.'s [176] meta-analysis of 217 research studies underscores the potential of training to improve spatial skills. Notably, these training effects can extend beyond the specific tasks directly trained. Newcombe's report [166] delves into strategies for capitalizing on this malleability in educational settings.

Direct Training

One approach involves the direct training of spatial skills. Kornkasem and Black [177] found that cognitive process-based tasks, incorporating external spatial representation, 3D technology, spatial cues, and technical languages, effectively improved spatial ability performance. Taylor and Utton [178] implemented an origami and pop-up paper engineering program for elementary-age children, yielding tangible improvements in visuospatial thinking. These findings highlight the effectiveness of targeted training interventions.

Indirect Training

Another strategy, as suggested by Newcombe [166], is to spatialize the curriculum. This approach integrates spatial thinking tools, such as spatial language, maps, diagrams, graphs, analogical comparison, physical activities embodying scientific or mathematical principles, gestures, and sketching, into educational content. Gold et al. [179] demonstrated that regular, short interventions throughout an academic semester significantly enhanced spatial thinking skills among undergraduate geology students, with additional gains in students who engaged in hands-on training interventions. These examples showcase the potential of incorporating spatial thinking into curricula as an indirect training method.

Sorby's spatial course in EE has also proven effective. Sorby and Baartmans [180] pioneered a course tailored to improve 3-D spatial visualization skills in first-year engineering students, resulting in measurable skill enhancement. Gerson et al. [181] developed multimedia software for similar purposes, which was integrated into specialized courses designed to enhance spatial skills. Sorby, Hamlin and Veurink [182] explored alterations to course structure, concluding that changes did not negatively impact skill improvements. In fact, students exhibited a slight increase in their overall enjoyment of the material. Sorby [183] refined the course methodology, emphasizing multimedia software and sketching exercises over traditional lectures. This adaptation yielded improved success and retention rates, especially among students initially lacking strong spatial skills.

These insights collectively underscore the malleability of spatial thinking and the diverse training methods available to nurture and expand these abilities. Moreover, they emphasize the role of education, whether through direct training or curriculum integration, in harnessing the potential of spatial thinking to enhance STEM education and careers.

In summary, spatial ability is a multifaceted cognitive capacity encompassing spatial perception, spatial visualization, and mental rotation. It is instrumental in STEMM fields and can be developed and improved through training. While there is a gender gap in spatial ability, education can play a pivotal role in reducing it and empowering individuals to excel in STEMM studies and careers. The subsequent sections of this paper will delve into the strategies and outcomes of a summer school program designed to enhance spatial ability in young female students, preparing them for future STEMM endeavors.

2.4 Italian context

2.4.1 Educational Overview

The Italian education system is renowned for its comprehensive structure, catering to the diverse educational needs of students across various stages of development. To gain a holistic understanding of this system, we delve into its architecture, compulsory education framework, and recent transformative developments.

The journey of Italian students commences with early childhood education, including nursery and kindergarten programs, commonly referred to as "asilo nido." These programs accommodate children up to the age of 3, fostering a nurturing environment conducive to early learning. From ages 3 to 6, children transition to "scuola dell'infanzia," a preparatory phase designed to lay essential foundations for primary education.

Primary education, known as "scuola primaria," follows, initiating at the age of 6 and spanning a duration of 5 years. This stage maintains a uniform curriculum nationwide, equipping young learners with fundamental knowledge and skills across a spectrum of subjects.

The educational journey progresses to lower secondary school, or "scuola secondaria di primo grado," which extends over 3 years. Similar to primary education, this stage adheres to a standardized curriculum, ensuring equitable access to education for all students.

Upper secondary education marks a pivotal juncture where students make profound choices that shape their educational trajectories. Three distinct tracks beckon, each spanning five years and culminating in a final examination:

- The "liceo" track caters to those pursuing a more academically oriented path, nurturing expertise in a wide range of subjects.
- Technical schools equip students with practical and vocational skills, preparing them for professions demanding specialized expertise.
- Professional schools, on the other hand, are dedicated to readying individuals for specific trades and careers, ensuring they are equipped with practical competencies.

The Ministry of Education plays a pivotal role in establishing the core curriculum for all upper secondary schools. These schools are further divided into sub-tracks, for example the Classical Lycée or the Scientific Lycée, each tailored to provide specialized knowledge and skills in various domains. Alternatively, some students opt for 3- or 4-year vocational courses administered by regional authorities, aligning their education with practical career goals.

Italian higher education adheres to the principles of the Bologna Process, bestowing Bachelor's degrees after three years of study and Master's degrees following an additional two years. Certain fields, notably medicine or law, entail longer degree programs, typically spanning five to six years.

Higher education in Italy boasts a highly specialized curriculum designed to equip students with the knowledge and competencies essential for their chosen professions. Professors and instructors in higher education are experts in their fields, often engaging in research activities alongside their teaching commitments.

A cornerstone of the Italian education system is the concept of compulsory education, spanning from the age of 6 (commencing with the first year of primary school) to 16 years old (typically culminating in the second year of upper secondary school). This mandate ensures that all eligible children enroll in educational institutions during this critical period.

Fascinatingly, Italy extends the right to receive formal training until the age of 18, exceeding the legal age of 16 when compulsory education concludes. This underscores the nation's unwavering commitment to providing educational opportunities beyond statutory obligations.

It's noteworthy that 86% of students successfully complete the full track of secondary school, which often extends to 19 years of age [184, 185]. However, only slightly over 50% of each cohort proceed to tertiary (university) education, with just 34% attaining a degree [186].

In recent years, Italian educational policies have revolved around several key priorities:

- Expanding childcare opportunities for children aged 0-2, striving to reach the European target of 33% enrollment, an increase from the current 24.7%.
- Addressing school dropout rates, which stand at 13.7% among the young population, with particularly alarming rates exceeding 20% in Southern regions.
- Elevating the percentage of young people attaining a university degree, aiming to bridge the gap between the current 27% and international benchmarks.

These initiatives reflect Italy's profound commitment to enhancing its educational landscape, ensuring equitable access, and improving educational outcomes.

Italy boasts a comprehensive and meticulously structured national curriculum that serves as the guiding framework for educational institutions throughout the country. These curriculum guidelines are thoughtfully designed to provide students with a well-rounded education, aligning with international standards and preparing them for the demands of the modern world.

The Italian national curriculum is organized across several educational stages, each characterized by unique features and priorities.

Primary Education: This foundational phase spans five years, encompassing subjects such as mathematics, Italian language and literature, history, geography, science, and physical education. Primary school teachers typically pursue an educational track during their studies, receiving specialized training in pedagogy, child psychology, and primary education.

Lower Secondary Education: Building on the primary education foundation, this stage lasts for three years and introduces more advanced topics in subjects like mathematics, sciences, literature, history, geography, and foreign languages. Lower secondary school teachers typically follow a subject track during their studies that allows them to teach specific subjects effectively.

Upper Secondary Education: Upper secondary education offers diverse tracks, including the "liceo" (Lyceum), technical schools, and professional schools. Mathematics remains a critical subject, especially in the "liceo scientifico" track, which is known for its rigorous math curriculum. Teachers acquire in-depth knowledge in their respective fields, enabling them to teach advanced and specialized subjects effectively.

Higher Education: Italian higher education follows the Bologna Process, with three-year bachelor's degrees and two-year master's degrees. Some fields, such as medicine or law, have longer degree programs. The curriculum at this level is highly specialized and designed to prepare students for their chosen professions. Professors and instructors possess advanced academic qualifications in their respective fields, often engaging in research activities alongside teaching.

Italy places a strong emphasis on STEM-related fields, recognizing their significance in the nation's economic and technological development. This commitment is evident in the curriculum's comprehensive coverage of STEM education, including mathematics, science, technology, and engineering. These subjects are vital in preparing students for the challenges of the modern world and ensuring Italy's competitiveness on the global stage.

Mathematics: Mathematics holds a central position in the Italian curriculum, especially in upper secondary education. Students pursuing STEM-related tracks, such as the "liceo scientifico," engage in advanced mathematics courses, including calculus, linear algebra, and probability, ensuring their preparedness for university-level STEM studies.

Science and Technology: The curriculum places a strong emphasis on science education, covering physics, chemistry, biology, and technology. Hands-on learning and practical experiments foster scientific curiosity and critical thinking, equipping students with essential skills.

Engineering: Reflecting Italy's engineering prowess, technical schools and vocational programs offer specialized education related to applied engineering fields. These programs prepare students for careers emphasizing practical skills and real-world applications, further contributing to the country's technological advancement.

In summary, Italy's national curriculum guidelines provide a comprehensive education framework with a pronounced focus on STEM subjects. Mathematics, science, technology, and engineering play pivotal roles in preparing students for the challenges of the modern world and securing Italy's position on the global stage. These priorities underscore Italy's dedication to excellence in education and the pivotal role of STEM disciplines in shaping the future.

The Italian education system places a significant emphasis on continuous assessment and evaluation as fundamental tools for gauging students' progress and their grasp of the curriculum. This assessment approach is designed to provide educators with valuable insights into students' learning journeys and to identify areas where additional support may be necessary.

Throughout the academic year, excluding higher education, assessment is an ongoing process. Teachers regularly evaluate students' performance through assignments, quizzes, oral examinations, and classroom participation. This continuous assessment allows educators to closely monitor individual progress, identify strengths and weaknesses, and tailor instruction accordingly.

At the conclusion of each secondary education stage, students sit for comprehensive final examinations, some of which are standardized national tests. These exams cover the subjects studied throughout the entire academic year and play a crucial role in determining students' eligibility for upper secondary schools and higher education programs, particularly in universities.

The Italian grading system employs a scale ranging from 0 to 10, with 10 representing the highest achievable grade. The passing grade is typically set at 6. Students are assessed on a subject-by-subject basis, and their final grades usually result from a combination of continuous assessment and performance in final examinations. This grading system provides a detailed and nuanced evaluation of students' knowledge and skills.

In Italian higher education, the grading system employs a scale from 0 to 30, with 30 signifying the highest attainable grade. The passing grade is usually set at 18. Grading standards are rigorous, demanding that students demonstrate a high level of proficiency to attain top grades.

In higher education, each course typically concludes with an examination, which students are free to take in other sessions if necessary. While coursework assessments are relatively rare, most courses require a final examination, which can be written, oral, or a combination of both. In graduate-level programs, a thesis or dissertation is often a mandatory requirement. This extended research project allows students to delve deeply into a specific topic within their field of study and is typically evaluated by a committee of faculty members.

In specific fields such as medicine, engineering, and education, practical training and internships are integral components of the curriculum. Students are assessed based on their performance during these practical experiences, which often involve real-world applications of their knowledge and skills.

In compulsary education standardized tests play a pivotal role in the Italian education system, offering a means to assess and benchmark students' academic performance at various stages of their education. The National Institute for the Evaluation of the Education and Training System (INVALSI) serves as the central authority responsible for designing and administering these standardized tests in Italy.

These standardized tests, including those developed and administered by INVALSI, are carefully crafted to evaluate students' knowledge and skills in key subjects such as mathematics, Italian language and literature, science, and foreign languages. They provide a standardized measure of student achievement, allowing educators, policymakers, and parents to gauge students' academic performance effectively.

INVALSI conducts standardized tests at specific compulsory assessment points during students' educational journeys. For instance, assessments take place at the second year and at end of primary education (scuola primaria), at the end of lower secondary education (scuola secondaria di primo grado) and at the end of upper secondary education (scuola secondaria di secondo grado). These assessments are critical in determining students' readiness to progress to the next educational level.

Standardized tests also feature at other key educational junctures, including the second and final years of primary school and the final year of lower secondary education, as well as upper secondary education. These tests serve as vital indicators of students' preparedness for the subsequent educational level.

These standardized tests are invaluable tools for measuring educational outcomes and identifying areas requiring improvement. The analysis of test results allows educational authorities to pinpoint strengths and weaknesses in the curriculum and instructional methods, paving the way for targeted interventions and reforms.

Moreover, test results, including those from INVALSI assessments, provide invaluable data for educational policymakers. These insights inform decisions related to curriculum development, teacher training, and resource allocation. They also contribute to the ongoing evaluation of the effectiveness of educational policies and initiatives.

Standardized tests are often designed to align with national and international educational benchmarks. This alignment enables comparisons of student performance, not only within Italy but also against international standards. Such comparative assessments help gauge the competitiveness of Italian education on a global scale. Further insights into INVALSI results in the STEM field are elaborated upon in the subsequent subsection.

2.4.2 STEM field at a glance

Within the Italian context, pivotal assessments like PISA and INVALSI offer valuable insights into the multifaceted benefits of early STEM education. PISA, a program administered by the Organisation for Economic Co-operation and Development (OECD), underscores that students exposed to rigorous STEM education at the outset of their academic journey exhibit notably superior performance in scientific literacy, mathematical proficiency, and problem-solving skills [187]. These fundamental skills not only bolster their academic accomplishments but also carry profound implications for their future career prospects, particularly within engineering fields where a strong foundation in science and mathematics is paramount.

Let's now present a comprehensive overview of the mathematics proficiency assessments conducted in primary and secondary education, drawing insights from the INVALSI reports of 2023 [188]. The aim of these assessments is to gauge students' mathematical competencies and their ability to engage with fundamental mathematical concepts. These assessments play a pivotal role in evaluating students' learning progress during their early years of education and beyond.

Mathematics Assessment in Primary Education (II Grade)

The mathematics assessment for students in the II grade of primary education serves as an initial gauge of their mathematical abilities, encompassing fundamental aspects of numerical reasoning. It offers an external perspective on students' learning progress during their first two years of schooling. This assessment assumes paramount importance as it significantly influences broader learning outcomes. Moreover, it serves as a valuable formative tool for promptly identifying areas that require additional support and consolidation.

Analyzing the trends from 2019 to 2023 2.1, it becomes evident that the national average score has experienced a noteworthy decline (-9.9 points between 2019 and 2023), particularly in the last two years under consideration. We hypothesize that this decline may still reflect the lingering impact of the pandemic on student learning.

Figure 2.2, which categorizes students' performance into various score bands, indicates a shift towards lower and higher bands, at the expense of intermediate

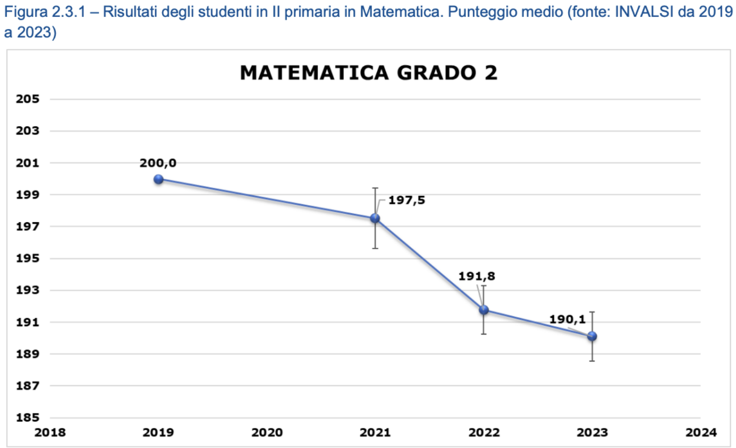


Fig. 2.1 Average score for the results for students in II primary education from 2019 to 2023

bands. In the II grade of primary education, approximately 64% of students reach at least the basic proficiency level, representing a 7-point decrease compared to 2022.

Even in this early stage of education, gender disparities in mathematics performance are apparent, with female students trailing behind their male counterparts by 6.1 percentage points. This early gender gap warrants scrutiny and emphasizes the need for appropriate measures to address it right from the outset of students' educational journey.

Mathematics Assessment in Primary Education (V Grade)

Figure 2.3 provides a concise overview of mathematics results, comparing outcomes from 2019 to 2023. Overall, there is a consistent decline in the national average score (-9.8 points between 2019 and 2023). This decline is more pronounced compared to the Italian language assessment, particularly in the last two years under consideration. Once again, it is plausible to attribute this decline, at least in part, to the enduring impact of the pandemic on learning outcomes.

Based on the score bands described in Figure 2.4 illustrates a shift towards lower and moderately lower score bands, at the expense of higher and moderately higher bands. Nonetheless, in V grade primary, approximately 63% of students still attain at least the basic proficiency level (-3 percentage points compared to 2022).

Despite being an assessment administered at the end of primary school, significant gender disparities in mathematics performance are already apparent. Female

Figura 2.3.2 – Studenti per fascia di risultato in Matematica in II primaria. Distribuzione percentuale (fonte: INVALSI da 2019 a 2023)

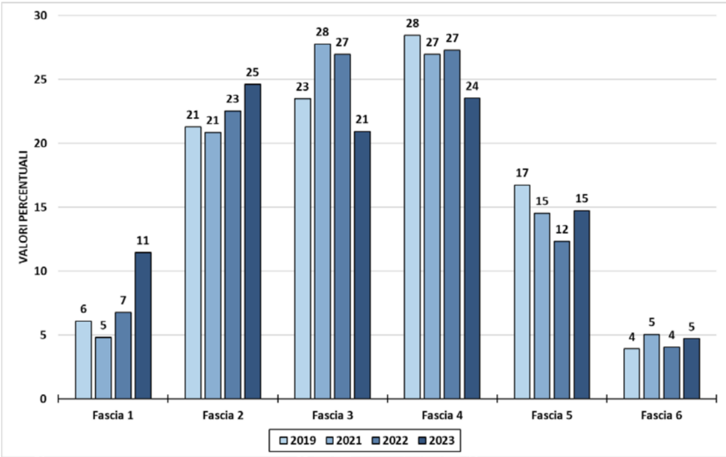


Fig. 2.2 Percentage distribution grouped by level ("fascia") for students in II primary education.

Figura 2.5.1 – Risultati degli studenti in V primaria in Matematica. Punteggio medio (fonte: INVALSI da 2019 a 2023)

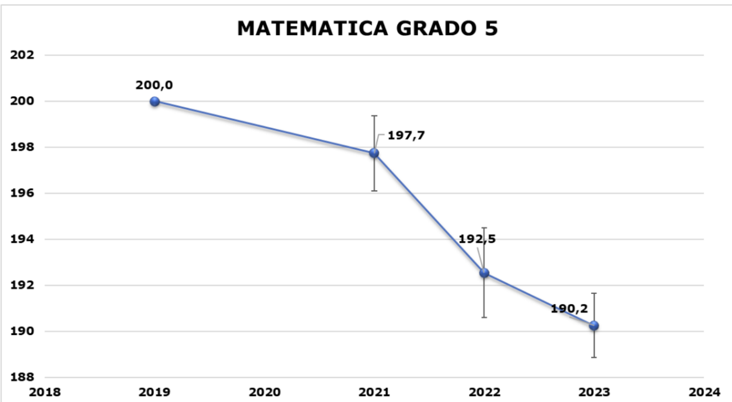


Fig. 2.3 Average score for the results for students in V primary education from 2019 to 2023

Figura 2.2.2 – Studenti per fascia di risultato in Italiano in II primaria. Distribuzione percentuale9 (fonte: INVALSI da 2019 a 2023)

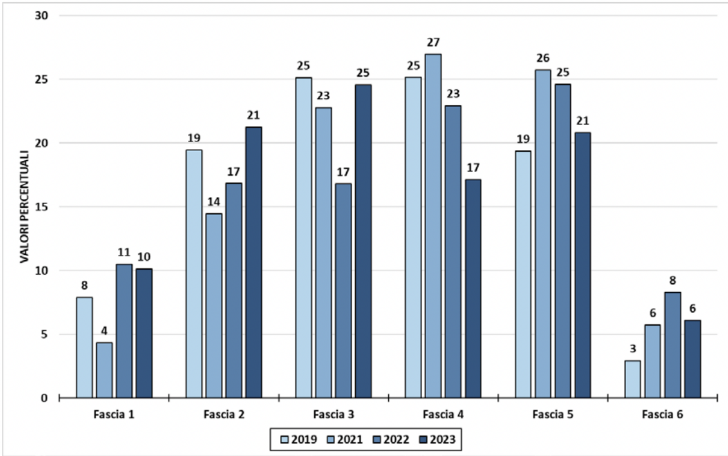


Fig. 2.4 Percentage distribution grouped by level ("fascia") for students in V primary education.

students, on average, score -4.6 percentage points lower than their male counterparts. As observed in the II grade primary assessment, the gender gap in mathematics is a concern prevalent in many countries, but in Italy, it assumes greater significance compared to other national contexts.

The socioeconomic background of students also plays a pivotal role in mathematics performance. Students from more advantaged social contexts achieve, on average, a 4.8 percentage point advantage in individual scores.

When considering all other factors, there remains a slight difference in outcomes between different regions, with the exception of the Southern and Islands regions where the disparity becomes significantly more pronounced (-5.2 percentage points).

Mathematics Assessment in Lower Secondary Education (VIII grade)

The INVALSI Mathematics assessment administered in the III grade of lower secondary education aims to measure basic mathematical competencies as students conclude the first cycle of instruction. This assessment comprises four content areas (Numbers, Space and Figures, Relationships and Functions, Data and Predictions) and provides a synthesized measure of the attainment of national educational guidelines, observable through a standardized test.

Figura 3.3.1 – Risultati degli studenti in Matematica al termine del primo ciclo d'istruzione. Punteggio medio (fonte: INVALSI da 2018 a 2023)

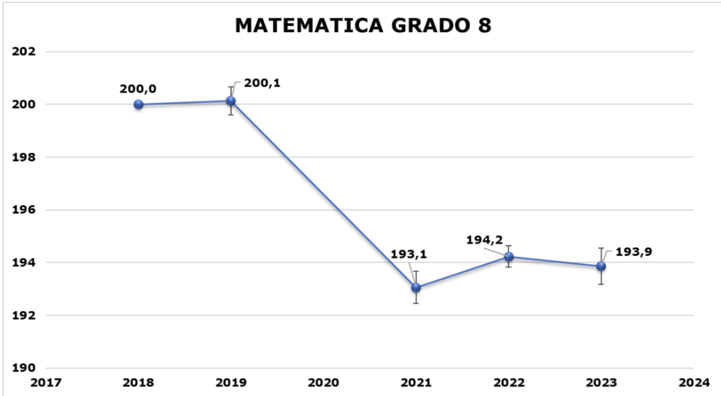


Fig. 2.5 Average score for the results for students in III Lower Secondary Education from 2019 to 2023

Figure 2.5 provides a concise overview of mathematics results, comparing outcomes from 2018 to 2023. In general, there is a decline in the national average score (-6.1 points between 2018 and 2023). This decline is more pronounced compared to what was observed in the Italian language assessment, although there is substantial stability between 2022 and 2023. This picture may signal that, despite efforts to recover learning losses following the pandemic (lockdowns and distance learning), disparities have not yet been fully bridged.

Considering the entire country, approximately 55.8% of female and male students reach at least level 3 in Mathematics. Level 3 represents outcomes in line with the essential aspects outlined in national guidelines, signifying the minimum threshold for adequacy. Levels 1 and 2 indicate inadequate performance.

With the introduction of Computer-Based Testing (CBT) in 2018, it becomes possible to compare results over time and assess how students in the third year of lower secondary education in 2023 perform in comparison to previous years.

Figure 2.6 monitors the percentage of students achieving at least acceptable results (from level 3 to level 5) at the end of the first cycle of education. Before the Covid-19 pandemic, 61% of students in 2018 and 60% in 2019 had reached at least the acceptability threshold. In all subsequent years, there is a decline, with no clear change in trend yet evident: 56%, a decrease of 4 percentage points before and after the emergency.

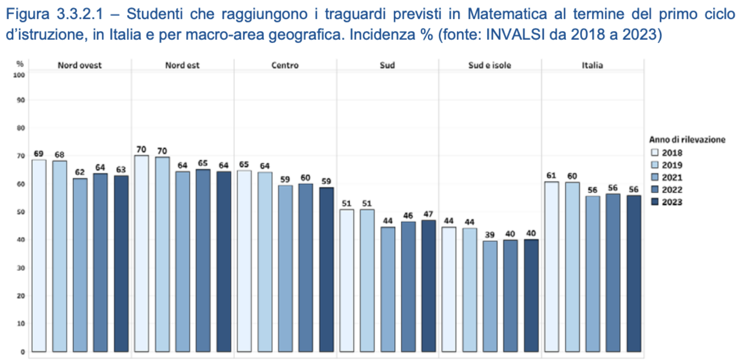


Fig. 2.6 Students who reach the expected goals in Mathematics at the end of the first cycle of education, in Italy and by geographical macro-area. Incidence %

Each student's results stem from various components. At a general level, we can attribute an individual student's observed result in an assessment to the influence of various factors: the outcomes of the teaching-learning process, specific individual characteristics (including gender, academic regularity, and the socio-economic-cultural context of the family), and the environment in which the student lives (e.g., geographic area of residence and the socio-economic-cultural context of the school). It is possible to attempt to isolate the impact associated with each of these factors, estimating their effect while holding all other conditions constant.

On average, female students achieve scores 7.3 points lower than their male counterparts. This difference equates to approximately half a school year of learning. Students who have repeated at least one year of study attain, on average, significantly lower results compared to the "typical" student, with a deficit of 22.4 points. This reaffirms that the practice of retention, overall, does not enable the recovery of learning deficits. Students from socially advantaged families have an average advantage of 8 points. When the entire school is composed of students from more socio-economically advantaged backgrounds, this advantage increases to 11.1 points. Despite considering all other previously mentioned conditions, there remains a significant difference in outcomes between different regions. The advantage is clearly in favor of the Northern regions (Northwest +8.4 points and Northeast +8.6 points) over the Central and especially the Southern regions (-10.3 points for the South and -17.1 points for the South and Islands, wider disparities compared to the Italian language assessment). Therefore, the estimated overall gap in terms of average results between

Figura 4.3.1 – Risultati degli studenti in Matematica in II secondaria di secondo grado. Punteggio medio (fonte: INVALSI da 2018 a 2023)

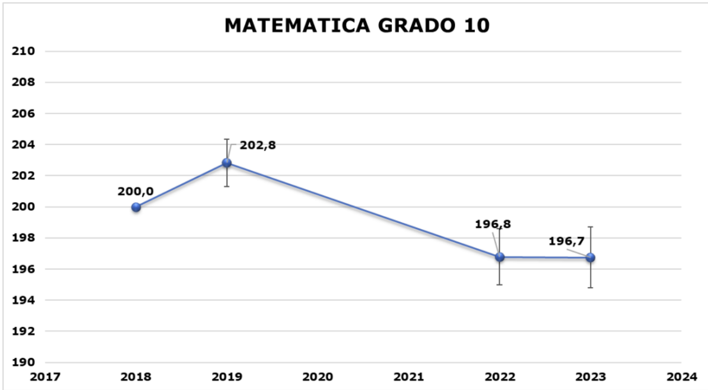


Fig. 2.7 Average score for the results for students in II Upper Secondary Education from 2019 to 2023

students from the Northeast and those from the South and Islands is 25.7 points, equivalent to approximately two years of presumed learning.

Mathematics Assessment in Upper Secondary Education (X Grade)

The Mathematics assessment taken in the II grade of upper secondary education aims to measure basic mathematical competencies at the conclusion of the first two years of the second cycle of education. This assessment is divided into four content areas (Numbers, Space and Figures, Relationships and Functions, Data and Predictions). It requires a strong foundation in basic mathematical skills, given that it occurs after ten years of schooling, and aims to provide insights into a fundamental competence necessary for exercising citizenship rights and responsibilities.

Figure 4.3.1 offers a concise overview of mathematics results, comparing outcomes from 2018 to 2023. Overall, there is a decline in the national average score since the onset of the pandemic (-6.1 points between 2019 and 2023), although not as pronounced as in the Italian language assessment. This reaffirms what was already observed at the end of the first cycle of education, namely that, following the learning losses observed during the pandemic (lockdowns and remote learning), disparities have not yet been fully recovered.

Considering the entire country without distinctions based on study tracks, it can be affirmed that 55% of female and male students reach at least level 3 in Mathematics. Remember that Level 3 represents outcomes in line with the essential aspects outlined in national guidelines and signifies the minimum threshold for adequacy. Levels 1 and 2 indicate inadequate performance.

With the introduction of CBT, it becomes possible to compare results over time and assess how students perform at the end of the first two years of the second cycle of education in 2023 compared to previous years.

Considering the evolution of the percentage of students achieving at least acceptable results (from level 3 to level 5), before the Covid-19 pandemic (2019), 62% of students had reached at least the threshold of acceptability. However, in subsequent years, a decline is observed: 54% in 2022 and 55% in 2023.

Each student's results are influenced by various factors. At a general level, we can attribute a student's observed result in an assessment to the influence of different factors: the outcomes of the teaching-learning process, specific individual characteristics (including gender, study track, academic regularity, and the socio-economic-cultural context of the family), and the environment in which the student resides (e.g., geographic area of residence and the socio-economic-cultural context of the school). It is possible to attempt to isolate the impact associated with each of these factors, estimating their effect while holding all other conditions constant.

On average, female students achieve scores 6.4 points lower than their male counterparts, an advantage equivalent to approximately half a school year of learning. Students who have repeated at least one year of study attain, on average, significantly lower results compared to the "typical" student, with a deficit of 8.1 points. This reinforces that the practice of retention, overall, does not enable the recovery of learning deficits.

Students attending scientific high schools achieve, on average, higher results by 19.7 points, while those enrolled in other types of high schools score 8.8 points lower, confirming that the outcomes in Mathematics for students in other types of high schools are more similar to those of technical education than of the classical high school. Additionally, a significant gap is observed between students in technical institutes and those in vocational schools (-16.1 points). Thus, the overall gap in terms of results between students in scientific high schools and those in vocational schools is 35.8 points, equivalent to more than two years of presumed learning.

The average advantage for students from socially advantaged families significantly decreases in the second cycle of education, settling at 1.4 points. This advantage is further compounded when the school caters to students with more socio-economic advantages, amounting to 16 points.

First-generation immigrant students achieve scores on average 8.5 points lower than students in the "typical" group (indicating that the gap in Mathematics has significantly reduced compared to the final year of lower secondary education). Similarly, second-generation immigrant students score 4.8 points lower.

Despite considering all other previously mentioned conditions, there remains a significant difference in outcomes between different regions. The advantage is clearly in favor of the Northern regions (Northwest +9.4 points and Northeast +12.5 points) over the Central and especially the Southern regions (-6.6 points for the South and -12.6 points for the South and Islands). Therefore, the estimated overall gap in terms of average results between students from the Northeast and those from the South and Islands is 25.1 points, equivalent to approximately two years of presumed learning.

Mathematics Assessment in Upper Secondary Education (XIII Grade)

The Mathematics assessment administered in the final year of upper secondary education aims to measure fundamental mathematical competencies at the culmination of the second cycle of education. This assessment is organized into four content areas (Numbers, Space and Figures, Relationships and Functions, Data and Predictions), with elements of differentiation based on the chosen study tracks.

Figure 2.8 offers a concise overview of mathematics results, comparing outcomes from 2019 to 2023. Over time, there is a noticeable decline in the national average score (-8.9 points between 2019 and 2023), although not as pronounced as in the case of the Italian language assessment, with substantial stability observed since 2021. This suggests that, following the learning disruptions caused by the pandemic (lockdowns and remote learning), the accumulated disparities have not yet been fully rectified.

Considering the entire country without distinctions based on study tracks, it can be affirmed that exactly half of female and male students reach at least level 3 in Mathematics (50%). Level 3 represents outcomes in line with the essential aspects outlined in national guidelines. Like the assessments in the III and II grades of upper

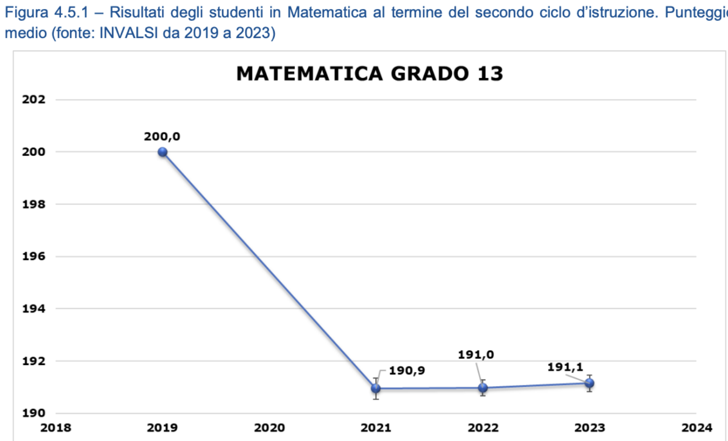


Fig. 2.8 Average score for the results for students in V Upper Secondary Education from 2019 to 2023

secondary education, level 3 signifies the minimum threshold for adequacy, while levels 1 and 2 indicate inadequate performance.

Comparing results over time and assessing how students perform at the conclusion of the second cycle of education in 2023 compared to previous years, it highlights the evolution of the percentage of students who, at the end of the second cycle of education, achieve at least acceptable results (from level 3 to level 5). Overall, before the Covid-19 pandemic (2019), 61% of students had reached at least the threshold of acceptability. However, in subsequent years, a significant decline is observed, although it stabilizes at 50% (representing an 11-percentage point decrease) from 2021 onward.

Each student's results are influenced by various factors. At a general level, we can attribute a student's observed result in an assessment to the influence of different factors: the outcomes of the teaching-learning process, specific individual characteristics (including gender, study track, academic regularity, and the socio-economic-cultural context of the family), and the environment in which the student resides (e.g., geographic area of residence and the socio-economic-cultural context of the school). It is possible to attempt to isolate the impact associated with each of these factors, estimating their effect while holding all other conditions constant.

On average, female students achieve scores 7.4 points lower than their male counterparts, an advantage equivalent to approximately two-thirds of the average annual school learning. Students attending scientific high schools achieve, on average, higher results by 20.2 points, while those enrolled in other types of high schools score 8.9 points lower. This confirms that the outcomes in Mathematics for students in other types of high schools are more similar to those of technical education than of the classical high school. Additionally, a significant gap is observed between students in technical institutes and those in vocational schools (-17.6 points). Thus, the overall gap in terms of results between students in scientific high schools and those in vocational schools is 37.8 points, equivalent to more than two years of presumed learning.

The average advantage for students from socially advantaged families significantly decreases at the end of the second cycle of education compared to the first cycle, settling at 1.4 points. However, this advantage is augmented by the school's context, which, on average, accommodates more advantaged students, adding an advantage of 13 points. Despite considering all other previously mentioned conditions, there remains a significant difference in outcomes between different regions. The advantage is clearly in favor of the Northern regions (Northwest +14.3 points and Northeast +16.8 points) over the Central and especially the Southern regions (-6.7 points for the South and -10.1 points for the South and Islands). Therefore, the estimated overall gap in terms of average results between students from the Northeast and those from the South and Islands is 26.9 points, equivalent to more than two years of presumed learning.

Several studies based on INVALSI data analysis the gender differences in math performance in Italy. For instance, Giberti et al. [189] suggests that these differences might be due to varying misconceptions held by males and females.

Additionally, research by Cipollone, Montanaro and Sestito [190] indicates that value-added measures can be employed to assess the effectiveness of Italian high schools. Furthermore, their work highlights that schools in Southern regions of Italy tend to exhibit lower starting levels of competencies and lower value-added in math and science.

Moreover, there appears to be a correlation between the performance of Italian schools in the Bebras Challenge on Informatics and Computational Thinking and their performance in INVALSI assessments, as suggested by Bellettini et al. [191].

Our subsequent analysis delves into science performance and gender disparities in science education, building upon these findings and exploring the factors contributing to gender differences in STEM subjects.

Science Assessment in Italy

Science education in Italy is meticulously evaluated through internationally recognized assessments, specifically the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA). These assessments provide valuable insights into what students know and their ability to apply that knowledge [192].

In the TIMSS assessment, Italian student performance in science is measured at both the fourth and eighth-grade levels. At the fourth-grade level, the Italian average score stands at 516 points, aligning closely with European peers like Serbia, the Netherlands, and Spain. However, this score is significantly lower than top-performing countries globally, such as Singapore (590 points), South Korea (589 points), Japan (569 points), and European leaders like Finland (554 points) and Poland (547 points).

Moving to the eighth-grade, Italian students achieve an average score of 499 points, placing them behind nearly all European countries except Malta and notably distant from countries like Slovenia (551 points), England (537 points), or Sweden (522 points). Over time, the trend for fourth-grade achievements exhibits a negative trajectory, with the average score consistently decreasing from 537 points in 2007 to 524 points in the 2011 round. Conversely, eighth-grade performance remains relatively stable, with scores at 495 in 2007 and 501 points in the 2011 round.

TIMSS further dissects results by content domains. At the fourth-grade level, students perform better in Life Science (519 points) compared to Physics (513 points) and Earth Science (510 points). In contrast, eighth-grade students face the most significant challenges in Chemistry (487 points) while performing relatively better in Earth Science (514 points) and aligning with overall results in Biology (496 points) and Physics (496 points).

In the PISA assessment, Italian students' scores in science lag behind with an average of 468 points, falling below the average OECD score of 489 (Fig. 2.9. This places Italy below the majority of participating European countries in science education.

Additionally, the 2018 PISA round confirms and exacerbates a declining trend observed between 2012 (494) and 2015 (481), counteracting the positive trajectory

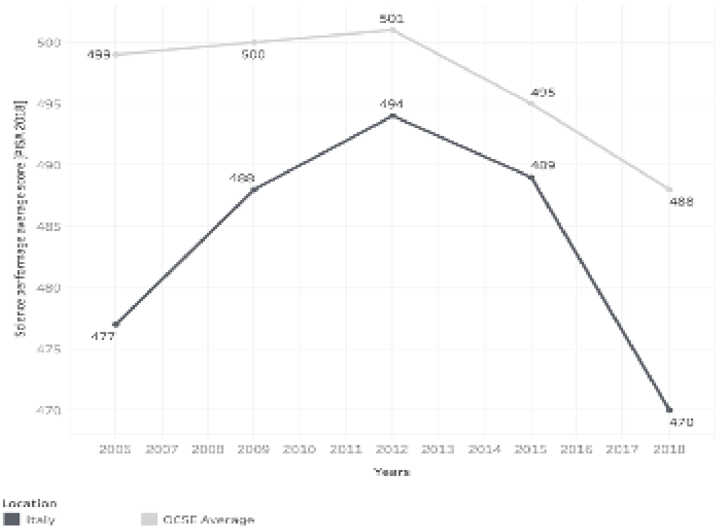


Fig. 2.9 Italian science performance score on PISA compared to the OCSE average

initiated in 2009 (489). This decline in performance raises concerns regarding the effectiveness of current science education practices.

Regional disparities in science education are evident, with a noticeable gradient in achievement from northern to southern regions of Italy. This disparity presents a considerable challenge for policymakers in addressing the geographical imbalance in science education outcomes. Differences among educational tracks further impact science education. While academically oriented tracks perform better than the OECD average score, technical, vocational, and professional tracks lag behind. These variations underline the need for tailored strategies to address specific track-related challenges and disparities in science education.

In a positive note, Italy exhibits gender parity in science achievement, with no significant differences between boys and girls. This aligns with the overall gender-neutral trend, where girls marginally outperform boys by just 2 points, emphasizing equal opportunities in science education.

In summary, science education in Italy is characterized by mixed results in international assessments. While efforts have been made to maintain gender parity, there is room for improvement in overall student performance, particularly in comparison to European and global counterparts. These challenges underscore the importance of continuous enhancements in science education to meet the demands of a modern workforce and foster scientific and technological advancements in the nation.

In conclusion, the comprehensive examination of mathematics and science education in Italy reveals a landscape marked by both achievements and challenges. While gender parity is a notable achievement in science education, overall student performance in international assessments, particularly in mathematics, calls for proactive measures. The decline in mathematics scores, exacerbated by the enduring impact of the pandemic, underscores the urgency of targeted interventions to bolster foundational skills. Likewise, regional and track-related disparities in science education necessitate tailored strategies to bridge these gaps and ensure equitable access to quality education across Italy. As the nation continues to grapple with these complexities, the pursuit of excellence in STEM education remains a fundamental driver for Italy's future innovation and competitiveness on the global stage.

2.4.3 Politecnico di Torino: A Hub of Technical Education

Politecnico di Torino (Polito), founded in 1859, draws its inspiration from the prestigious French Ecole Polytechnique model. This venerable institution is a cornerstone of technical education in Italy, specializing in the fields of Engineering and Architecture.

Following the Bologna model, the university offers a comprehensive educational structure. This includes a three-year Bachelor's program (Laurea) and a two-year Master of Science program (Laurea Magistrale). Additionally, there is an opportunity for students to continue their academic journey with a three-year doctoral path, showcasing the university's commitment to research excellence.

Polito provides a rich educational landscape with 50 distinct programs. Within these, approximately 40% are Bachelor's programs, spanning various disciplines in Engineering (such as industrial, ICT, civil-environmental, and management) and Architecture. For specific program details, one can refer to the official Polito website (www.polito.it).

In alignment with the Italian university system, Polito employs a credit-based system. Students are required to accumulate 180 credits for a Bachelor's degree and 120 credits for a Master's degree. Each course is evaluated based on a score range of 18 to 30, with 30 indicating excellence. To progress to the second year, students must earn a minimum of 28 credits, approximately half of the annual requirement.

Admission to the Architecture Bachelor's program is regulated by a national-level unified test established by the Italian Ministry of Education, University, and Research (MIUR). In contrast, for Engineering programs, Polito has introduced an admission process since the 1990s. Initially, it was based on a non-selective aptitude test developed nationally by CISIA (Consorzio Interuniversitario Sistemi Integrati per l'Accesso). However, in 2008/09, PoliTo transitioned to a selective online test known as the Test in Laib (TIL). This change aimed to enhance flexibility, tailor the test content to assess specific aptitudes, and provide immediate feedback to applicants.

As of the academic year 2017/18, Polito boasts a student population of approximately 33,000, with roughly 4,500 freshmen in Engineering Bachelor's programs. The university's international appeal has grown significantly over the years, attracting around 5,000 students from over 100 countries, constituting approximately 15% of the total student body.

Remarkably, PoliTo has experienced a steady increase in applications for Engineering Bachelor's programs in contrast to national and international trends. This trend is further fueled by the high employment rate of its graduates, making PoliTo a global leader in graduate employability.

To manage the burgeoning demand, Polito introduced a numerus clausus (a maximum number of admitted students) starting from the academic year 2012/13. This number has progressively decreased and was set at 4,500 since 2015/16. The determination of this cap is an intricate process that considers available resources and complies with national regulatory constraints.

It's noteworthy that Polito is navigating challenges related to its academic staff. The number of professors with permanent contracts is diminishing, offset by temporary contracts. This situation is influenced by factors such as the spending review and limited turnover of retired teaching staff.

For Engineering Bachelor's students, the first year is a foundational period. At Polito students are exposed to a diverse set of subjects covering fundamental science disciplines regardless the major choosen, including Chemistry, Computer Science, Mathematical Analysis, Linear Algebra and Geometry, and Physics. These courses form the so called "anno comune" and provide not only essential knowledge but also cultivate crucial soft skills necessary for success in engineering studies.

3

Nurturing STEM Pathways: Fostering Learning and Diversity

"Two roads diverged in a yellow wood,
And sorry I could not travel both
And be one traveler, long I stood
And looked down one as far as I could
To where it bent in the undergrowth;
Then took the other, as just as fair,
And having perhaps the better claim,
Because it was grassy and wanted wear;
Though as for that the passing there
Had worn them really about the same,
And both that morning equally lay
In leaves no step had trodden black.
Oh, I kept the first for another day!
Yet knowing how way leads on to way,
I doubted if I should ever come back.
I shall be telling this with a sigh
Somewhere ages and ages hence:
Two roads diverged in a wood, and I—
I took the one less traveled by,
And that has made all the difference."

– Robert Frost , *The Road Not Taken*

In STEM education, the journey of aspiring engineers is a tapestry woven with preparation, discovery, and diversity. The pivotal role of students in this narrative cannot be overstated – they are the architects of their own learning journeys, the seekers of knowledge, and the future torchbearers of innovation. As they traverse the educational landscape, their experiences shape the foundation of their engineering aspirations and contributions to society.

This chapter delves into the multifaceted world of Engineering Education (EE) from the student's perspective. It sheds light on the transformative stages that students undergo, beginning with the preparatory phase that lays the cornerstone for their future pursuits. From there, the exploration extends to the terrain of higher education, where students delve deeper into their chosen disciplines, honing their skills and fostering a spirit of innovation. An essential component of this journey is the exploration of gender perspectives, highlighting the importance of diversity in EE and its potential to reshape the landscape.

The chapter is structured to encompass a spectrum of insights, each contributing to a holistic understanding of the student's role in EE. It embarks on a journey through preparatory studies, where the seeds of curiosity are sown through hands-on activities and captivating experiences. The exploration then advances to higher education, where the convergence of methodologies, projects, and inclusive initiatives culminate in a rich tapestry of learning. Amidst these endeavors, the chapter introduces the gender dimension in engineering, recognizing the significance of a balanced and inclusive representation.

As the chapter unfolds, it underscores the collective impact of these stages, highlighting that EE is not just a transmission of knowledge, but a transformative journey that shapes the intellect and perspective of each student. Through this exploration, the chapter aims not only to showcase the challenges and triumphs faced by students but also to celebrate their indomitable spirit and potential to engineer a better future.

In this pursuit, we embark on a voyage through the diverse landscapes of EE from the student's lens. By delving into the preparatory studies, higher education initiatives, and gender-inclusive paradigms that influence this intricate journey, we aim to contribute to a comprehensive understanding of how students contribute to the vibrant mosaic of engineering innovation.

Within these pages, we invite readers to delve into the intricate narratives of students' aspirations, triumphs, and contributions in the realm of EE. Join us as we navigate the paths of preparatory studies, higher education pursuits, and inclusive perspectives, uncovering the threads that weave the fabric of excellence in EE.

3.1 Preparatory Study

In today's rapidly evolving world, fostering a deep interest and proficiency in STEM subjects has become increasingly vital. Recognizing the significance of early-age exposure to these fields, particularly in engineering, it becomes imperative to explore innovative approaches that engage and empower students from the earliest stages of their academic journey. The early years of education serve as a vital period for igniting young minds' curiosity and laying the groundwork for future success in STEM disciplines, particularly in the field of engineering.

This section delves into the significance of early-age engagement in STEM and its profound implications for shaping future career paths. Drawing upon compelling data from Subsection 2.4.2, which highlights crucial insights from PISA and INVALSI assessments, we explore the multifaceted advantages of early STEM education. By understanding the transformative power of introducing STEM concepts at an early age, we can unlock the potential of students to become adept problem solvers, critical thinkers, and skilled engineers, ultimately shaping the trajectory of both their careers and the broader landscape of STEM innovation. Therefore, after this short discussion, we present a range of initiatives and tools aimed at nurturing students' STEM learning experiences, beginning with introducing SixBricks, an educational resource designed to enhance engineering understanding through hands-on activities. We then shift our focus to Matabì, a pioneering tool developed to support primary school students' mathematical proficiency. Subsequently, we explore the SMaILE App, which leverages technology to facilitate playful learning experiences in Artificial Intelligence education. Building upon these foundations, we delve into the SaperI Summer School program, an immersive educational endeavor that fosters girls' passion for engineering. Finally, we examine the transformative potential of Test in Laib (TIL) analysis, the entrance examination administered by Politecnico di Torino (PoliTo), in evaluating and optimizing STEM learning outcomes. Through this comprehensive exploration, we aim to highlight the value of early-age engagement and innovative educational tools in shaping successful STEM trajectories, preparing students for the challenges of the TIL examination, and ultimately contributing to a future generation of skilled engineers and problem solvers.

3.1.1 Importance of Early Age in a Future Career in STEM

Early-age engagement in STEM subjects is significant as it lays the foundation for shaping future career paths, particularly in engineering. Research consistently indicates that introducing STEM concepts at an early age nurtures a natural curiosity and fascination with the world around us [193]. According to data from the European Union, students who engage in STEM education from an early stage exhibit a higher likelihood of pursuing STEM-related careers, including engineering [194]. This early exposure enables young learners to develop a strong affinity for scientific inquiry, problem-solving, and critical thinking skills essential for success in the dynamic world of STEM.

Within the Italian context (see Section 2.4), critical assessments such as PISA and INVALSI provide valuable insights into the multifaceted advantages of early STEM education. The PISA, conducted by the OECD, reveals that students exposed to rigorous STEM education early in their academic journey perform significantly better in scientific literacy, mathematical proficiency, and problem-solving skills [195]. These foundational skills not only contribute to their academic achievements but also have far-reaching implications for their future career prospects, particularly in engineering fields that rely heavily on scientific and mathematical expertise.

The INVALSI further reinforces the importance of early STEM engagement. Through comprehensive assessments, INVALSI evaluates students' knowledge and skills in various subjects, including STEM. The results consistently demonstrate that students exposed to high-quality STEM education from an early age exhibit higher levels of mathematical proficiency, problem-solving abilities, and critical thinking skills [196]. These fundamental competencies are closely aligned with the skills required for success in engineering disciplines, where logical reasoning, analytical thinking, and innovative problem-solving are paramount.

Early-age engagement in STEM has transformative power, enabling students to become adept problem solvers, critical thinkers, and skilled engineers. By introducing STEM concepts and hands-on experiences at an early stage, students develop a deep understanding of fundamental principles and gain practical skills that form the building blocks for advanced engineering knowledge [197, 198]. This transformative power extends beyond individual students, as a generation of young learners equipped with strong STEM foundations contributes to the broader landscape of STEM innovation and drives societal progress through groundbreaking technological advancements.

Recognizing the significance of early STEM education, educational institutions, policymakers, and educators must prioritize developing and implementing effective STEM curricula and resources. We can unlock students' potential by fostering an environment that promotes curiosity, creativity, and exploration, igniting their passion for STEM and empowering them to pursue careers in engineering and other STEM fields [199]. Investing in early-age STEM engagement not only shapes the trajectory of individual careers but also plays a pivotal role in cultivating a diverse and skilled workforce, driving innovation, and ensuring a prosperous future in the ever-evolving landscape of STEM disciplines.

3.1.2 SixBricks: Enhancing Understanding Through Hands-on Activities

A well-utilized methodology refers to building block activities to effectively prioritize early STEM education and provide students with the necessary resources and opportunities. Research has shown that building blocks, such as LEGOs, have the potential to support STEM education in early childhood [200–202]. These studies have demonstrated the positive impact of incorporating building blocks into curriculum and software design, resulting in significant assessed learning gains in mathematics [200]. Additionally, the development of STEM-based and parent-involved engineering design curricula using building blocks has been found to contribute to children's knowledge, skills, feelings, and dispositions towards STEM [201]. Furthermore, using building blocks, such as LEGOs, in higher education settings, including high school and teacher education, has successfully encouraged STEM education by simulating real-world manufacturing scenarios and integrating technology and engineering into math and science instruction [202]. These findings highlight the effectiveness of building blocks as a versatile and engaging tool to support early

STEM education, fostering a solid foundation of knowledge and skills in young learners.

In this context, Care for Education, with the support of the Lego Foundation, has developed the SixBricks methodology. It is a unique and innovative approach designed to enhance early STEM education by fostering hands-on learning experiences. Developed by a team of educators and researchers, SixBricks aims to provide young learners with a solid foundation in STEM concepts through the use of a carefully curated set of six interlocking bricks. These bricks are specially designed to promote creativity, critical thinking, problem-solving, and collaboration among students in their early education years [203]. The primary objective of the SixBricks methodology is to cultivate a love for STEM subjects and lay the groundwork for future success in engineering and related fields. By engaging students in enjoyable and interactive activities, SixBricks aims to instill a passion for STEM, nurturing young minds to become the next generation of innovative thinkers and problem solvers.

The SixBricks methodology represents a distinctive and pioneering approach aimed at enriching early STEM education by facilitating hands-on learning experiences. SixBricks endeavors to establish a robust framework for young learners, enabling them to acquire a solid foundation in STEM concepts by utilizing a meticulously curated set of six interlocking bricks developed collaboratively by a team of experienced educators and researchers. These specialized bricks are meticulously designed to foster the development of perceptual, literacy, numeracy, physical, and socio-emotional skills among students during the formative stages of their educational journey together with creativity, curiosity, critical thinking, problem-solving, and collaboration [203]. Fig. 3.1 describes in short the key points of the SixBricks methodology. At its core, the SixBricks methodology seeks to cultivate a profound affinity towards STEM subjects while laying the groundwork for future achievements in engineering and its associated domains. By actively engaging students in captivating and interactive activities, SixBricks endeavors to imbue them with an unwavering passion for STEM, thereby nurturing young minds to emerge as the vanguards of innovation and adept problem solvers in the next generation, reinforcing their personal visual perception ability [204].

The inception of the SixBricks methodology stands as a direct response to the pressing imperative for adequate early STEM education resources. As previously dis-

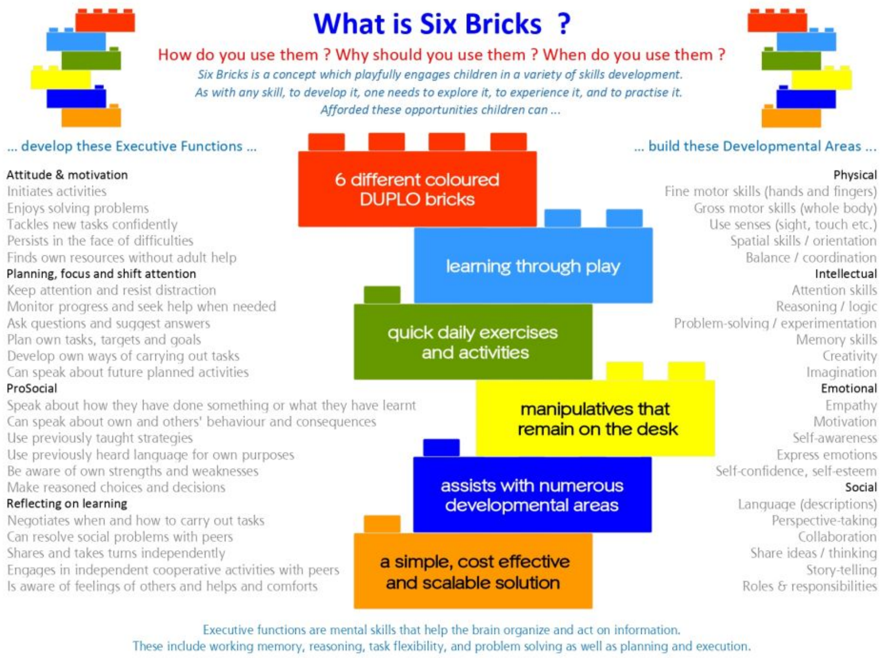


Fig. 3.1 SixBricks in short: executive functions and developmental areas

cussed, investing in STEM engagement during the early years is paramount in shaping students' career trajectories and cultivating a proficient and diverse workforce in the domains of science, technology, engineering, and mathematics. Nonetheless, realizing these objectives necessitates the availability of suitable tools and strategies that cater to the developmental requirements of young learners. In this context, SixBricks represents an invaluable contribution by providing educators with a versatile and accessible methodology that fosters engagement, curiosity, and exploratory learning during the foundational years of education [205, 206]. By equipping teachers with a structured yet adaptable framework, SixBricks empowers them to establish dynamic and stimulating learning environments thanks to the learning through-play philosophy, enabling students to participate in hands-on activities actively. This proactive approach serves to construct a formidable knowledge base and skill set, which will not only accompany them throughout their educational journey but also prepare them for their future careers. Thus, the SixBricks methodology exemplifies a pivotal stride towards effective early STEM education, promoting the acquisition of essential competencies and instilling a lifelong passion for scientific inquiry and discovery.

The idea behind SixBricks is straightforward: Six different colored Duplo Lego bricks with the same shape (2x4), two of which are similar in color, to help develop language and other concepts. It's learning through play where children are actively involved. Quick daily exercises and activities. Five to ten minutes does not have to fit into any curriculum. It's manipulatives that remain on the desk permanently. It assists with numerous developmental areas of physical, intellectual, emotional, social, and perceptual skills and covers literacy and numeracy. It's a simple, cost-effective, and scalable solution.

The history of the SixBricks methodology can be traced back to 2013 when extensive experimentation with various educational manipulatives, primarily LEGO educational products, was conducted in schools located in Atteridgeville, a township outside Pretoria [205]. This initiative aimed to identify a scalable, cost-effective, and simplified solution for schools in South Africa. It became evident that a return to basics was necessary, as perceptual development among children was lacking, and crucial developmental areas were overlooked. In-depth research was undertaken to explore the relationship between concrete manipulation, learning, and development. The focus was on enhancing perceptual and motor skills, identifying activities and exercises to support these skills, and designing brief yet engaging activities. Research findings suggested that children needed to construct beyond their field of vision within five steps or manipulatives to maintain engagement. It was discovered that five DUPLO bricks provided the ideal size for this purpose. Still, a middle point was required for children to cross the midline and facilitate bilateral integration exercises. The addition of a sixth brick resolved this challenge, giving rise to the concept of the SixBricks methodology.


Fig. 3.2 SixBricks kit

The initial selection of colors for the SixBricks set followed a deliberate process. The four primary LEGO brick colors, namely red, green, blue, and yellow, were chosen as they were readily available and easily sourced. However, the choice of additional colors posed a challenge. Black and white were excluded as options, and after careful discussions within Care for Education, it was decided to include two similar shades of blue (light blue and dark blue) to support language concept development. Furthermore, orange was chosen as the sixth color due to its availability and strong contrast with the other colors. The SixBricks set was intentionally designed to comprise only six colors to eliminate visual distractions and to provide a balanced selection that catered to the diverse needs of learners.

The SixBricks methodology is centered around comprehensive Teacher training, which provides educators with detailed instructions and insights into implementing the method effectively. At the end of each training level, teachers receive a guide booklet offering a range of engaging activities, carefully curated to enhance specific skills and cater to different learning styles. The activities are designed to be flexible, allowing educators to adapt them to their unique classroom environments and student needs. By incorporating SixBricks into their teaching practices, educators can create an engaging and inclusive learning experience that fosters the development of critical STEM skills from an early age.

The impact of the SixBricks methodology has been widely recognized and celebrated. Numerous educators have reported significant positive outcomes, both in terms of early-age students' engagement and their acquisition of STEM knowledge and skills [204]. The hands-on nature of the activities, coupled with the open-ended design of the SixBricks, promotes creativity, critical thinking, and problem-solving abilities among students. Additionally, the collaborative nature of the activities fosters communication and teamwork skills, which are essential for success in engineering and other STEM fields. Fig. 3.3 shows different activities that involve the use of SixBricks in an italian Kindergarten.

In summary, the SixBricks methodology offers a unique and innovative approach to enhancing early STEM education. By leveraging the power of hands-on learning experiences and the versatility of six interlocking bricks, SixBricks empowers educators to foster a passion for STEM among young learners and lay a solid foundation for future success in engineering and related fields. By actively engaging students in enjoyable and interactive activities, SixBricks cultivates curiosity, critical thinking, and problem-solving skills, paving the way for a generation of innovative thinkers and skilled engineers.

Fig. 3.3 Activities with SixBricks in an Italian Kindergarten

3.1.3 Enhancing Math Learning in Primary Schools with Matabì

We conducted an in-depth investigation of the SixBricks methodology, assuming the role of facilitators for Levels 1 and 2. This understanding enabled us to develop a new educational tool called Matabì, explicitly focusing on fostering spatial abilities while teaching mathematics in elementary schools, particularly in the third and fourth years. The project, primarily aimed at reducing the gender gap in math and science, is promoted by Exor and implemented by Fondazione Agnelli in collaboration with us, with the support of The LEGO Foundation. The new kit, an evolution of SixBricks, includes eight additional bricks of varying dimensions and thickness. Notably, Matabì kit, as shows Figure 3.4, consists of two long 2x6 bricks, one red and the other light green, two square bricks (one red and one light green), and four thinner dark blue bricks (two of which are required to make one standard brick). In this subsection, we will introduce Matabì, discuss its underlying ideas and principles, provide examples of its incorporation into primary school classrooms, and share positive outcomes and success stories related to its use.

Matabì is a pedagogical tool designed to provide students with a hands-on and interactive learning experience that fosters spatial thinking and problem-solving skills. Through the use of manipulatives and construction-based activities, Matabì

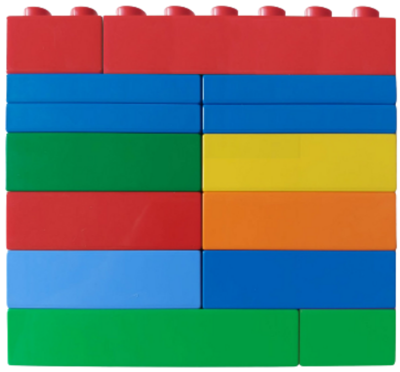


Fig. 3.4 Matabì kit

encourages students to explore mathematical concepts in a concrete and tangible way.

Various research and pedagogical frameworks inform the development of Matabì. Drawing from cognitive psychology and educational neuroscience, Matabì incorporates spatial cognition and learning principles. Matabì seeks to bridge the gap between abstract mathematical concepts and students' concrete understanding by leveraging spatial abilities.

For instance, Matabì can be used to reinforce specific content, such as angle classification. In this case, students spread the SixBricks on their desks. The teacher initially defines how each angle can be represented using two bricks (Fig. 3.5:

- Full turn [360°]: The two bricks overlap.
- Straight [180°]: The two bricks have four pins in common and follow a straight line.
- Right [90°]: The two bricks have four edge pins in common and are perpendicular to each other.

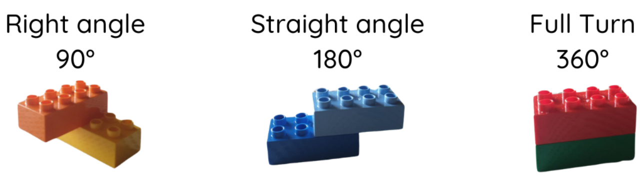


Fig. 3.5 Angles using Matabì kit

	Light blue
Straight	Red
Right	Green
Right	Dark blue
Straight	Yellow
Full turn	Orange

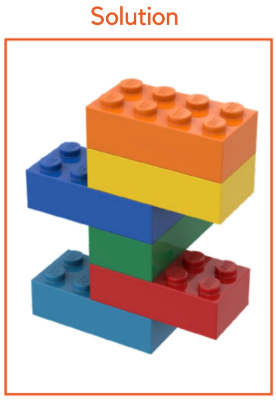


Fig. 3.6 Example of a dictation of angles

The teacher will announce a color, which serves as the base color for a tower, followed by another color and the name of an angle (e.g., "full turn"). Each student must correctly fit the bricks by building the tower accordingly. After the five instructions (as a six-brick tower always contains five angles), the teacher can quickly assess if everyone has constructed it correctly (Fig. 3.6). This activity takes a couple of minutes and can be played at the beginning of the day to reinforce previously covered concepts.

Another way to use Matabì to support math learning is by introducing new topics. For example, the concepts of length measurement and units of measure can be taught using the kit. The activity begins by explaining to the children that each will be assigned a dimension of a brick from the Matabì. They are instructed to place the brick on the desk and count how many bricks make up the entire length using their assigned unit of measurement. Except for two children, each is given a specific brick and its dimensions. The remaining two children are asked to measure the length by counting the "pins" on the brick. After measuring, the sizes are recorded on the board. The children then discuss and compare their measurements, exploring strategies and observing similarities and differences. The concept of units of measurement and equivalence is explained using pins and bricks. The history of length measurements is briefly discussed, leading to the universally recognized conventional unit of measurement, the meter. Fig. 3.7 shows pupils measuring their desks using "pin" or bricks as a unit of measurement and the measurements summary collected on the blackboard for discussion.

Fig. 3.7 Workshop on the concept of lenght measurement and units of measure

Finally, each child measures their assigned brick with a ruler, converts the length to centimeters, and the activity concludes by highlighting the achieved objectives.

Additionally, Matabì aligns with constructivist and inquiry-based approaches to education. It encourages students to construct mathematical knowledge actively through exploration, experimentation, and collaboration. Students develop a deeper understanding of mathematical concepts and cultivate critical thinking skills by engaging in open-ended tasks and problem-solving activities.

Matabì is designed to support daily learning rather than reorganize the curriculum. Teachers can integrate Matabì activities into their lesson plans to provide students with hands-on experiences that complement traditional instructional methods. As we have seen, Matabì can be used to explore geometric concepts, visualize fractions, or solve word problems through physical manipulations.

Furthermore, Matabì supports differentiated instruction, allowing teachers to tailor activities to meet the diverse learning needs of their students. It provides opportunities for both independent and collaborative work, fostering peer-to-peer interactions and promoting a positive learning environment.

Currently, in 88 classes across different Italian cities, students and teachers are experimenting with Matabì after completing a 20-hour training course delivered by us (see Subsection 4.1.1). We hope the impact evaluation entrusted to the CRENoS University of Cagliari confirms the initial positive impressions regarding the project's effectiveness in mathematics learning. In that case, the objective will be to introduce Matabì to as many Italian schools as possible in the coming years. In the ongoing

Randomized Control Trial (RCT), we aim to demonstrate how students who engage with Matabì improve their spatial thinking abilities, increase motivation, and develop a deeper understanding of mathematical concepts. Additionally, we hope that by enhancing spatial thinking, Matabì can promote gender equality in math education by reducing both the math and spatial abilities gaps. Based on feedback from focus groups, teachers have noted that Matabì facilitates rich discussions, enhances student engagement, and fosters a positive attitude towards mathematics. However, the results of the first RCT will be available in 2024.

3.1.4 Unveiling the Potential of Game App in Middle School and High School Context

In EE, the investigation of playful learning also extends to learning game apps. Learning game apps can be categorized into different types based on their approach and design, providing valuable insights into their utilization within the field. Formal and informal learning game apps are well-known classifications, offering distinct characteristics and potentials.

Formal learning game apps are designed explicitly with predefined educational objectives in mind, aligning them with established curriculum standards. These apps are typically structured, goal-oriented, and emphasize acquiring specific knowledge or skills. They often incorporate assessments and progress-tracking mechanisms to measure and evaluate learning outcomes. In EE, formal learning game apps can be employed to enhance students' understanding of fundamental engineering concepts, reinforce problem-solving skills, and promote knowledge acquisition within a structured framework.

On the other hand, informal learning game apps embrace a more open-ended and exploratory approach. They prioritize self-directed learning, creativity, and problem-solving, allowing users to engage in unstructured activities and discover knowledge through experimentation. In the context of EE, informal learning game apps can encourage students to explore engineering concepts in a relaxed and flexible environment, fostering creativity, critical thinking, and innovation. These apps provide opportunities for learners to independently investigate engineering phenomena, design and test solutions, and collaborate with peers, thereby promoting a deeper understanding of engineering principles.

Scholars have extensively discussed the distinctions between formal and informal learning game apps in EE. For instance, Haaranen and Kinnunen[207] highlights the potential benefits of informal learning through games, suggesting that educators can draw valuable insights from informal learning processes related to computing. Similarly, Yelland [208] identifies that children enjoy games that transcend traditional mathematical tasks and provide opportunities for problem-solving. Viberg, Andersson and Wiklund [209] argues that in order to integrate formal and informal learning effectively, designers must give precise definitions of the concepts of "formal" and "informal," enabling learners to customize their learning paths accordingly. Rogoff et al.[210] further examines the organizational differences between informal and formal learning, highlighting that informal learning is characterized by its non-didactic nature, integration with meaningful activities and emphasis on learner initiative and interests. These studies collectively suggest that informal learning game apps offer unique benefits and opportunities for EE by promoting student engagement, creativity, and the application of knowledge in real-world contexts.

However, it is crucial to consider the age appropriateness and the potential implications of technological device usage within EE. Research indicates that learning game apps for early ages can have both positive and negative effects. Prensky [211] posits that video games can serve as positive tools for engaging children in genuine learning experiences. Griffith [212] identifies evidence supporting the use of interactive apps to support early academic development, particularly in the domain of early mathematics learning for typically developing children. Conversely, Gul [213] emphasizes the importance of game activities being designed in a genuine game format rather than merely incorporating game-like elements to ensure the overall well-being of children. Yahya et al. [214] reviews papers demonstrating the positive effects of game applications on learning and improving the learning process. However, it is also acknowledged that excessive screen time can be detrimental, and the extent to which interactive apps support early learning still requires further exploration within the EE context.

Examples of learning game apps can be found across various age groups in EE. For instance, Aunkon et al. [215] developed an educational game targeting children aged 2-6 years, aiming to teach them how to write and read letters in both Bangla and English. Greipl et al. [216] found that a math learning game applied to participants ranging from 19 to 79 years of age, emphasizing the need to appropriately adapt performance metrics related to speed according to the player's age. Laranjeiro [217] developed game-based learning apps specifically designed for preschoolers, which were validated by children and educators, highlighting the potential for incorporating interactive technology in early EE.

In summary, exploring different types of learning game apps within EE, such as formal and informal, offers valuable insights for educators and researchers. Understanding their distinct characteristics, potentials, and implications can guide the selection and integration suitable tools to support engineering learning. Furthermore, considering age appropriateness and the responsible use of technological devices is crucial to ensure the effective and ethical implementation of learning game apps in EE contexts.

3.1.5 Case study: SMaILE app

The SMaILE project (Simple Methods for Artificial Intelligence Learning and Education) is a research endeavor led by Polito in collaboration with the University of Torino and Royal Holloway University of London. This project emerged as the winner in the "Education and Training" category of the "Artificial Intelligence, Human, and Society" 2021 call, which the Compagnia di San Paolo Foundation promoted.

Artificial intelligence (AI) is rapidly becoming an indispensable component of our daily lives, permeating various societal domains. Its pervasive presence necessitates a proactive approach to incorporating AI education into the academic curriculum, considering its potential impact on future engineering professionals. Anticipating a surge in AI reliance in the form of autonomous driving mechanisms, robotic systems, and personalized medicine, it is imperative to equip students with a comprehensive understanding of AI principles and aptitudes.

The educational landscape has witnessed a paradigm shift due to the unprecedented disruptions caused by the Covid-19 pandemic. The subsequent enforcement of social distancing measures prompted a swift transition to remote learning modalities. In this context, the pressing challenge is establishing adaptable blended learning models that effectively cater to distance and in-person educational settings while delivering optimal learning outcomes.

Italian primary and secondary school curricula exhibit a striking need for more digital competencies encompassing AI-related knowledge and skills. Consequently, a pressing need arises to introduce AI as a discipline of study, accompanied by broader informatics competencies, and leverage it as a pedagogical tool to enhance the quality and efficacy of education. This critical exigency calls for integrating novel methodologies to facilitate the acquisition of digital literacy and AI awareness among young students while simultaneously optimizing the learning experience through the proficient utilization of AI.

The SMaILE project emerges as a pivotal intervention in this context, aiming to facilitate the effective utilization of AI tools while fostering an in-depth understanding of AI principles, codes, characteristics, and applications.

To accomplish its overarching objective, SMaILE harnesses the principles of Game Theory and employs gamification techniques as educational instruments. This strategic utilization aims to maximize student engagement, enabling profound internalization of knowledge and the practical acquisition of AI application skills.

The main objectives of the project can be summarized as:

- Facilitate the comprehension of AI principles and techniques among young learners.
- Promote the effective and responsible utilization of AI tools across diverse disciplines and applications.
- Formulate novel learning trajectories in AI education, addressing the prevailing curricular gaps.
- Contribute to positioning the city of Turin as a pioneering hub and educational laboratory for AI instruction.
- Disseminate the research project's outcomes to a broad audience, encompassing both national and international realms.

The SMaILE project endeavors to bridge the existing gaps in AI education, empowering students with digital competencies and nurturing a future generation of engineers proficient in leveraging AI technology responsibly and knowledgeably.

Given the inherently multidisciplinary nature of AI, the SMAILE project adopts a comprehensive approach by engaging a team of mathematicians, computer scientists, engineers, and psychologists. This diverse team brings extensive research and teaching expertise in the field of AI, representing academic institutions, cultural associations, schools, and leading companies in the gaming and innovation sectors. The project encompasses three distinct sub-projects, each addressing specific aspects of AI education:

1. Games4AI: This sub-project focuses on theoretical exploration, incorporating concepts from Game Theory and Mechanism Design alongside gamification techniques. The primary objective is to develop an innovative pedagogical methodology for teaching AI principles to Generation Z students and individuals interested in delving into the realm of AI. Games4AI aims to leverage gamified approaches to make the learning process engaging and interactive.

2. SMaILE App: The SMaILE App constitutes a mobile application designed to introduce young learners to artificial intelligence through an edu-gaming experience. The app guides players on a playful, educational journey, where they assume the role of protagonists in constructing a sustainable SMAILE City. Powered by AI tools and engines, the SMaILE App provides an immersive and interactive platform to foster AI understanding among its users.

3. EmpAI: This sub-project aims to identify innate abilities in children and adolescents that, if nurtured, can enhance their comprehension of machines and systems exhibiting rational behaviors. Through EmpAI, the SMaILE project develops an educational platform and a range of ludic activities to stimulate computational skills and foster the acquisition of fundamental AI competencies in young learners. The focus is empowering students to develop computational thinking and engage with AI concepts hands-on and experientially.

The integrated structure of the SMAILE project, comprising the Games4AI, SMaILE App, and EmpAI sub-projects, enables a holistic exploration of AI education. The project aims to foster a comprehensive understanding of AI principles while nurturing the next generation of AI-literate individuals by incorporating theoretical foundations, interactive applications, and skill-building activities. Through collaborations with various stakeholders and leveraging cutting-edge methodologies, SMAILE seeks to revolutionize AI education and position Turin as a prominent hub for AI instruction and innovation.

Although the entire project has many different aspects, we will focus on developing a learning game app, the SMaILE app.

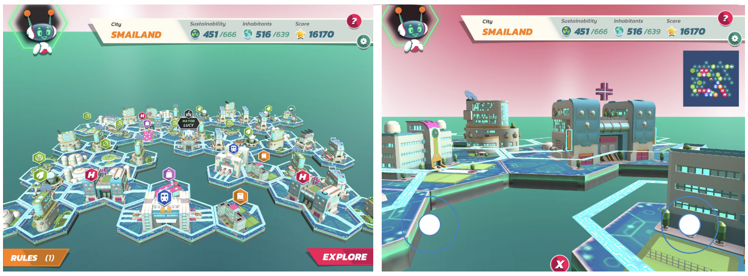


Fig. 3.8 View of the city in SMaILE app (2D and 3D)

The SMaILE App [218], designed for lower and upper secondary school students, is a simulation game that aims to engage and educate young learners about AI principles using a constructionist pedagogical approach. The app utilizes game-based learning and gamification techniques to transform enjoyable activities into profound knowledge, fostering a deeper understanding of AI concepts. Through the city-building game (Fig. 3.8), students progressively construct a sustainable and livable smart city, applying AI concepts and principles in their decision-making processes. The game mechanics follow a constructionist approach, enabling users to experience, use, and link each tile within the city to specific learning outcomes, all contributing to the overarching mission of teaching AI principles to students.

The app incorporates various key features and functionalities that enhance students' learning experiences in AI. Firstly, the game mechanics are based on fundamental AI concepts, ensuring that each activity and service in the city corresponds to a specific mini-game that serves as a training ground for specific concepts:

- City building - Constraint Satisfaction Problem
- Hospital - Heuristic Search
- Park selection - Min Max Algorithm
- Park cleaning - Winning strategy
- Gardening - Game Theory
- Supermarket - Neural Network and classification
- Station - Alpha Zero and Monte Carlo technique
- School - Reinforcement Learning

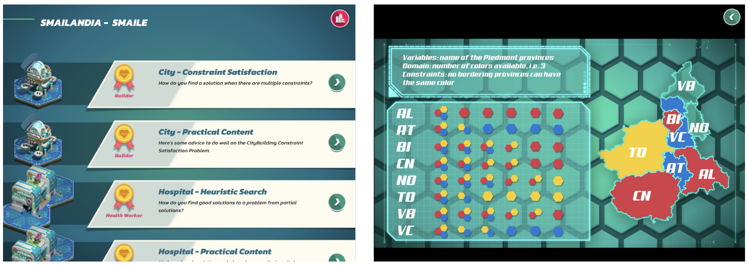


Fig. 3.9 Educational video in SMaILE App with an example

- Cinema - Natural Language Processes

Additionally, the app offers educational videos (see Fig. 3.9) for each activity or service in the city that provide formal explanations and guidance to students, further consolidating their understanding of AI principles.

Moreover, the SMaILE App incorporates gamification elements to maximize user engagement and motivation. Points, rewards, and virtual goods are employed to incentivize students to actively participate in the learning process and progress through the different levels and challenges. By gamifying the experience, the app creates an immersive and enjoyable environment where students can develop problem-solving skills, enhance their computational thinking abilities, and foster creativity. These elements provide a more engaging and interactive learning experience than traditional lecture-based approaches.

Incorporating the SMaILE App into the educational process yields several benefits, particularly in promoting student engagement and fostering a deeper understanding of STEM concepts, specifically in AI. The interactive and hands-on nature of the app encourages active participation, allowing students to explore various solutions and strategies to build and manage their smart cities. By linking AI principles to real-world applications within the game, students can witness the direct impact of their decisions and develop a holistic understanding of the subject matter. This not only enhances their knowledge but also cultivates critical thinking, problem-solving, and decision-making skills, all of which are crucial in the field of engineering and other STEM disciplines.

Furthermore, the SMaILE App empowers students by giving them a sense of agency and ownership over their learning (Fig. 3.10). Through the gamified experience and the opportunity to create and customize their smart cities, students become active participants rather than passive recipients of knowledge. This sense of agency

Fig. 3.10 Some pictures and screen example of the SMaILE app in action

not only increases motivation but also fosters a more profound understanding of connection and investment in the learning process.

The impact evaluation of the SMAILE project employs an RCT methodology. The study targets students in the second year of lower secondary schools in Piedmont, Italy. Each school is required to participate with at least two classes. A random assignment of classes receiving the SMaILE App is implemented to assess the project's impact [219]. Within each school, the classes that will receive the SMaILE App from the beginning of the 2022-23 academic year are selected through random allocation. The remaining students will receive the app at the end of the school year. This randomization process creates two similar and comparable groups, the only difference being their participation or non-participation in the intervention. The control group represents the "counterfactual scenario," i.e., what would have happened without the intervention.

This experimental design enables a rigorous and scientific evaluation of the potential positive effects of the intervention regarding AI concepts, STEM learning, and spatial and computational thinking. However, the investigation is not limited to learning content or thinking development but investigates the interest toward STEM and career intention.

With the support of the Regional School Office, particularly the Territorial Training Team, 20 schools, comprising 58 classes, have participated in the study. Consent from parents was obtained for 1,031 students, and after the baseline test, the classes were randomly assigned to either the experimental or control group. A total of 527 boys and girls gained access to the SMaILE App. In May and June 2023, the post-test evaluation (endline) was conducted, with 95% of the participants successfully completing the entire assessment.

This comprehensive evaluation framework, incorporating the RCT methodology and the collaboration of regional educational authorities, allows for a rigorous and scientific quantification of the potential positive effects of the SMAILE project. The results obtained from the impact evaluation will be available in early 2024. From a first analysis, it seems that students have played less than expected. Therefore additional focus groups were organized to contribute to evidence-based decision-making and provide valuable insights for further enhancing AI education initiatives.

In conclusion, the SMaILE App seems to be an effective tool in EE, specifically in teaching AI principles to 10-18-year-old students. By leveraging game-based learning, gamification techniques, and a constructionist pedagogical approach, the app enhances students' learning experiences, promotes engagement, and facilitates a deeper understanding of STEM concepts. Incorporating the SMaILE App into the educational process offers transformative and substantial contributions to developing students' skills and competencies, ultimately preparing them for future challenges in engineering and related disciplines.

3.1.6 Evaluate the competencies background of potential engineering students: TIL

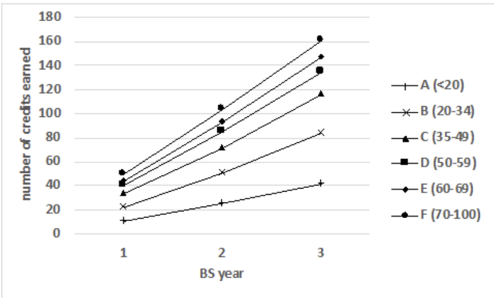
Preparatory engineering studies encompass a blend of formal and informal learning modalities, each contributing to the development of STEM-oriented minds. These learning approaches encompass diverse techniques and elements that support the cultivation of competencies essential for potential engineering students, like the one discussed in this section. Considering the heterogeneous range of background competencies requisite for success in EE, a meticulous evaluation of students' preparation becomes imperative. Understanding the diverse nature of individuals' STEM acquisition pathways enables educational institutions to implement comprehensive assessment strategies that consider both formal and informal learning contexts. Such an extensive evaluation process ensures the identification and adequate preparation of students possessing the necessary competencies to navigate the challenges inherent in an engineering curriculum. This rigorous assessment approach plays a pivotal role in fostering excellence in EE and nurturing a cohort of proficient and adept engineering professionals.

As said, assessing prospective engineering students' competencies before enrollment in a university has become crucial in ensuring a successful academic journey. This section focuses on the Test in Laib (TIL) solution and its significance in evaluating the competence background of engineering students. The primary objective of the TIL is to assess the competence background required for a successful career in a technical university. The TIL has been developed to address the need for an effective and robust evaluation process associated with merit, as well as to enhance the attractiveness and quality of incoming students while reducing the dropout rate.

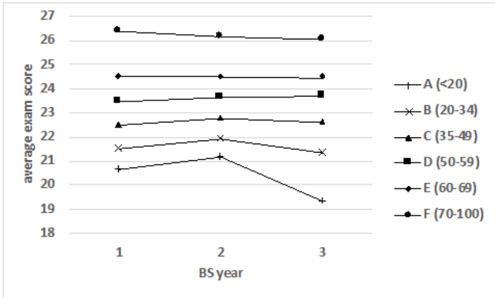
The TIL is an innovative tool designed to evaluate potential engineering students' competence background at the Polito. It was developed in response to the introduction of the numerus clausus and the growing demand for a robust evaluation process based on merit. The TIL consists of 42 multiple-choice questions divided into four sections: Mathematics, Physics, Verbal Comprehension, and Logic. This comprehensive test provides a reliable and predictable means of assessing the competence background required for a successful career in a technical university. Additionally, the TIL incorporates a self-assessment feature that allows applicants to make informed decisions regarding their individual choices.

The TIL analysis demonstrates the effectiveness of this assessment tool in evaluating and improving STEM learning outcomes. The TIL analysis involved integrating data from various sources, including the population of professors at Polito and the total number of enrolled students. By comparing test results with students' subsequent academic careers, it is evident that the TIL is a reliable predictor of students' performance. The introduction of the numerus clausus and the implementation of the TIL test have significantly improved the competence background of students entering engineering programs. This, in turn, has increased incoming students' overall attractiveness and quality while maintaining a high employability rate.

The TIL analysis [220] employed a data-driven approach, incorporating various sources of information. The test was designed to evaluate aptitude and assess the effectiveness of previous preparatory studies. The scoring system awards 1 point for each correct answer while deducting 0.25 points for incorrect answers. The TIL analysis involved merging data from different sources, such as the population of professors at Polito and the total number of enrolled students. The strong correlation between test results and indicators of students' success, such as full earned credits (Fig. 3.11a), average exam scores (Fig. 3.11b), and global career duration, emphasizes the predictive power and validity of the TIL. This correlation reinforces the TIL's predictive power and underscores its role in identifying students who are likely to succeed in their university careers.



(a) Correlation between the total number of credits earned andthe TIL score category



(b) Correlation between average exam scores and TIL scorecategory

Fig. 3.11 Similar trend is observable correlating the average number of credits and the average exam scores at the end of each BS year to the TIL result

The TIL analysis highlights the tool's effectiveness in evaluating and improving STEM learning outcomes. The results indicate that introducing a numerus clausus and a selective test, such as the TIL, have improved the competence background of incoming engineering students. Furthermore, the TIL has demonstrated its ability to predict students' university career outcomes, as evidenced by the correlation between test results and indicators of success. Establishing a minimum test score requirement has contributed to enhancing the overall quality of first-year students and reducing the dropout rate through targeted selection at the entrance stage.

In conclusion, the TIL represents an effective solution for evaluating the competencies of potential engineering students. By assessing the competence background before enrollment, the TIL contributes to improving STEM learning outcomes, reducing the dropout rate, and enhancing the quality of incoming students. The TIL has demonstrated its reliability, robustness, and predictive capability in selecting engineering students, thereby facilitating their successful academic journey and enhancing their employability in technical fields.

3.1.7 Preparatory Study in Short

The preparatory study for EE represents a crucial phase in shaping the competencies and capabilities of potential engineering students. This section has highlighted the significance of a comprehensive evaluation process that considers both formal and informal learning modalities to identify and prepare students adequately for the challenges of an engineering curriculum.

The blend of formal and informal learning approaches plays a pivotal role in nurturing STEM-oriented minds and developing the necessary competencies for EE success. By understanding the diverse nature of individuals' STEM acquisition pathways, educational institutions can implement effective assessment strategies encompassing a wide range of skills, knowledge, and problem-solving abilities.

Through the rigorous evaluation of competencies, the evaluation process ensures the identification and preparation of students who possess the necessary foundation to navigate the complexities of engineering disciplines. This meticulous assessment approach not only promotes excellence in EE but also fosters the development of proficient and adept engineering professionals who can contribute meaningfully to society.

The integration of assessment tools like the Test in Laib (TIL) demonstrates the commitment of educational institutions to enhancing the quality and attractiveness of incoming engineering students. The TIL, with its comprehensive multiple-choice questions in Mathematics, Physics, Verbal Comprehension, and Logic, provides a reliable means of evaluating the competence background required for a successful technical university career. Its effectiveness is evident through its ability to predict subsequent academic performance, thereby aiding in selecting students who are likely to excel in their university journey.

Furthermore, implementing measures such as numerus clausus and selective evaluation processes like the TIL has led to notable improvements in the competence background of incoming engineering students. By establishing minimum test score requirements, institutions have enhanced the overall quality of first-year students and effectively reduced the dropout rate. These initiatives contribute to the overall advancement and reputation of EE while simultaneously addressing the demands of the industry for highly skilled and employable graduates.

In summary, the preparatory study for EE demands a comprehensive evaluation process that recognizes the diverse learning pathways of potential students. The integration of assessment tools like the TIL and the implementation of selective measures signify the commitment of educational institutions to identify and prepare students with the necessary competencies to excel in engineering disciplines.

3.2 Higher Education study

The role of study and its significance within higher education institutions cannot be overstated in EE. Study is a fundamental pillar for acquiring and developing essential knowledge, skills, and competencies engineering students require. It forms the basis for the understanding and application of theoretical concepts, principles, and methodologies, enabling students to become proficient in their chosen engineering disciplines.

Within the context of higher education, the study serves several crucial purposes. Firstly, it fosters a deep comprehension of engineering principles and theories, facilitating knowledge transfer from academic settings to real-world engineering practices. Through rigorous study, students engage in critical thinking, problem-solving, and analytical reasoning, which are essential for addressing complex engineering challenges.

Secondly, study enhances the cognitive abilities of engineering students. It promotes intellectual growth, develops logical thinking skills, and expands the capacity for information processing. By immersing themselves in focused study, students strengthen their cognitive foundations, enabling them to grasp intricate engineering concepts and contribute to innovative problem-solving approaches.

Furthermore, study in higher education serves as a platform for self-directed learning. It encourages students to take ownership of their educational journeys, promoting autonomy and self-regulation. Through diligent study practices, students develop effective time management, organizational skills, and the ability to set and achieve their learning goals. These qualities are essential for engineering professionals who must navigate complex projects, work independently, and continuously update their knowledge and skills throughout their careers.

This section aims to delve into various initiatives and approaches within the realm of EE that aim to optimize the study experience for students. By exploring these initiatives, we seek to understand their impact on student learning outcomes, engagement, and overall educational experience. By examining these innovative approaches, this section aims to shed light on practical strategies that enhance study practices, promote student success, and contribute to advancing EE.

In the subsequent sections, we will explore specific initiatives, such as the CIAO! (Corso Interattivo di Accompagnamento Online), Progetto Talenti, DayByDay, Math game without frontiers, STEMM game, a shared remote laboratory between Polito and TTPU (Uzbekistan), and the application of Problem-Based Learning (PBL) in a university course on structural analysis. These initiatives have been carefully designed and implemented to facilitate the study process, address students' needs, and foster a dynamic and engaging learning environment. By examining the outcomes and benefits of these initiatives, we aim to provide insights into effective educational practices that can be adapted and adopted by engineering educators to enhance the study experiences of their students.

In summary, this section aims to underscore the importance of study in higher education while introducing specific initiatives and approaches that optimize the study experience in EE. By investigating these initiatives, we aim to contribute to the broader field of EE and provide valuable recommendations for educators, administrators, and policymakers to enhance the quality and effectiveness of study practices in engineering curricula.

3.2.1 Addressing the Missing Prerequisite: CIAO!

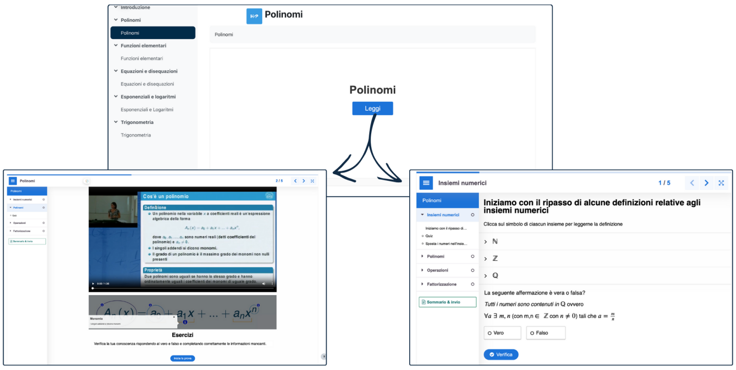
Building upon the comprehensive evaluation process highlighted by the Test in Laib (TIL) discussed in the previous subsection (Subsection 3.1.6), it becomes evident that assessing the competence background of prospective engineering students before university enrollment plays a pivotal role in ensuring a successful academic journey. The TIL has successfully addressed the need for a robust evaluation process based on merit, ultimately enhancing the quality and attractiveness of incoming students while reducing the dropout rate. However, competence assessment goes beyond the initial evaluation and requires ongoing efforts to bridge the knowledge gap and ensure a smooth transition into higher education. Recognizing the heterogeneous range of background competencies requisite for success in EE, providing students with effective means to fill any existing knowledge gaps is imperative. In this context, the Corso Interattivo di Accompagnamento Online (CIAO!), or Online Accompanying Interactive Course (OAIC!), serves as an initiative aiming to support incoming students by providing interactive and engaging materials that facilitate the acquisition of fundamental mathematical prerequisites. By addressing the knowledge gap before commencing the core curriculum, CIAO plays a crucial role in promoting a solid foundation of mathematical competencies and fostering academic success among engineering students.

The CIAO is an innovative project developed at the Polito in 2021 to provide interactive and personalized support to incoming students to address any deficiencies in their mathematical knowledge before commencing the core curriculum. The primary goal of CIAO is to enable students to acquire a solid foundation of mathematical prerequisites by promoting active and engaging learning.

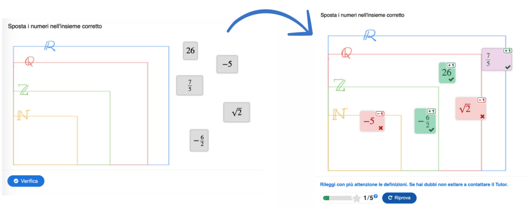
The course is accessible through the university's Moodle platform. It offers a wide range of interactive materials, including interactive e-books with videos, interactive exercises with immediate feedback, concise theoretical texts, games, and definitions implemented using H5P (Fig. 3.12a and Fig. 3.12b). One distinctive feature of CIAO is the adoption of game-based learning principles, allowing students to accumulate experience points during their interactions with the course content (Fig. 3.13) and engage in a final challenge within a gaming environment represented by an escape room (Fig. 3.14).

In September 2021, the CIAO was initially introduced solely in Italian and was not compulsory for students. However, recognizing the need to cater to an international student body, an English version of CIAO was subsequently developed and made available in 2022. Furthermore, as of September 2023, CIAO has transitioned into an Obligatory Additional Training (OFA) module, requiring all students who receive a low score in the mathematics section of the Test in Laib (TIL) to complete the CIAO program. This mandatory implementation of CIAO aims to address and bridge the knowledge gap in mathematical competencies among students, ensuring a solid foundation before embarking on their EE journey. In general, the key objectives of CIAO include the following:

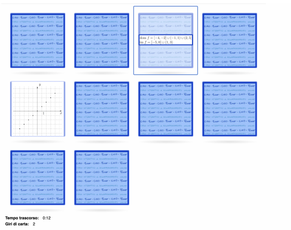
- Remediation of mathematical deficiencies: The course aims to provide students with tools and resources to address any gaps in their mathematical skills.



(a) A book with some examples of video and interactive materials



(b) Example of interactive game with immediate feedback



(c) Learning the domain of functions using memory

Fig. 3.12 Screenshot of CIAO! course

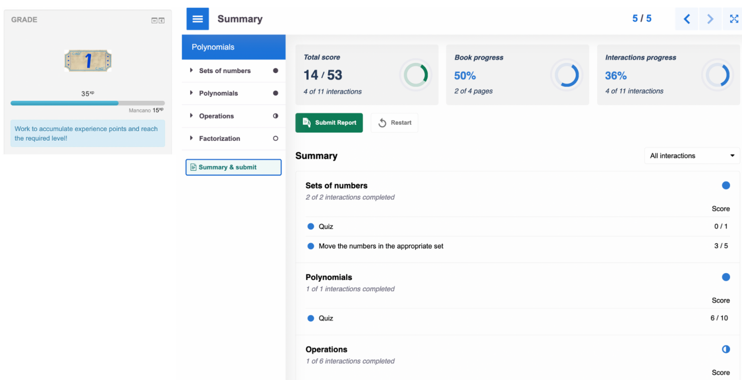


Fig. 3.13 Gamification elements in CIAO! course

Fig. 3.14 Screenshot of EscapeRoom

CIAO seeks to reinforce the fundamental mathematical knowledge required for successful university studies through an interactive and engaging approach.

- Promoting active learning: By employing innovative teaching methodologies such as game-based learning, CIAO encourages students to participate in the learning process actively. The interactivity of the materials, immediate feedback, and moments of assessment within the gaming environment stimulate student interest and foster active engagement in mathematics.
- Enhancing student confidence and self-assurance: Through successfully completing challenges presented by CIAO and achieving positive outcomes, students develop increased confidence in their mathematical abilities and a greater sense of self-assurance in their choice of study. This translates into greater active participation and a higher likelihood of academic success.
- Reducing early attrition rates: Another crucial objective of CIAO is to reduce early dropout rates in university studies. By addressing mathematical deficiencies and equipping students with a solid foundation of prerequisites, the course aims to diminish feelings of frustration and decrease the likelihood of premature discontinuation.

The CIAO! is structured into five modules: Polynomials, Elementary Functions, Equations and Inequalities, Exponentials and Logarithms, and Trigonometry. Each module is presented through an interactive book implemented using H5P technology. The interactive books incorporate various elements such as short videos, theoretical content, and diverse exercises aimed at engaging students actively in the learning process. Upon completing each exercise, students receive immediate feedback presented in a gamified visual format, where a moving star indicates their score on a progress bar, accompanied by an explanatory message.

Furthermore, CIAO! utilizes a game-based learning approach to enhance student motivation and participation. As students interact with the course content, they accumulate experience points, allowing them to progress to higher levels. Each level attained unlocks a "lottery ticket" (Fig. 3.13) allowing students to participate in unique draws. Additionally, CIAO! features an intriguing challenge in the form of an online escape room designed to promote self-evaluation and consolidate knowledge within a playful environment. The escape room scenario involves solving enigmas related to CIAO topics, with the ultimate goal of successfully navigating through different locations, such as the Aula Magna, courtyard, main hall, and ultimately finding the correct classroom and seat (Fig. 3.14). Students are given 24 hours to complete the challenge and evaluate their understanding of the course material. As a reward for completing the escape room, prizes are drawn based on the number of accumulated lottery tickets.

While students have various means to address missing prerequisites, such as self-study, face-to-face courses, tutoring sections, MOOCs, and online resources, it has been observed that the incorporation of playful learning experiences and gamification elements significantly increases students' interest in bridging their knowledge gaps. Introducing a gamified approach within CIAO incentivizes students to actively engage with the course material, fostering a more enjoyable and practical learning experience. This approach not only promotes knowledge acquisition but also enhances students' intrinsic motivation, thereby contributing to a more comprehensive and successful preparation for their engineering studies. Considering the positive results achieved, CIAO has expanded its scope and now includes the prerequisite assessment of other subjects, such as physics, further enhancing its effectiveness in preparing students for their engineering journey.

3.2.2 An Inclusive and Stimulating Environment: Talenti Project

Starting university marks a significant milestone in students' academic journey, where they embark on a path of higher education and specialized knowledge acquisition. At Polito, guided by the indispensable assumption of the absolute centrality of the student, comprehensive support and services have been provided to students throughout their educational journey. As part of this commitment, the initial year is dedicated to establishing a solid foundation in key knowledge areas, including Mathematical Analysis, Computer Science, Chemistry, Physics, Algebra, and Geometry. The university offers various teaching support initiatives to facilitate the transition from high school to university, such as realignment courses for students with specific gaps in Mathematics and Physics (like the CIAO program mentioned in the previous section), recovery courses for those who did not pass the initial Mathematics exam, recorded lessons available online, and tutoring assistance.

While these initiatives cater to the needs of a significant portion of the student population, it is essential to further focus on the quality of students' preparation and take specific actions to cater to a segment of the student population exhibiting exceptional skills. A technical university must explore and implement innovative approaches to strengthen the learning processes, particularly during the Bachelor's years, in light of evolving didactic potentials and social requirements. In this context, the board of Polito has posed several fundamental questions: How can a technical university effectively support talented students? Can this process be inclusive without completely segregating them from their peers? Additionally, what is the impact of these actions on the overall student population, including students with difficulties and those following a standard career trajectory?

To address these inquiries, we delve into the examination of the "Research among Quality-Young Talent program," known as the Talenti project. This program, introduced at Polito, focuses on fostering excellence and inclusivity within the Engineering domain [221].

The Talenti project emerged from the recognition that some students possess exceptional aptitude and potential in engineering. These students demonstrate a strong inclination towards STEM subjects and exhibit remarkable abilities compared to their peers, as determined by their TIL scores. The need to provide an enriched learning experience to these talented students arises from the desire to foster their intellectual growth, nurture their talents, and cultivate their potential as future leaders in the engineering field. This section will explore the rationale behind working with talented students and address the research questions that drive the Talenti project.

The Talenti project was initiated in the academic year 2014/15 to provide specialized support and opportunities to top students pursuing engineering degrees. The project encompasses a comprehensive framework integrating talented students into the regular curriculum while offering additional resources and tailored activities to enhance their educational experience. The selection process is a critical component of the Talenti project, which aims to identify exceptionally bright students with the potential to excel in engineering. By analyzing the PoliTo incoming population over the past few years and their TIL scores, a distinct cohort of bright students has been observed, spanning all different Engineering mayors. Therefore, the project selection is based on the strong correlation between the students' scores in the TIL admission test and their subsequent academic performance, establishing the TIL score as a reliable selection instrument [220].

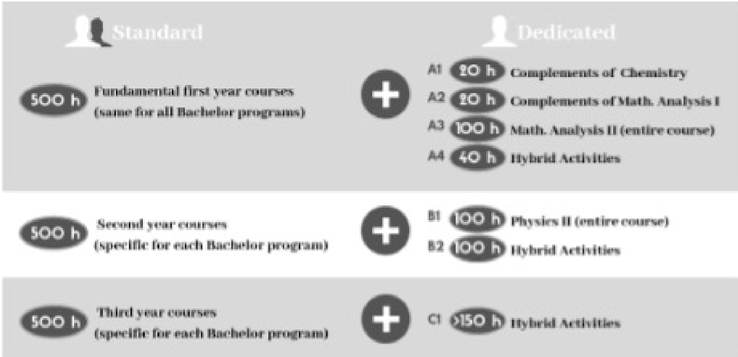


Fig. 3.15 The detailed structure of the program

Approximately 7% of the students, out of the approximately 5,000 who undertake the TIL test every year, achieve a score equal to or greater than 70/100, making them the ideal candidates for the Talenti project. These students form a highly promising pool of participants. It is important to note that the initial experiment was conducted in Italian. However, the program is open to both national and international students, provided they have a basic knowledge of the Italian language. In any case, the standard courses within the program can be pursued in either Italian or English.

The number of participants in the Talenti project amounts to approximately 4% of the total student enrollment, corresponding to around 200 seats. To ensure continued participation in the program, students must meet specific checkpoints at the end of each academic year, including the end of the first semester, first year, second year, and third year. If students fail to fulfill the requirements at any of these checkpoints, they continue their studies through the regular academic path. Moreover, new students can be included in the program during the first two checkpoints while still adhering to the maximum enrollment capacity of 4% of the total student population.

The Talenti program offers talented students a structured and enriched curriculum, encompassing a range of activities and opportunities designed to stimulate their intellectual growth and foster their talents. The project implements a comprehensive and structured curriculum for the entire bachelor (three years), combining standard academic courses with dedicated activities. The program aims to provide a hybrid learning experience that extends beyond technical subjects, fostering students' development in non-technical areas. The detailed structure of the program is depicted in Fig. 3.15.

During the first year, the selected students attend standard courses with their peers, including Chemistry, Computer Science, Mathematical Analysis I, Linear Algebra and Geometry, and Physics I. These courses are conducted in parallel classes of approximately 250 students each. To enhance the student's learning experience, reinforcement activities are organized in the first semester for Chemistry and Mathematical Analysis I. These interventions promote practical application in laboratory sections, offer in-depth exploration of the covered topics, and encourage autonomous study. Interdisciplinary themes are also emphasized. In the second semester, ahead of the regular schedule, students participate in a reinforced course of Mathematical Analysis II, as well as Physics II in the third semester.

Hybrid activities form a core element of the Talenti project and are incorporated throughout the three-year curriculum. The program progressively increases the scope of these activities each year. Students attend a three-day full-immersion training weekend in the first year in November. This activity involves seminar classes to foster a creative problem-solving approach, team-based problem-solving competitions, and educational hiking in natural surroundings. This strategically positioned event allows students to familiarize themselves with one another and cultivate teamwork skills. During the second semester, a guided visit to CERN in Geneva is organized, providing students with an opportunity to meet scientists, explore the innovative research center's organization and management, and gain exposure to cutting-edge research.

In the second year, the Talenti project strengthened its ties with local industrial stakeholders through visits to renowned companies such as Maserati manufacturing plants. Additionally, laboratory sections are conducted within the FCA (FIAT Chrysler Automobiles) factory in Turin. These small-group laboratory activities enable students to reinforce their knowledge of labor processes. The experience comprises a two-hour plenary session focused on vehicle development, production processes, and automotive research objectives, followed by thematic sessions of 4 to 8 hours in CRF (Research Centre of FIAT) laboratories. Students can choose from various practical experiences, including crash Finite Element Method (FEM) analysis, computational fluid dynamics, electromagnetic compatibility, powertrain development, smart materials, and cooperative and wearable robotics. This hands-on engagement allows students to delve into specific phases of the research and development (R&D) process, collaborating closely with FCA and CRF engineers and technicians.

In the third year, students are divided into small groups to pursue different activities. These activities include study abroad opportunities, encouraging students to spend a semester at partner universities within an extensive network of agreements; interdisciplinary projects focusing on improving the local environment in collaboration with public administrations; seasonal schools offering immersive learning experiences to strengthen specific knowledge; and internships providing work experience within innovative local factories. Furthermore, special events and conferences, such as the "Building up the future" lecture series, explore scientific, humanistic, and ethical aspects relevant to engineering.

Throughout the program, students benefit from the guidance of mentors who not only enhance their technical knowledge but also contribute to their cultural background, personal growth, and integration within the group. Mentors transfer technical expertise, professional experience, and labor market skills.

In addition, participating students receive various benefits, including educational incentives, economic advantages, and welfare support. To obtain the Talenti project diploma, students must fulfill all program requirements, complete all the required activities, and graduate within the specified timeframe (by December of the third year of the Bachelor's program). Tuition fees are determined based on family income, with exemptions for students whose fees are less than or equal to 1,500 euros and a reduction of 1,500 euros for those with higher fees. Additionally, students receive a package that includes a local transportation subscription for bus and bike sharing and a card granting free access to numerous regional museums.

The TalentI project has yielded valuable findings and insights regarding the impact of working with talented students in EE. Analysis of the data collected from multiple cohorts reveals several noteworthy findings in the project's first four years.

Firstly, the gender distribution among the enrolled students was skewed, with 86% males and 14% females. Geographically, approximately 30% of the students came from Piedmont, the region where PoliTo is located. While 15% came from Apulia, 12% from Sicily, and the remaining students represented other Italian regions and foreign countries. Evaluation of the students' TIL scores demonstrated a positive trend over time, indicating an improvement in the quality of enrolled students (Fig. 3.16). This trend is supported by an increasing number of first-year students achieving TIL scores higher than 70/100. Furthermore, the percentage of students graduating within three years or within 3.5 years has shown a consistent increment.

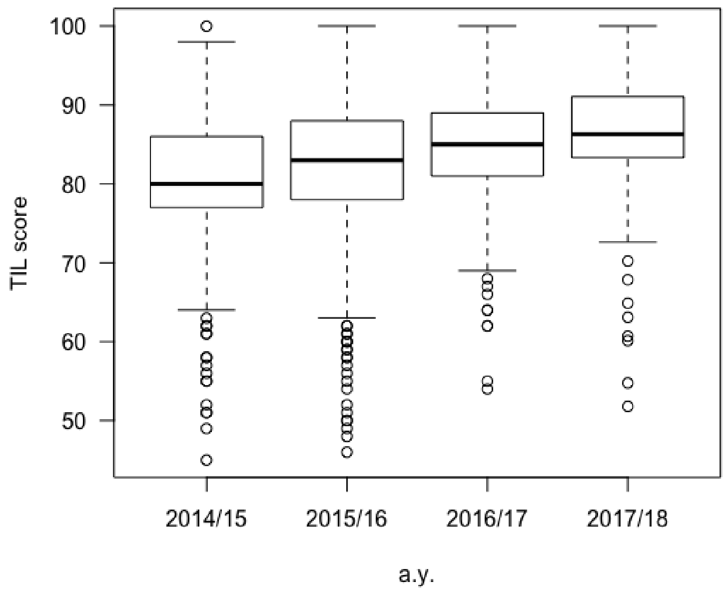


Fig. 3.16 Boxplot of the TIL score related to students of each cohort

A stable number of students in the program is observed across the first three cohorts, with the first cohort seeing 83% of Talenti students obtaining the "Talenti" diploma (Fig. 3.17). Regarding further studies, all students enrolled in the project continued

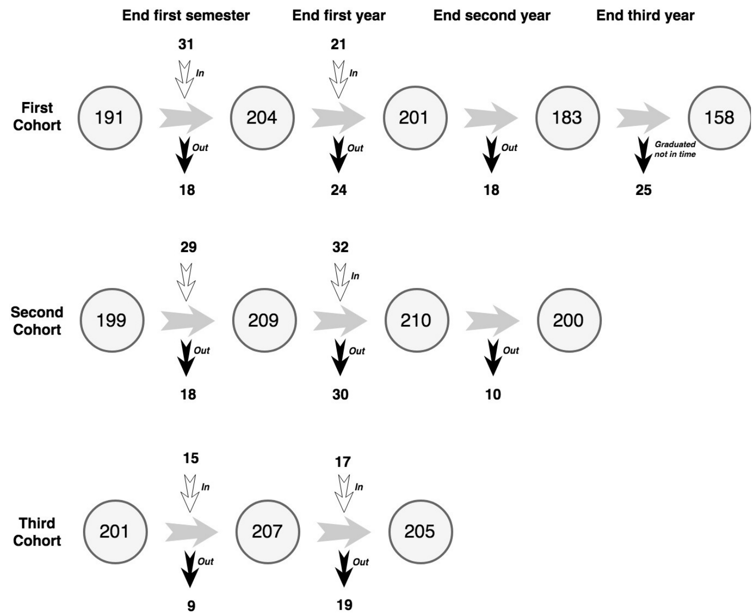


Fig. 3.17 Number of students involved step-by-step (in the circles), entering (white arrows) or leaving (black arrows) the program

their education, with 124 of the 158 graduates applying to a Master of PoliTo and 34 students pursuing their studies in highly ranked European universities. The qualitative analysis of students' feedback highlighted various aspects. For instance, mentorship support received low evaluation scores, leading to its deactivation and the introduction of a generic tutor. Additionally, students emphasized the importance of laboratory sections in Chemistry and suggested a better balance of workloads between semesters. As a result, adjustments were made, such as enriching Chemistry laboratories and moving the Computer Science course to the first semester. Trials and student feedback helped refine courses, leading to the introduction of a new Linear Algebra and Geometry course in the standard track(Fig. 3.18). The usage of

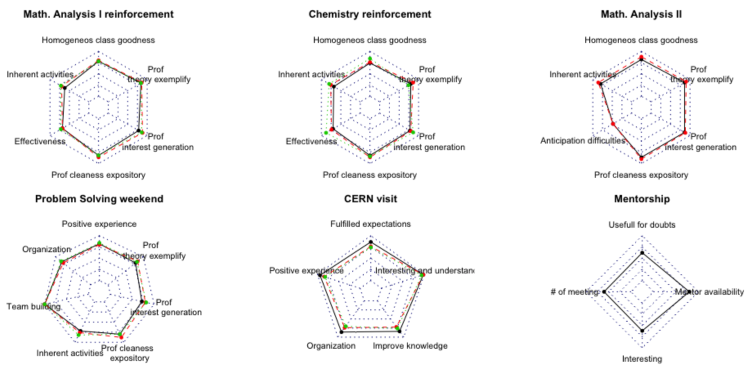


Fig. 3.18 Radar graph for each activity of the first year for the three cohorts

benefits like the Museum card, Bike card, and Public transportation card was found to be high and valuable for students. These findings contribute to understanding the Talenti project's effectiveness in improving student outcomes and provide insights for further enhancing the program's structure and offerings.

In conclusion, the TalentI project has proven to be a valuable initiative in EE, addressing the needs of exceptionally talented students and providing them with the resources and support necessary to reach their full potential. Through a rigorous selection process and a structured program, the project has fostered an inclusive and stimulating learning environment, cultivating the talents of the next generation of engineers. The findings of the TalentI project contribute to the broader field of EE, emphasizing the importance of catering to the needs of talented students and promoting collaborative learning for all students.

3.2.3 Reverse Inclusion: a new Perspective

One of the key strengths of the Talenti project lies in its capacity to stimulate and motivate not only the talented students themselves but also the broader student community [222]. The project establishes an environment that fosters peer learning and collaboration by incorporating talented students into regular classes. This approach yields positive outcomes for students overall, including reduced dropout rates, improved academic performance, and increased graduation rates.

Reverse inclusion, a concept closely associated with the Talenti project focuses on the indirect inclusion and support of protégé students through the participation of talented students in regular classes. Speaking about 'reverse inclusion' can seem a paradox. However, the empirical definition can be stated as the process that, by stimulating the talented students, indirectly includes the protégé. This idea came from the observation of the impact that the presence of bright students attending the Talenti project can have a beneficial impact on the learning environment for all students.

By integrating talented students in standard class settings, reverse inclusion promotes peer interaction, knowledge sharing, and exchange of ideas. In these mixed-class settings, talented students serve as role models and mentors, guiding and supporting their peers. This interactive environment allows students with varying ability levels to engage with challenging subject matter and cultivate a deeper comprehension of the material. By working collaboratively on projects and assignments, students can benefit from the diverse perspectives and expertise brought by the talented students. Furthermore, the participation of talented students in regular classes provides an opportunity for protégé students to observe and learn from the accomplishments of their peers, thereby fostering motivation and raising the overall quality of education. This has been registered with a reduction in the graduation time with a higher score degree average, despite an increase of first-year students (Table 3.1).

The reverse inclusion approach also facilitates curriculum improvements. As talented students represent a standard class size, they can offer valuable feedback on course content, organization, and workload distribution. This feedback loop enables lecturers to optimize course design, identify areas for improvement, and tailor the curriculum to meet the needs and capacities of all students. The insights gained

a.y.	Matriculated	Graduated in 3 years	Average degree 3 years	Graduated within 3.5 years	Average degree 3.5 years
2011/12	3989	733	100,4/110	1078	94,2/110
2012/13	4007	872	100,0/110	1152	96,8/110
2013/14	4168	893	100,9/110	1261	97,1/110
2014/15	4432	980	101,2/110	1390	100,1/110

Table 3.1 The number of students who graduated in 3 years and within 3.5 years with the related average degree.

from talented students' experiences can inform pedagogical strategies, assessment methods, and the integration of real-world applications into the curriculum.

For example, based on the annual survey findings, talented students expressed concerns regarding the workload imbalance between the first year's two semesters. To address this issue, the Computer Science course was identified as the most suitable candidate for being moved from the second to the first semester, considering the students' background requirements. Consequently, starting from the academic year 2015/16, this course adjustment was implemented for all students, ensuring a more balanced curriculum.

Similarly, the standard Geometry class required a content review focusing on reinforcing the Linear Algebra component and introducing the use of MatLab software. A new course combining Linear Algebra and Geometry was meticulously planned. Leveraging the talented students' ability to simulate a standard class environment and provide valuable input, the revised course was proposed within the Talenti program. As their feedback indicates, the students responded positively to this new course (Figure 3.19). This trial not only facilitated the coordination between different courses but also led to the decision to introduce the new 'Linear Algebra and Geometry' course to all students following the traditional path, starting from the academic year 2016/17, thereby replacing the previous Geometry course.

The concept of reverse inclusion carries significant implications for EE, as evidenced by the "Inclusion: a new reverse perspective" [222] paper's recognition with the "Most Original Contribution" award at the UK&IE EERN symposium on November 2nd, 2018, in Portsmouth.

By integrating the Talenti project and reverse inclusion strategies into EE, institutions can establish inclusive learning environments catering to student's diverse needs

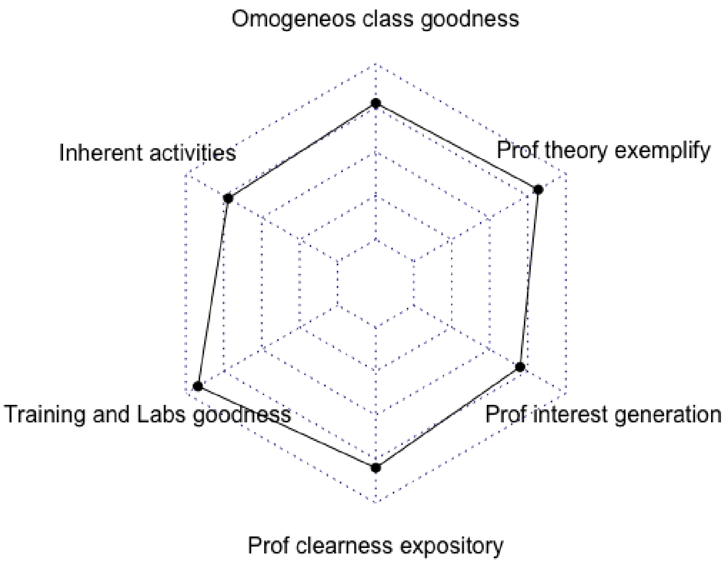


Fig. 3.19 Radar plot with the results of the Linear Algebra and Geometry course's survey

and abilities. This integration necessitates designing inclusive programs that address the challenges and opportunities of nurturing talented students in regular classroom settings. Additionally, providing appropriate resources and support for talented students, such as advanced learning materials, specialized workshops, and mentorship programs, further enhances their educational experience. Furthermore, fostering meaningful interactions among students with varying abilities through group projects, peer mentoring, and collaborative problem-solving promotes a culture of inclusivity and collective learning.

In summary, the Talenti project and the concept of reverse inclusion challenge the traditional teacher-centered model and promote student-centered learning environments that foster collaboration, critical thinking, and the development of higher-order skills. By embracing these approaches, Polito has created an educational landscape where the potential of all students, including talented individuals, is recognized, nurtured, and harnessed to benefit the entire student body.

3.2.4 Methodological Support for Learning How to Study: DayByDay

The DayByDay project was developed based on a meticulous analysis of the *Analisi Matematica 1* (Mathematical Analysis 1) course, employing the principles of the

ADDIE (Analysis, Design, Development, Implementation, Evaluation) instructional design methodology. The role of introductory science courses, such as Mathematical Analysis 1, is not limited to pure knowledge transfer but represents a preliminary approach to science. As a secondary goal, they also reinforce many soft skills that engineering studies require.

Incorporating the ADDIE methodology ensured a systematic approach to developing and implementing the DayByDay project. In the analysis phase, the lecturers conducted a comprehensive needs assessment, examining the students' performance in the TIL assessments and analyzing the data from their academic careers. The TIL results indicated that a considerable number of students struggled with specific mathematical concepts and needed help applying them in problem-solving scenarios. The analysis of the students' careers further revealed that they faced methodological challenges related to study habits, time management, and self-assessment, which impacted their graduation time and the number of exams passed in each session.

In the academic year 2019/20, a pilot qualitative study was conducted to support the project's development. This study involved only one of the twenty parallel courses, with approximately 60 out of 250 students participating voluntarily. These students did not receive additional points for the final exam, but they received a detailed study program and the opportunity to take an online weekly quiz. The students received email reminders if the quiz was not completed within a week. At the end of the semester, the data relating to the weekly quizzes and the exam outcomes were analyzed. The majority of voluntary students who participated in the pilot study successfully passed the exam in the winter session. This positive outcome provided valuable insights and served as the basis for the structured DayByDay project that was designed and implemented in the academic year 2020/21.

During the academic year 2019/20, a group of dedicated lecturers regularly came together to follow the ADDIE methodology. It thoroughly examined the results from the TIL assessments, the reverse inclusion study, and the pilot study. This rigorous analysis not only revealed content-related gaps but also shed light on the methodological challenges faced by the students.

Using these valuable insights, the lecturers proceeded to the design phase of the DayByDay project. They devised strategies to address the identified challenges by leveraging appropriate rewards and instructional resources to support both the content and methodology. They decided to introduce ongoing activities to support the continuous engagement of students, and these activities were assessed and counted towards the final exam score, with a maximum weight of 3 points. This change required revising the entire exam structure, as summarized in Table 3.2.

	a.a. 2019/20	a.a. 2020/21	
Multiple choice test (T)	min 12/20	min 8/15	Same for all courses
Written exam (W)	min 5/13	min 8/15	Same for all courses
On-going (Og)	-	max 3	Each course can organize its own
Oral exam (O)	Not mandatory	Not mandatory	
Final grade	T+W+O	T+W+Og+O	

Table 3.2 Structure of the Mathematical Analysis 1 before and after the introduction of the ongoing activities in the academic year 2020/21

Through a careful selection process, the lecturers created a set of activities and materials that aimed to scaffold the student's learning process effectively. They also took into account the unique circumstances imposed by the COVID-19 pandemic, incorporating measures to support distance learning and foster student engagement.

To study the impact of this new approach, the DayByDay project was made available to 7 out of the 20 parallel mathematical courses at Polito. Each course consisted of 60 hours of lectures and 40 hours of exercise classes. The theoretical lessons were devoted to presenting the topics, including definitions, theorems, examples, properties, and proofs, which were believed to facilitate the learning process and students' metacognition. Every theoretical aspect was associated with introductory examples. The exercise hours aimed to develop proficiency in computation.

As the project entered the development phase, the lecturers refined its structure to ensure clarity in communication and prompt student support. They established well-defined evaluation criteria, allowing students to assess their own progress and receive constructive feedback. An overview of the evaluation criteria for the main activities proposed by the DayByDay project is presented in Table 3.3.

An activity was proposed weekly, following the pattern T, E, EC (as shown in Figure 3.20, the activities calendar for the academic year 2020/21). Students could choose when to fulfill these activities within the week, starting from the fourth week. All the activities replicated the exam environment, with the tests using the same structure and platform and the exercises structured similarly to the written part.

Evaluation Criteria	Description	Mode	Max activities points for each
Individual Activities [T]	4 set of 15 multiple-choice tests [T1, T2, T3, T4]	1 attempt only, 1 hour, open a week	T: 15
Group Activities [E & EC]	3 sets of 12 exercises [E1, E2, E3] to be performed with teammates. Then, each team is asked to evaluate the work of another team [EC1, EC2, EC3]	1 week for submit the set of exercises, 1 week for evaluate the work of another team	E+EC: 36 (24+12)

Table 3.3 Evaluation Criteria in the DayByDay Project

data	Inizio attività **ore 16:00**	Consegna attività **entro ore 12:00**
30 ottobre 2020	**T1**	
6 novembre 2020	**E1**	**T1**
13 novembre 2020	**EC1**	**E1**
20 novembre 2020	**T2**	**EC1**
27 novembre 2020		**T2**
4 dicembre 2020	**E2**	
11 dicembre 2020	**EC2+T3**	**E2**
22 dicembre 2020	**E3**	**EC2+T3**
4 gennaio 2020	**EC3**	**E3**
8 gennaio 2021	**T4**	
11 gennaio 2021		**EC3**
15 gennaio 2021		**T4**

Fig. 3.20 Activities calendar for academic year 2020/21

The individual activities consisted of four sets of 15 multiple-choice tests performed via the Moodle platform. Each test allowed only one attempt and lasted one hour. The group activities involved three sets of 12 structured exercises to be solved in collaboration with teammates. The solutions were uploaded to Moodle. The following week, each team received another group's solution and was asked to evaluate it, correct any mistakes, and upload the revised document on Moodle. Students received a structured layout where they needed to fill in the list of participants, the exercise solution, the peer-to-peer score, and the corrections made by the lecturer. The lecturer could confirm or modify the peer-to-peer score associated with the exercise solution and award one point for an acceptable correction or zero if something were missing or incorrect. Each group activity could receive a score of up to 36 (24 for the solution and 12 for the correction).

The evaluation criteria for the activities were as follows:

- Individual activities:
  - 1 point: Four tests performed with a score of 8/15 or higher, with at least two tests scoring 12/15 or higher.
  - 0.5 points: At least three tests were performed with a score of 8/15 or higher.
- Group activities:
  - 2 points: Three sets of exercises delivered with a score of 20/24 or higher, with at least two sets scoring an overall score of 32/36 or higher after the correction phase.
  - 1.5 points: Three sets of exercises delivered with a score of 20/24 or higher, with at least one set scoring an overall score of 32/36 or higher after the correction phase.
  - 1 point: At least two sets of exercises delivered with a score of 20/24 or higher.
  - 0.5 points: At least one set of exercises delivered with a score of 20/24 or higher.

During the implementation phase, the DayByDay project was successfully executed. The lecturers ensured clear and timely communication with the students, providing them with a structured learning environment. They offered well-defined evaluation criteria, enabling students to monitor their progress effectively. Moreover, the lecturers remained attentive to the potential stressors and difficulties faced by students, offering necessary support with the help of three senior tutors.

At the beginning of the course, the lecturers organized homogeneous groups of about ten people based on the admission test results. This allowed for maintaining similar average scores and variance within each group. Each group autonomously chose a spokesperson responsible for file uploads and coordinating meetings for the group activities. Students could decide where to meet, but all meetings were held online due to the pandemic conditions. The lecturer had the option to join these meetings to check participation and the distribution of the workload within the team. The lecturer played an auditing role and did not intervene in the discussions.

The number of students participating in the DayByDay project and their engagement levels are presented in Table 3.4.

# Course	Students	New enrolled students	T		E&EC	
			min	max	min	max
1	268	213	182	217	213	217
2	402	329	285	315	315	344
3	250	205	172	199	193	206
4	261	224	192	217	208	216
5	334	211	204	234	228	236
6	252	208	175	212	204	218
7	59	56	49	55	55	55
Total	1826	1446	1259	1449	1416	1492

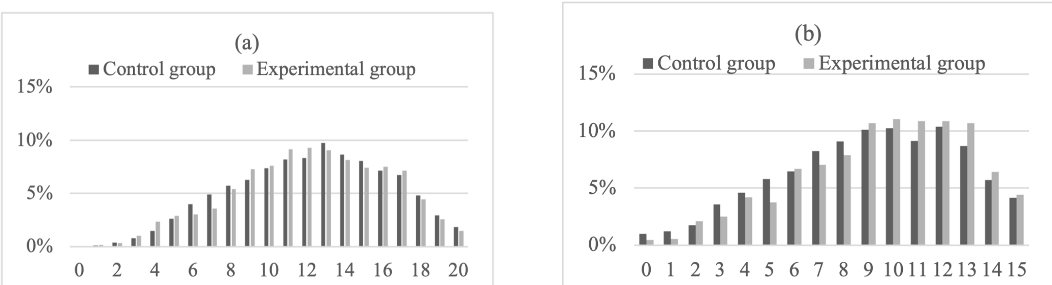
Table 3.4 Number of students in each course within DaybyDay with the relative participation in the activities

An evaluation of the project's effectiveness was conducted to assess its impact. A comparative analysis between the intervention group (the seven parallel courses that adopted DayByDay) and the control group revealed significant differences in student outcomes. One crucial element for evaluating the impact of the DayByDay project is the number of students who decide to take the exam in January. Applying to the first available call at the end of the course implies that students have followed the course and remained on track with their studies. In the academic year 2020/21, the experimental group had a 2.34% higher number of students who sat for the test than the control group (Table 3.5).

	January 2020		January 2021	
	Experimental group	Control group	Experimental group	Control group
Test passed	730 (47,04%)	1560 (48,84%)	839 (56,38%)	1587 (50,64%)
Test not passed	548 (35,31%)	1121 (35,10%)	313 (21,04%)	766 (24,44%)
No showed up	274 (17,65%)	513 (16,06%)	336 (22,58%)	781 (24,92%)
Total	1552	3194	1488	3134

Table 3.5 Test results related to January call in the academic year 2020/21

However, it should be noted that for both groups, the overall number of examinees decreased, which can be attributed to the pandemic conditions and the shift to online courses. The two groups were comparable in the number of students who passed the multiple-choice test in the academic year 2019/20. The test had random questions, but each set was comparable in difficulty and the variety of topics addressed. Therefore, the test provided an objective measurement. In the academic year 2020/21, the experimental group had a 5.74% higher number of students who passed the test compared to the control group. Analyzing the score distribution (Figure 3.21b), the experimental group had a higher average (9.51/15 points vs. 9.05/15 points) with a lower standard deviation (3.37 vs. 3.53). Similarly, in the academic year 2019/20, there was no significant difference in the scoring average (12.12/20 vs. 12.22/20) and standard deviation (4.02 vs. 4.03) between the two groups (Figure 3.21a).



(a) January 2020 (b) January 2021

Fig. 3.21 Test score distribution in (a) January call 2020 and (b) January call 2021

In the end, considering the overall exam, which includes the written test that is the same for all courses, the assessment becomes less objective compared to the test. In a tiny proportion of cases, the lecturers or the students required an oral exam. Table 3.6 shows the results of Analysis Mathematical 1 at the end of the first session (including both the January and February calls).

	First session 2020		First session 2021	
	Experimental group	Control group	Experimental group	Control group
Exam passed	851 (54,84%)	1662 (52,03%)	823 (55,31%)	1441 (45,98%)
Exam not passed	486 (31,31%)	1135 (35,54%)	431 (28,96%)	1168 (37,27%)
No showed up	215 (13,85%)	397 (12,43%)	234 (15,73%)	525 (16,75%)
Total	1552	3194	1488	3134

Table 3.6 Exam results related to the first session

The results indicate the positive impact of the DayByDay project. The intervention group exhibited higher engagement and success rates than the control group. Furthermore, the intervention group achieved significantly higher average exam scores, demonstrating a deeper understanding of the course material. These results have been presented as a poster at the SEFI conference [223]

In conclusion, the DayByDay project exemplifies the value of methodological support in EE. By applying the principles of the ADDIE instructional design methodology and leveraging insights from the TIL assessments and the reverse inclusion study, the lecturers developed a comprehensive framework that effectively addressed content-related gaps and methodological challenges. The project's outcomes, as evidenced by the evaluation results, underscore its effectiveness in enhancing student learning experiences and improving academic performance.

3.2.5 Math Game Without Frontiers: Reinforcing Mathematics Through Playful Learning

In addition to the DayByDay project, another innovative initiative called the Math Game Without Frontiers [224] was introduced to enhance further the learning experience for first-year students in the Mathematical Analysis 1 course. This initiative aimed to reinforce the course contents through engaging and interactive games, incorporating playful learning elements to provide a unique and enjoyable approach to mastering mathematical concepts.

The Math Game Without Frontiers served as a complementary tool to traditional classroom instruction and study materials, creating a dynamic learning environment that fostered active participation and critical thinking among students. Through various game-based activities, students were able to apply their mathematical knowledge in practical and stimulating contexts, enhancing their understanding and retention of the course material.

This section delves into the details of the Math Game Without Frontiers competition, exploring its objectives, methodology, and the positive outcomes it yielded. By incorporating playful experiences into the learning process, this initiative aimed to make studying the first Mathematical course at the University more engaging and enjoyable for first-year students.

The Math Game Without Frontiers competition took place at the College of Merit CAMPLUS, located in different cities in Italy from South to North, during the autumn of 2020 and 2021, involving first-year STEM students. Initially held in person, the competition transitioned to an online format due to the COVID-19 pandemic, enabling participation from colleges all over Italy. The competition consisted of several rounds, with teams of students competing against each other to earn points based on their performance in the mini-games.

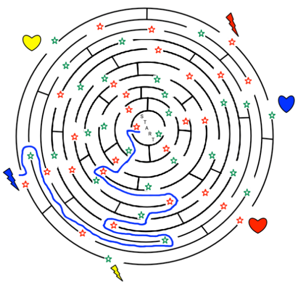
The challenge was open to all first-year students living in one of the Italian Camplus and with at least one mathematical exam in the university's first year. The first edition involved 52 participants (15 females and 37 males) from 9 colleges. In the second edition, there were 30 participants (14 females and 16 males) from 7 colleges. Students autonomously formed couples within the same Camplus, with some exceptions in the first edition when two mixed pairs came from different Camplus. Teams were free to choose whether to play physically or remotely. A private instantaneous message channel between lecturers and each couple was established to collect the game's solutions.

Applying the game-based learning methodology, the games incorporated well-known puzzles to familiarize students with Mathematical basics content, partially inspired by the work of Morando [225] and further developed for remote play. "Math games without frontier" consisted of five one-hour-long sessions of playful scored activities. The events took place one week apart and required mathematical knowledge, teamwork, and strategy. In the 2020 edition, the first three evenings focused on essential knowledge (elementary functions such as trigonometric, exponential, and logarithmic functions; equations and inequalities), while the last two reinforced the concepts of limits and derivatives. In the 2021 edition, the first two evenings work on essential knowledge, while the remaining three reinforce the concepts of limits, derivatives, and integrals. The inclusion of questions about integration in the second edition was based on feedback from the final survey of the competition's first edition. The rules and any printed materials for each challenge were made available to students the day before each session. Each evening consisted of three different games played in various rounds. To maintain students' concentration throughout the game session, the lecturers showed and discussed all the solutions at the end of the meeting. Teams received their scores during the week, and their ranking positions were provided at the beginning of each session. At the end of the experience, a winning team and a winning Camplus were selected, each receiving a prize.

The Math Game Without Frontiers competition employed several mini-games to challenge and assess students' mathematical skills. These games included Labyrinth, Ordering, Math Twins, Colouring Puzzle, Treasure Hunt, Guess What?, Target, Sudoku, and Connect the Dots. Each game focused on different mathematical concepts, requiring students to apply their knowledge and problem-solving abilities within a limited time frame. Each game's rules and scoring criteria were carefully designed to promote engagement and competition among the participants. Here, we provide a summary of the basic rules used during the competition for each game:

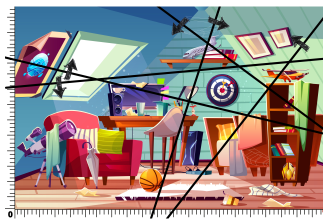
Labyrinth

The Labyrinth game presented True and False exercises in which the tutor read ten statements twice. Starting from the center, the answers formed a path to exit the labyrinth, with true answers matching the green star and false answers matching the red star (see Fig. 3.22a). After the reading ended and 30 seconds elapsed, all the statements appeared on the screen for 1 minute, with the game concluding 30 seconds later (a total of 120 seconds from the end of the reading). Teams earned 1 point for each correct answer, two bonus points if they submitted within 30 seconds of the reading's end, and one bonus point if they submitted within 90 seconds. The first team to submit gained an additional two bonus points. This exercise not only assessed mathematical skills but also trained listening abilities that are not typically associated with mathematics.



(a) Labyrinth

(b) Coloring puzzle



(c) Treasure hunt with the target) [image: freepik.com]

Fig. 3.22 Solutions of different games

Ordering

The game is divided into two rounds: in the first one, teams have to order eight values of trigonometric functions in ascending order, while in the second, eight values must be sorted in a decreasing manner. Each heat has a duration of 4 minutes. Each team has a "STOP" to indicate the point to end the sequence's validation. Teams have one extra minute for the sequence's delivery. Pairs gain 1 point for each correctly ordered sequence but get 0 points if the series order is wrong, even for a single value. Teams get two bonus points if the complete sequence is correct and delivered before time runs out.

Math Twins

A table of 12 + 12 elements to be paired is given to each team. In 5 minutes, the team has to form as many pairs as possible, and within 1 minute, they must send the complete list of pairs. Each team gains 1 point for each correct pair but loses 1 point for each wrong couple. If all pairs are matched correctly, two bonus points are awarded. If the total score is negative, the team score equals zero.

Colouring Puzzle

Another example is the Colouring Puzzle, where each team had to blacken spaces in a figure containing the solutions of 15 mathematical expressions (such as inequalities, equations, or limits; see Fig. 3.22b). The available time for this activity was 12 minutes, and once completed, the team had to submit a photo of the obtained image to the tutors. Suppose the figure is colored correctly; the couple scores ten points. The team loses 1 point for each incorrect or missing box. The team gains two bonus points if the correct figure is delivered before time runs.

Treasure Hunt

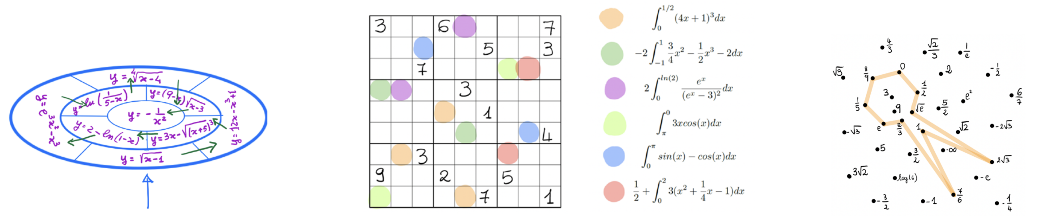
Each team has to solve a system of inequalities graphically, with the goal of identifying the object constrained in the solution plane region of the system. Axes origin is assumed in the lower-left corner (see Fig. 3.22c). The available time to complete the game is 5 minutes. Teams that deliver the correct object within 3 minutes gain ten points; couples that provide the proper object after 3 minutes earn five points. If the object is wrong, the team gets no points. Two bonus points are assigned to the first team that identifies the correct object.

Guess What?

Thirty plots of functions are shown to teams. The tutor secretly chooses one between all the figures. Couples can ask questions about a specific feature defined in advance, with yes or no answers, to guess the tutor's choice. Teams that think they have identified the correct function send a message to the tutors, and the game ends as soon as a pair correctly guesses. Each team has at most three attempts, playing the game in multiple rounds. The team that identifies the correct function gains three points; the same team gains one bonus point if it identifies an admissible analytic expression within 30 seconds and two bonus points if it identifies two different expressions in 30 + 30 seconds.

Target

A target made up of boxes is shown to teams. Each box contains one function. The game's goal is to reach the center of the target by passing over each box at most once, starting from the pointed box. One can move from one box to another if the two boxes are adjacent and the functions follow a prescribed property (for example, Fig. 3.23a shows the case in which the rule is: the intervals of increasing monotony of two functions have a non-empty intersection). The available time is 7 minutes plus one extra minute for delivery. Teams gain 1 point for each correct passage between boxes. They earn one bonus point if they deliver within 7 minutes and gain another two bonus points if, for each box, they indicate the specific property (for example, the interval in which the function is increasing).



(a) Target (b) Sudoku (c) Connect the dots

Fig. 3.23 Examples of different games

Sudoku

Each team has to solve a Sudoku with some empty colored dots (see Fig. 3.23b). Each color is associated with a definite integral. To solve them, they must correctly place the numbers and complete the Sudoku. The time to complete the game is 20 minutes, plus one minute for delivery. Teams are asked to deliver the starting scheme with the integrals computed in order to obtain points: one point for each correct result within 10 minutes and 0.5 points for each proper answer delivered before the end. Six bonus points are gained by the teams that complete the Sudoku within 15 minutes, five points within 20 minutes, and 4 points if the solved scheme is delivered at the end of the time.

Connect the Dots

Each team must solve ten limits and, following the given order, use the solutions to connect the related dots (see Fig. 3.23c). The aim is to draw the secret image within 10 minutes. Each number correctly linked gives one point. The team receives two bonus points if they deliver the correct picture within 10 minutes.

The Math Game Without Frontiers competition has positively impacted the participants' mathematical abilities. Students improved their logical reasoning, calculation skills, and graphical understanding of mathematical concepts through engaging in the mini-games. The competition also provided teamwork, strategy development, and healthy competition opportunities. Feedback from the participants indicates a high level of satisfaction with the experience, with many students expressing a desire for future competition editions. Moreover, the games were found helpful and educational in aiding students' understanding of mathematical concepts. The limited time constraints fostered healthy competition, making mathematics more challenging.

Furthermore, analyzing each game's results provided insights into mathematics's critical aspects for first-year students. For instance, the Labyrinth game was played on three different evenings, and initial concentration was identified as the main difficulty when answering True or False questions based on spoken sentences. As students are primarily accustomed to solving mathematical problems by reading the written text, in both editions, only a few teams delivered their solutions on the first evening before instructions appeared on the screen. However, on the last evening, the number of couples who immediately returned after the end of the reading increased considerably, indicating an improvement in their skills to formalize problems spoken aloud.

The Ordering game was played only on the first evening but also highlighted a critical fact discovered in other games. Students need to familiarize themselves with trigonometric expressions and find it difficult to quantify them. In 2020, 75% of teams scored zero despite having the "stop" available. Similar results came out in the 2021 edition, where 50% of couples were unable to solve at least one of the two "ordering" games proposed. This suggests that many students still feel confident in the results, although they still need to gain a complete mastery of trigonometric functions. Therefore, this could explain why few have used the stop.

The Math Twins game confirmed students' difficulty associating the algebraic expression of a function with its graphs. The game was played on three different evenings, and each evening, there was a different type of twins: trigonometric expressions and numerical values, functions and derivatives, functions and graphs. Teams reached higher scores in the game when the associations were not graphical. Conversely, scores are lower when students associate the graph with the analytic expression; notice that almost 50% of teams scored zero on the first evening of both editions. Scores of the other games suggest the same conclusions. In particular, the Treasure Hunt game highlighted again that most students need to become more familiar with the graphical exercise's solution.

Furthermore, a common factor in all games is the short time to complete challenges: quickly solving exercises requires a specific mastery of mathematics. Since the goals of this challenge are to develop the ability to intuitively visualize the graph of an analytic function and support preparation in differential calculus, these games suggest that more emphasis has to be devoted to the graphical part.

In the second edition, we introduced two new games: Sudoku and Connect the Dots. Regarding the Sudoku, only three teams were able to solve the integrals and complete the scheme. It seems that students made mistakes in calculating elementary integrals quickly. Then, when they got stuck on the Sudoku, they did not realize that the error was on the computation of the integrals, not the scheme solution. Similar considerations can be drawn for the second added game. As before, the time limit seems to be a significant obstacle for students.

The Math Game Without Frontiers competition has not only provided an enjoyable and interactive learning experience for the students. Still, it has also effectively complemented the teaching of the first university course in Mathematics, enhancing students' mathematical skills and preparing them for further studies in the field.

3.2.6 STEMM Games: Developing Soft Skills While Playing with STEMM Subjects

The environment of merit colleges, as exemplified by the "Math Games Without Frontiers" competition, provides a fertile ground for exploring cutting-edge multidisciplinary courses, thanks to the diverse composition of its students. At the Polito, students have the opportunity to access two merit colleges in the region: Collegio CAMPLUS and Collegio R. Einaudi (present in multiple locations).

In this subsection, we will explore the concept of STEMM games and their role in developing soft skills among students. We will discuss a specific edition that took place at the Collegio R. Einaudi. Building upon the richness of multidisciplinarity present in these colleges, the project aimed to leverage the multidisciplinary nature of the academic community to design a course that follows the principles of playful learning and game-based learning, ultimately strengthening the students' soft skills.

STEMM games refer to educational games that revolve around science, technology, engineering, mathematics, and medicine subjects. These games are designed to provide an interactive and engaging learning experience, combining gameplay elements with educational objectives. Unlike gamification, which involves integrating game-like features into non-game environments, game-based learning employs actual games, often on digital platforms, for educational purposes with defined learning outcomes [226]. Games' immersive nature and social perspective make them an ideal medium for effective learning in higher education, as they increase enjoyment and reduce anxiety while enhancing deep learning and higher-order thinking [227, 228].

STEMM games offer a unique opportunity to foster soft skills development among students. Soft skills, also known as transferable or non-technical skills, are essential attributes that complement technical knowledge and expertise. They include problem-solving, teamwork, time management, creative thinking, and critical thinking, among others. These skills are highly valued in the workplace and are crucial to personal and professional success.

Fig. 3.24 Example of the spider diagram inside an individual report

The project involved a series of games conducted over five sessions, each focusing on a specific theme related to one of the five areas: Science, Technology, Engineering, Mathematics, and Medicine. The challenge duration was 11 hours, divided among the sessions, with 27 students participating, forming five teams. The project took place between October and mid-December 2021, and each group gathered physically in a separate space while being connected online with other groups and tutors.

The STEMM games kicked off with an engaging introduction night, setting the stage for the exciting journey that awaited the participating students. During this inaugural event, each student was invited to complete an online self-assessment questionnaire on their soft skills, utilizing the SoftSkillOrienta platform (https://www.softskillorienta.it/). The questionnaire generated a short report with a spider diagram 3.24, offering insights into the students' proficiencies across different areas. This initial evaluation not only provided a baseline understanding of their strengths but also served as a starting point for personal and collective growth throughout the project. The introduction night fostered a sense of anticipation and curiosity among the students, sparking their enthusiasm for the upcoming STEMM games and the opportunity to develop their soft skills in a dynamic and interactive learning environment.

The sessions were organized as follows:

Game 1: Engineering

The first game focused on Engineering. It was organized in a structured manner to ensure an engaging and competitive experience for the participating teams. The challenge involved constructing towers with the goal of achieving maximum height while being capable of supporting the greatest weight. Each team was provided with materials such as A4 papers, large adhesive tapes, canned goods weighing 400 grams each, and a measuring tape to facilitate the competition.

The organization of the game consisted of three distinct phases. Firstly, there was a 15-minute strategy session where team members could discuss their approach with the camera turned on but microphones muted. This allowed teams to plan their tower construction strategies collaboratively. Next, there was a 30-minute construction phase, where team members actively worked on building their towers while keeping their cameras and microphones on for real-time communication and coordination. This phase provided an opportunity for teams to apply their problem-solving skills, teamwork, and leadership abilities.

Finally, there was a 20-minute construction phase where the camera was on, but the microphones were muted, allowing teams to focus on finalizing their towers without distractions. At the end of the designated construction time, the towers were evaluated based on two criteria: height and strength 3.25. Points were awarded based on the tower's height, with the tallest tower receiving 50 points. Additionally, the towers' resistance to holding canned goods for specific durations resulted in additional points awarded based on the number of cans supported and the duration of support.

This organization of the first game provided a structured framework for teams to strategize, collaborate, and put their engineering skills to the test. The planning, construction, and evaluation phases allowed participants to showcase their problem-solving abilities, teamwork, and creativity in designing and building sturdy towers.

Game 2: Medicine

In collaboration with Dr. Chiara Vignati, the second game centered around Medicine. The challenge was meticulously organized to facilitate engaging debates and foster

Fig. 3.25 Picture of the towers before measuring the height

critical thinking among the participating teams. "Defend Your Position" followed a structured format that allowed teams to present their arguments, counter-arguments, and concluding remarks within specified timeframes.

Each team defended either a favorable or opposing position, and different team members served as speakers for each argument. The thesis presented in the medicine game challenged participants to explore the topic of inclusivity in athletics. Specifically, the question posed was whether Paralympic athletes who meet the participation criteria should be allowed to compete alongside non-disabled athletes in track and field events. This thought-provoking thesis encouraged students to delve into the ethical, logistical, and practical considerations surrounding inclusivity in sports.

The organization of the game involved several phases. Firstly, there was a 15-minute planning session where teams could strategize their arguments with their cameras turned on but microphones muted. This initial phase allowed teams to coordinate their approach, assign roles, and develop their key points.

Next, there were multiple rounds of argumentation, each with specific time allocations. In the first round, each team had three minutes for their speaker to present their arguments. Following this, there was a 10-minute planning phase with cameras on and microphones muted, allowing teams to prepare counter-arguments. In the second round, each team had two minutes for their second speaker to present their counter-arguments. Subsequently, teams had another 10-minute planning phase to prepare their concluding remarks, once again with cameras on and microphones muted. In this last round, their position was forced to change: the team favoring the thesis would argue an opposing position and vice versa. Each team had one minute for their third speaker.

Throughout the game, points were awarded based on the clarity, persuasiveness, and organization of the arguments presented. The judges evaluated the quality of the arguments and the overall effectiveness of each team's communication skills. This well-structured organization of the second game provided a platform for teams to engage in thoughtful and well-articulated debates on various medical topics.

The timed rounds and planning phases allowed for a balanced exchange of ideas, while the evaluation criteria emphasized the importance of critical thinking, persuasive communication, and empathy. By examining the implications from various perspectives, participants had the opportunity to critically analyze and construct compelling arguments for or against the integration of Paralympic athletes into able-bodied competitions, developing and showcasing their skills in argumentation, critical analysis, and effective communication.

Game 3: Science

The third game of the STEMM project focused on the field of science and was thoughtfully organized to enhance scientific communication and foster collaboration among the participating teams. The game revolved around the challenge of becoming effective science communicators tasked with explaining a given scientific topic in the most straightforward possible manner while covering all key concepts. The game followed a well-defined structure to encourage teamwork, resilience, and trust.

The organization of the game involved several phases. Firstly, teams were given three different scientific topics and had 15 minutes for organization. During this planning phase, the teams could discuss their strategies and allocate roles for each member. Cameras were turned on, but microphones remained muted, allowing teams to collaborate visually while formulating their approach.

Next, there was a two-minute session where teams had available the keywords of two of the three topics assigned to them. This phase provided a glimpse into the chosen topics and allowed other teams to guess and engage in interactive learning. Following this, teams underwent a series of three rounds, each lasting five minutes.

In each round, a team member was randomly chosen as the presenter, who had one minute to explain the assigned topic most straightforwardly, focusing on key concepts. The team's performance was evaluated based on the clarity and simplicity of their explanations, as well as the number of correctly guessed keywords by other teams. This format fostered collaboration, resilience, and trust among team members as they collaborated to distill complex scientific concepts into accessible explanations.

The structured organization of the third game provided a platform for teams to enhance their collaboration, develop resilience in scientific communication, and cultivate skills in simplifying complex concepts. By engaging in these activities, participants not only expanded their scientific knowledge but also refined their ability to communicate effectively and engage with diverse audiences.

Game 4: Mathematics

The fourth game of the STEMM project, centered around mathematics, was thoughtfully organized to foster problem-solving skills, autonomy, and creativity among the participating teams. The game encompassed two phases: problem-solving and the invention of a new game based on an assigned topic.

The organization of the game involved several steps. Firstly, teams were given 20 minutes to problem-solve with their cameras on but muted microphones. During this phase, teams collaborated to solve mathematical problems, leveraging their problem-solving skills, critical thinking abilities, and mathematical knowledge. They worked together to devise solutions, discuss strategies, and analyze the mathematical challenges. Like the one used in the "Math game without frontiers" (see Section 3.2.5).

Next, there was a 30-minute phase dedicated to inventing a new game. Teams brainstormed and created a unique game concept based on the assigned topic, showcasing their creativity, innovative thinking, and mathematical understanding. Throughout this phase, teams actively engaged in designing game mechanics, rules, and objectives that integrated the assigned mathematical concepts engagingly and interactively.

Finally, teams presented their newly invented games. Each allocated three minutes for their presentation. During this time, teams explained their games' rules, mechanics, and educational objectives, highlighting the mathematical concepts incorporated and potential learning outcomes. This presentation phase allowed teams to demonstrate their communication skills, creativity, and the application of mathematical principles in a game context.

Points were awarded based on the accuracy and creativity of the solutions developed during the problem-solving phase. Additionally, the newly invented games were evaluated based on their originality, educational value, and integration of mathematical concepts.

The organization of the fourth game provided a structured framework for teams to engage in mathematical problem-solving and unleash their creativity in designing new games. Participants could showcase their abilities in applying mathematical concepts to practical scenarios by combining logical thinking, mathematical skills, and innovative ideas. The game format encouraged autonomy, critical thinking, and the development of novel approaches to mathematical challenges.

Game 5: Technology

The fifth and final game of the STEMM project, focused on Technology, was organized to encourage resilience, problem-solving, collaboration, and curiosity among the participating teams. The game revolved around the challenge of creating a compact closing mechanism for an A3-sized panel: "The Great in the Small". Drawing inspiration from the mechanisms used by astronauts to open panels, teams were tasked with designing an efficient and practical closing mechanism [229].

The organization of the game involved several stages. Initially, teams were given 1 hour and 5 minutes for the folding process. During this time, teams collaboratively explored different folding techniques, shared ideas, and strategically experimented with various approaches to create the most effective closing mechanism. Cameras were on, allowing teams to communicate and observe each other's progress visually.

Following the folding phase, teams were granted three opportunities for constructive requests, during which they could seek clarification or specific instructions related to their design. This stage encouraged critical thinking as teams identified areas for improvement and sought expert guidance.

Finally, teams had 2 minutes to present their closing mechanism, highlighting its practicality, efficiency, and compatibility with the assigned A3-sized panel. The designs were evaluated based on the quality of constructive requests and the overall practicality of the proposed mechanism.

Throughout the game, participants utilized their resilience, problem-solving skills, collaboration, and curiosity to develop innovative closing mechanisms within the given time frame. The organized structure allowed teams to approach the challenge creatively and ingeniously while fostering a spirit of friendly competition. By combining their knowledge of technology, problem-solving abilities, and teamwork, participants could showcase their skills in designing practical and efficient closing mechanisms for the A3-sized panel. y engaging in this interactive and hands-on challenge, participants not only developed a deeper understanding of technological concepts but also honed their abilities to solve complex problems, work effectively as a team, and think creatively in the realm of technology.

Soft skills played a vital role throughout the STEMM games project. Each session targeted specific soft skills and provided opportunities for students to develop and apply them in a practical context. By working in diverse teams with complementary skills and backgrounds, students had the chance to leverage their collective strengths, communicate effectively, and learn from one another. The interactive and competitive nature of the STEMM games required students to think critically, be creative, and adapt to dynamic situations. They had to strategize, plan their actions, and make quick decisions while working under time constraints. These challenges allowed students to refine their problem-solving abilities, enhance their resilience, and cultivate an open mindset.

The students participating in the STEMM project perceived the challenges as stimulating and enriching experiences. Through their feedback and reflections, it was evident that they embraced the opportunities presented by the project with enthusiasm and a sense of purpose. The challenges were seen as platforms for personal and collective growth, allowing them to apply their knowledge, skills, and creativity in practical and engaging ways.

The students expressed high motivation and engagement throughout the project, finding the challenges intellectually stimulating and rewarding. They appreciated the multidisciplinary nature of the games, which provided them with a broader perspective and allowed them to explore various fields within STEMM subjects. The opportunity to work collaboratively in teams further enhanced their experience, as it fostered camaraderie, cooperation, and the sharing of diverse perspectives.

Moreover, the students recognized the value of the project in developing their soft skills. They acknowledged that the challenges not only tested their technical knowledge but also emphasized the importance of skills such as problem-solving, critical thinking, time management, creative thinking, and teamwork. By actively participating in the games, they acquired practical experience in applying these transferable skills, preparing them for future challenges in their academic and professional lives.

Overall, the students perceived the challenges as empowering and transformative, enabling them to grow both academically and personally. They expressed gratitude for the opportunity to engage in hands-on, experiential learning that went beyond traditional classroom settings. The challenges provided them a platform to push their boundaries, explore their capabilities, and develop a broader understanding of the STEMM fields, ultimately equipping them with valuable skills and perspectives for their future endeavors.

In conclusion, the STEMM games gave students a unique opportunity to develop soft skills while engaging playfully and interactively with STEMM subjects. The multidisciplinary nature of the project, combined with the competitive aspect, created a rich learning environment that nurtured creativity, collaboration, and critical thinking. By integrating game-based learning principles into EE, the project successfully demonstrated the effectiveness of this approach in enhancing students' soft skills and promoting holistic development. By leveraging the power of games, students were able to develop essential soft skills alongside their technical knowledge. The project showcased the effectiveness of this approach in fostering collaboration, problem-solving, critical thinking, and other transferable skills. The participating students' positive feedback and self-reported benefits indicate the value of incorporating STEMM games into engineering curricula to enhance the educational experience and prepare students for future career challenges.

3.2.7 The Importance of Laboratory Activities for Comprehensive Understanding: a Remote Laboratory experience

Laboratory activities play a crucial role in EE as they provide students with hands-on experience and a deeper understanding of theoretical concepts. The practical application of knowledge in a controlled environment enhances students' problem-solving skills critical thinking abilities, and fosters a deeper connection with the subject matter. However, traditional laboratory setups often face limitations regarding accessibility, resource allocation, and scheduling conflicts. To address these challenges and promote more active learning experiences, implementing remote laboratories has gained significant attention in recent years.

Recognizing the importance of hands-on learning, the Tashkent Technical University (TTPU) in Uzbekistan identified the need to enhance its educational approach and incorporate more active teaching methodologies. In the next chapter, we will shift our focus to the perspective of teachers, and we will describe more in-depth the GYM: Grow You Methodology call (see Subsection 4.2.3)[230]. The TTPU is a private institution set up in the Spring of 2009 based on an agreement between the governmental entity in the automotive market, Uzavtosanoat SC, General Motors Corporation, and Polito. Both local and Italian professors jointly deliver TTPU lectures.

Implementing a remote laboratory into an Automatic Control course was one of the ideas awarded, which resulted in creating the Remote Experimentation for Automation Learning (REAL) platform [231]. The experimental activities on modeling and design control systems were performed in the Autumn of 2019 in the bachelor course at TTPU on a set of actual laboratory processes available in PoliTo through a suitable remote laboratory software/hardware platform.

Based on this first positive experience, the remote automatic control lab has been further extended in order to be also exploited in the course of Laboratory of Robust Identification and Control (LRIC), offered in Autumn 2020 to the students of the Master of Science in Mechatronic Engineering at PoliTo. The extension of the laboratory activities to Italian courses at PoliTo opened up new avenues for enhancing the educational experience of Italian students as well. By integrating the REAL platform into their curriculum, PoliTo aimed to provide their students with the same hands-on learning opportunities and practical insights that were being offered to their Uzbek counterparts. This extension of the laboratory activities to Italian courses not only broadened the reach and impact of the REAL platform but also facilitated students' independence in accessing laboratory activities.

The REAL remote laboratory implementation timeline, as depicted in Figure 3.26, showcases the various stages of development, testing, and deployment. This timeline highlights the iterative design process, which involved the collaboration between educators, engineers, and students from TTPU and Polito.

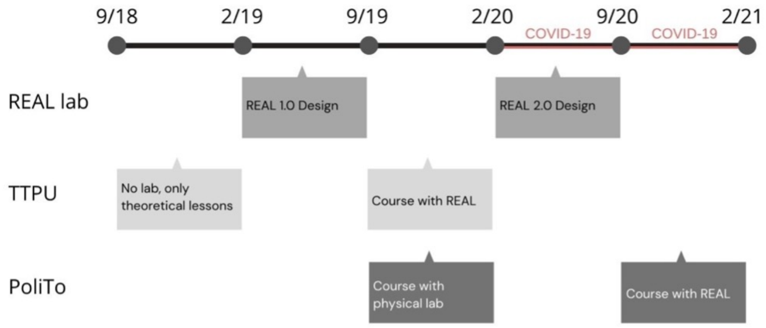


Fig. 3.26 REAL design implementation timeline

The first edition of REAL (REAL 1.0) was made by a computer located at Polito in Turin, connected to a set of magnetic levitation systems. The remote lab architecture consists of two parts: a client, used by the student, and a server, installed on a computer in the Polito lab. The students can study and simulate the Matlab/Simulink environment's control problem and then move to the real plant. Through a suitable Matlab library distributed to the students, they can connect to the computer located at the Polito lab, program the controller with their parameters, and test the system's performance. The students have direct control of the magnetic levitator, which can be switched on and off. A dedicated webcam pointed to the systems allows the student to visualize the experiment in real time. During the investigation, the student receives accurate measurements of the interest signals that can be plotted in real time or stored for a deferred analysis. In the second edition (REAL 2.0), the system has been modified and extended to handle the significantly more significant number of students attending the LRIC course. More precisely, a stand-alone software package based on Labview has been designed and made freely available to the students. Using such software, the students can directly and simultaneously connect to the REAL system to collect experimental data and/or implement their control algorithms without involving Matlab or any other proprietary software. Furthermore, the second edition of REAL also includes an online reservation system allowing the students to book the desired lab system for one or more specific time slots in the week.

Introducing the REAL remote laboratory has brought numerous benefits to students and international education. Firstly, the accessibility and flexibility of the remote laboratory allow students to engage in hands-on activities at any time, expanding learning opportunities beyond traditional classroom hours. This feature is precious for students facing scheduling constraints or limited access to physical laboratory facilities.

The performance indicators presented in Table 3.7 demonstrate the positive impact of REAL on the Automatic Control course at TTPU. The increased attendance rate, higher exam success rate, improved average marks, and a notable rise in the percentage of students achieving the highest marks reflect the effectiveness of the remote laboratory in enhancing student learning outcomes.

Performance indicator	2018/2019 (no lab activity)	2019/2020 (with REAL)
Students	53	82
Attendance rate	8%	35%
Exam success rate	48%	58.5%
Average mark	22.4/30	24.7/30
% of highest mark (30/30)	6%	15%

Table 3.7 REAL Performance Indicators for the Automatic Control Course at TTPU

Similarly, Table 3.8 presents the performance indicators for the LRIC course at PoliTo. Despite the challenges posed by the COVID-19 pandemic, the remote laboratory maintained a high attendance rate, consistent exam success rate, improved average marks, and a sustained percentage of students achieving the highest marks.

Performance indicator	2019/2020 (live lab activity)	2020/2021 (with REAL)
Students	80	125
Attendance rate	85%	78%
Exam success rate	77%	77%
Average mark	27.8/30	29.0/30
% of highest mark (30/30)	71%	72%

Table 3.8 REAL performance indicators for the LRIC course at Politecnico di Torino

The optimization of resources through the implementation of remote laboratories, such as REAL, not only enhances the educational experience for students but also supports educational institutions in developing countries. The collaboration between TTPU and PoliTo has successfully implemented a remote laboratory, demonstrating its effectiveness in promoting active learning, improving student engagement, and enhancing learning outcomes. The positive outcomes observed in both the Uzbek and Italian contexts highlight the potential of remote laboratories in offering inclusive and high-quality education.

In the next chapter, in particular in Section 4.2.4, we will shift our focus to the perspective of teachers and explore the impact of the REAL remote laboratory on their teaching practices and professional development.

3.2.8 Bridging the Gap: Implementing Project-Based Learning to Teach Engineering Concepts to Architecture Students

Polito faces a unique challenge in supporting architectural courses with engineering subjects. While the course content may overlap, architecture students' backgrounds and skill sets differ significantly from those of engineering students. This presents an excellent opportunity to explore the implementation of Problem-Based Learning (PBL) methodology in the Fundamentals of Structural Analysis (FSA) course, catering to a diverse international audience of architectural students with varying levels of technical expertise. This section delves into the application of PBL in the FSA course, aiming to bridge the gap between architectural and EE while nurturing critical problem-solving skills and interdisciplinary collaboration.

Problem-Based Learning (PBL) is an educational approach that places the problem itself at the core of the learning process, as opposed to the traditional didactic teaching based on the transmission of theoretical concepts. In the context of EE, PBL has been widely adopted due to its promotion of active student engagement, teamwork, and the acquisition of practical skills.

PBL involves the active participation of students in solving real or simulated problems, stimulating self-directed learning, research, and critical reflection. Students are presented with complex situations and technical challenges that require applying theoretical knowledge to develop concrete solutions. This approach aligns well with the demands of the professional world, where engineers must tackle intricate problems and find innovative solutions.

FSA is a mandatory third-year course in the Architecture bachelor program at Polito. The FSA course challenges architectural students due to its technical and engineering content, especially in understanding theoretical concepts and manual and numerical solution procedures. FSA course at Polito has traditionally followed a lecture-based model, with a single instructor using slides and a whiteboard to deliver the content. However, this methodology encountered several difficulties, especially in engaging students and promoting the transition from theory to qualitative analysis, which is particularly challenging for architecture students.

The redesign of the FSA course to adopt PBL as a teaching methodology was inspired by several studies on its effectiveness in technical and engineering contexts. In the case of architecture, this change required a degree of creativity and adaptability, but it proved highly beneficial in addressing student learning difficulties and improving their engagement.

The chosen project for the FSA course is the design and structural analysis of a small pedestrian bridge inspired by a real case study (Fig. 3.27). This project offers a blend of theoretical and practical aspects, encouraging students to consider a wide range of skills and knowledge acquired during their academic journey. For example, it aims to foster creativity, problem-solving, and interdisciplinary thinking by allowing students to select their bridge's location and building materials based on their cultural backgrounds and experiences.

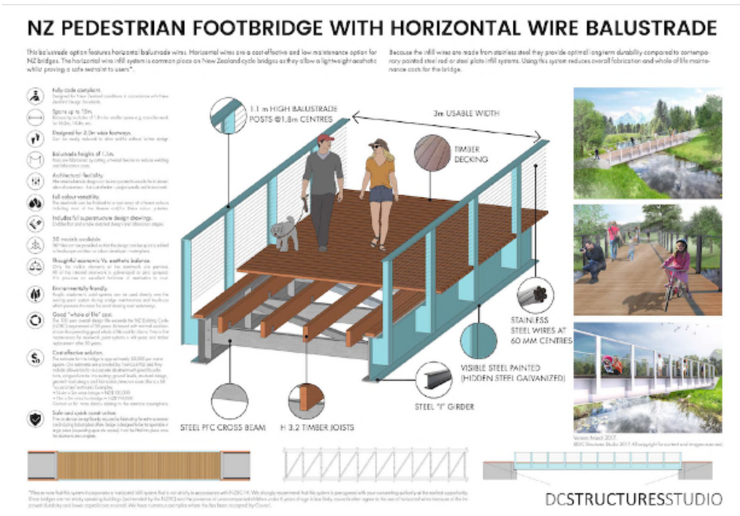


Fig. 3.27 New Zealand standard footbridge design (elementary 18 m pedestrian bridge).

To support the students throughout the PBL implementation, a team of tutors, selected from civil engineering master students, were assigned to assist and guide the teams during their project work. These tutors are crucial in facilitating learning and ensuring equal task distribution within the teams. Their guidance and support are essential to help students overcome initial disorientation and maximize their conceptual understanding of structural analysis.

The course calendar was structured into three main components: lectures, tutoring sessions, and presentations. The lectures covered theoretical concepts, computational exercises, and essential content related to the project. The tutoring sessions allowed students to discuss their projects with the assigned tutors, ensuring personalized guidance and feedback. The presentations offered students the opportunity to showcase their progress and ideas to the class and external experts, such as the DC Structures Studio of Cambridge (NZ), which was involved in the evaluation process.

The application of PBL in the FSA course has yielded several significant advantages:

- **Active Student Engagement** PBL has empowered students to actively participate in their learning, encouraging them to investigate, explore, and solve problems independently. This active involvement has increased student interest in the course and improved their motivation to understand theoretical concepts through practical application.
- **Development of Transversal Skills** PBL promotes teamwork and peer-to-peer learning. Working in teams of 3-4 students encourages collaboration and helps develop essential soft skills, such as communication, organization, time management, and leadership, which are crucial for future architecture professionals, as they often collaborate with colleagues from diverse disciplines.
- **Critical Reflection** PBL fosters critical reflection on the outcomes of the learning process. Students are encouraged to evaluate their knowledge, skills, and problem-solving approach. By encountering authentic challenges in designing a pedestrian bridge, students learn to critically analyze structural aspects, consider various materials and locations, and make informed decisions based on research and analysis. This reflection helps them develop awareness about their learning and autonomy in improving their competencies.
- **Active and Meaningful Learning** PBL has enabled students to connect previously acquired knowledge with the pedestrian bridge problem. This connection has made learning more meaningful as students comprehend how to apply theory to real-world situations. It also increases students' motivation and interest in the subject matter, leading to improved attendance and participation during lectures.

The results obtained from the initial implementation of PBL in the FSA course have been generally positive, as presented at the EDUCON 2020 conference [232] and in a long paper [233]. The participation of students has increased significantly compared to previous academic years, indicating higher engagement and interest in the subject matter. The interaction between the lecturer and students has also improved, with increased communication through emails and active learning activities implemented during lectures.

Students have embraced the freedom to choose bridge locations and materials, boosting their interest and motivation to explore design solutions aligned with their cultural backgrounds. Using tutors has been instrumental in guiding students and ensuring equitable task distribution within teams, further supporting students' learning outcomes.

Final assessment data showed a significant improvement in the number of students who passed the course exam (Table)3.9). Compared to the previous academic year, there was an increase both in the number of students who passed the exam and in the average grades obtained.

	academic year 2018/19			academic year 2019/20			
Exam session	# students	Test results	Final grade	# students	Test results	Project results	Final grade
Winter	5 (11%)	21,4 /30	21,4 /30	41 (66%)	14,82 /18	10,29 /12	25,26 /30
Summer + Autumn	33 (73%)	23,2 /30	23,2 /30	11 (18%)	14,18 /18	8,55 /12	22,78 /30
None	7 (16%)			10 (16%)			
Total	45			62			

Table 3.9 Students distribution at the assessment and their average score

The application of PBL in the FSA course has been demonstrated to be an effective educational methodology in teaching engineering concepts to non-engineering students, particularly within the context of architecture. Students appreciated the opportunity to address a real and relevant project, enabling them to apply theoretical knowledge practically. Active involvement and autonomy in developing solutions have led to an improved learning process and the acquisition of essential transversal skills. Students have shown increased interest in the course and heightened awareness of their own learning.

However, there were some challenges, such as monitoring the progress of individual team projects and adapting the methodology to accommodate varying student competencies. Language difficulties for non-native speakers also required additional resources to ensure proper comprehension of technical concepts. Some of these aspects will be discussed in the next chapter that considers the lecturer's perspective (see Section 4.2.4)

Overall, the application of PBL in the FSA course has proven successful and serves as a solid foundation for further development and enhancement of EE. The methodology has been shown to prepare students to become competent and conscientious future professionals capable of creatively and innovatively addressing real-world challenges.

3.2.9 Higher Education in Short

This section has delved into the transformative journey towards innovative EE at Polito, with a focus on optimizing the study experience for students. The initiatives and approaches explored here foster active student engagement, critical thinking, interdisciplinary collaboration, and the acquisition of practical skills, all of which are essential for engineering students' success.

One of the key initiatives, the *CIAO! (Corso Interattivo di Accompagnamento Online)*, addresses the mismatch of mathematical skills among students, providing tailored support to enhance their proficiency. Through interactive online courses and personalized tutoring, students can strengthen their mathematical foundations, improving their readiness for engineering coursework.

Another noteworthy program, *Progetto Talenti*, strives to support talented students and promote inclusivity through reverse inclusion. By pairing talented students with protege partners, the program encourages mutual learning and knowledge exchange, fostering a collaborative and enriching educational environment.

To enhance study practices and promote continuous improvement, the *DayByDay project* offers students a platform for self-directed learning. This initiative empowers students to take ownership of their educational journey, develop effective time management, and engage in regular reflection to optimize their learning experiences.

Recognizing the significance of game-based learning, the *Math game without frontiers* and *STEMM game* initiatives harness the power of play to enhance technical and soft skills. Through interactive and engaging games, students can develop problem-solving abilities, critical thinking, and teamwork, ensuring a holistic approach to EE.

Providing hands-on opportunities, the *REAL (Remote Engineering Active Learning)* project offers a shared remote laboratory between Polito and TTPU (Uzbekistan). This innovative platform enables students to access laboratory activities remotely, fostering accessibility, flexibility, and inclusive education.

Additionally, this section explored the application of Problem-Based Learning (PBL) in a architecture course on structural analysis. By adopting PBL methodology, the course bridges the gap between architecture and EE, nurturing problem-solving skills and interdisciplinary collaboration.

In summary, the initiatives and approaches presented in this section underscore the importance of study in higher education and its pivotal role in shaping competent and proficient engineering professionals. These transformative initiatives have demonstrated their effectiveness in enhancing student learning outcomes, engagement, and overall educational experience. By embracing and adapting these innovative practices, engineering educators can further advance the quality and effectiveness of study practices, preparing students to thrive in complex real-world engineering challenges.

3.3 Gender Perspective in Engineering: A Highlight

In recent years, addressing gender equality and inclusivity has become a critical imperative for fostering a more sustainable world. As underscored in Goal 5 of the United Nations Sustainable Development Goals (SDGs), gender equality is not only a fundamental human right but also an essential foundation for peace, prosperity, and sustainability [234]. Within this broader context, the issue of gender imbalance in Science, Technology, Engineering, and Mathematics (STEM) fields has drawn considerable attention.

The gender gap in STEM, especially in the field of EE, has been a longstanding challenge worldwide. Strachan et al. [235] emphasizes the importance of a more diverse workforce in engineering and highlights the necessity of addressing unconscious bias to achieve this goal. Cohen and Deterding [236] further underscores that the gender gap in engineering is predominantly due to inadequate enrollment of women, calling for efforts to increase female representation in the field.

While progress has been made to promote gender diversity in STEM, there remains a need to address the accumulation of small advantages for men and small disadvantages for women, which contributes to the persistent gender gap in engineering [237]. Betancur and Torres-Madronero's [238] findings in Colombia reveal a significant gender gap in engineering programs, with women representing less than 20% in disciplines such as electrical, electronic, and mechanical engineering.

Fulcher and Coyle [239] emphasize that the gender balance in STEM has a double dimension: horizontal and vertical. Researchers and policymakers have developed frameworks to study the vertical balance, focusing on influences on STEM career choices and ways to support a balanced environment in academia and industry [240–244].

A large-scale longitudinal study conducted in the USA revealed that around 50% of women in STEM fields left their jobs within 12 years of graduation. Surprisingly, this work shift could not be linked to family factors [245]. However, family factors do play a role during the recruitment stage, as STEM careers are often perceived as conflicting with family goals [246]. Interestingly, having a woman family member in a STEM field positively influences girls' interests in STEM [247].

The horizontal gap, often referred to as the "leaky pipeline," is a crucial aspect that needs to be addressed to support the retention and career progression of women in STEM. This gap involves two distinct campaigns: the recruitment campaign focuses on attracting young girls to STEM fields, while the retention campaign aims to support and retain those already enrolled in STEM disciplines, facilitating their transition into the labor market [248, 249].

The World Economic Forum's Global Gender Gap Report [250] provides crucial insights into the status of gender equality worldwide. In the 2023 edition, the report highlights a notable improvement, with the gender disparity level decreasing slightly from 68.1% in 2022 to 68.4% in 2023. This positive change indicates progress towards gender parity globally. The report estimates that it will take approximately 131 years to achieve full gender equality, one year less than the estimate made in the previous year.

However, despite this overall improvement, the gender gap in certain sectors, including STEM fields, continues to be a pressing concern. The report's data from more than 160 countries reveals that women represent 41.9% of the global workforce in 2023. Nonetheless, there is a significant discrepancy in women's representation in leadership positions, with only 32.3% of women in C-Suite, director, or vice-president roles (Fig. 3.28).

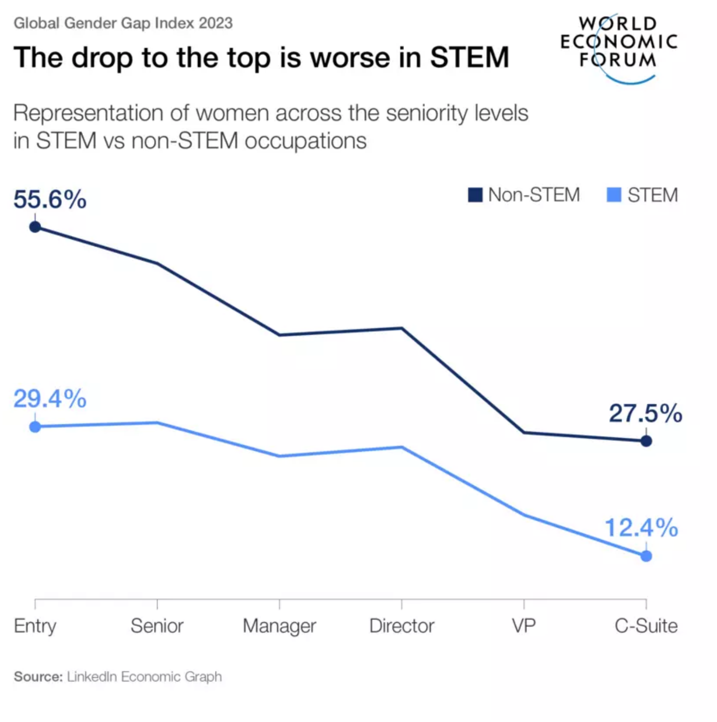


Fig. 3.28 Representetion of women across the seniority levels in STEM and non-STEM occupations

In examining the distribution of employment across various sectors, the report indicates that women are primarily engaged in Health care and case services, followed by Education and Customer Services. The share of women in Technology, Information, and Media sectors has seen a slight decline compared to previous years (Fig. 3.29)

Regarding gender parity in Europe, the continent exhibits the highest level of gender equality among all regions, with a score of 76.3%. However, Italy's ranking in the global gender gap list has declined from 63rd in 2022 to 79th in 2023, indicating concerning trends. Political participation by women also worsened, moving from the 40th position to the 64th.

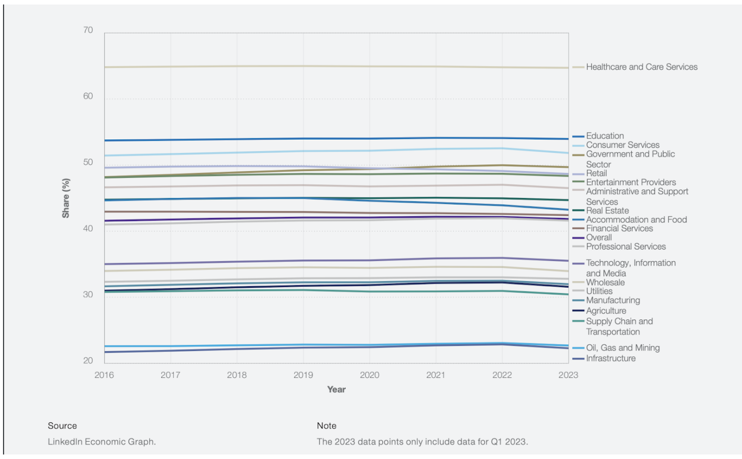


Fig. 3.29 Concentration of the female population in the workforce, divided by sector and measured during the period 2006-2023.

In STEM fields, the representation of women is still lacking, despite an increase in girls' interest in scientific disciplines. The concern lies in the lower percentage of women who actually pursue careers in STEM. Although more women are choosing scientific faculties, the female employment rate in these fields is still below 30%. On the other hand, in non-STEM professions, the percentage of women employed is nearly half, at 49.3%.

Efforts to promote diversity and inclusion (D&I) in the workplace have been observed in Italian companies, indicating progress in some aspects. However, there is still much work to be done to bridge the gender gap in various sectors, including STEM, and to increase the representation of women in leadership positions.

With a rich history of EE, Polito has actively undertaken attraction campaigns to reduce the gender gap in its engineering enrollment [251]. Pioneering women, such as Emma Strada, the first female engineer in Italy who graduated from Polito in 1908, have paved the way for female representation in STEM fields.

In alignment with the university's strategic plan "Polito4Impact" (2018/2024), Polito aims to increase the average percentage of female students enrolled in engineering programs and achieve full gender equality in specific degree programs by 2024. This reflects the institution's commitment to fostering a diverse and balanced educational environment [252].

Both recruitment and retention strategies benefit from the presence of role models, but their focus differs. For recruitment, female role models play a significant role in inspiring young girls to pursue STEM education [253]. In contrast, for retention, both male and female role models can contribute to achieving the desired objectives [249]. The motivations behind women's academic decisions differ between the two phases, with intrinsic and extrinsic factors playing a dominant role during recruitment, while personal stimulus and experiences become more influential during retention [254].

Furthermore, attitudes towards STEM, including spatial ability and mental rotation factors, can impact women's career choices in STEM fields [160]. Understanding these variables is crucial for designing effective strategies to bridge the gender gap in STEM education.

This section serves as an introductory exploration of the gender gap in STEM, focusing specifically on EE, with insights drawn from global gender reports and seminal research studies. It also delves into the efforts made by Polito to promote gender equality and inclusivity in its academic and professional domains.

By analyzing the challenges and interventions related to both the recruitment and retention of women in STEM, we aim to identify best practices that can contribute to reducing the gender gap in EE. We seek to provide evidence-based strategies to address unconscious bias, foster gender diversity, and promote an inclusive environment in STEM education.

3.3.1 Recruitment and Retention Strategies to Address the Gender Gap in Engineering: The "We Are HERe" Project

The issue of gender imbalance in STEM fields has been a longstanding challenge worldwide, drawing considerable attention in recent years. Within this context, the gender gap in EE has been a particular concern, with efforts focused on both recruitment and retention strategies to address the disparity.

In this subsection, we delve into the recruitment and retention actions implemented at Polito as part of their pioneering "We Are HERe" campaign. This campaign, aligned with the university's strategic plan "Polito4Impact," aims to increase female representation in engineering programs and achieve gender equality. We explore the role of recruitment and retention in bridging the gender gap and how the "We Are HERe" campaign's unique approach utilizes experiences and female role models to inspire and support young girls in pursuing STEM careers [255]. By analyzing the challenges and interventions related to both recruitment and retention, we seek to identify evidence-based strategies that contribute to reducing the gender gap in EE and fostering a more inclusive and diverse academic environment.

The Polito's new organizational approach embraces a fresh perspective on horizontal segregation, envisioning a campaign that is more organic, precisely targets the audience, and effectively leverages social media. To achieve this vision, direct involvement of students in shaping the new strategy becomes crucial. Thus, on Women's Day (March 8th, 2019), the university launched a 24-hour hackathon called SheHacks@Polito, where students were encouraged to contribute their best ideas for the campaign [256]. The objective was to gather suggestions directly from the student population and engage them actively in the campaign's creation process.

Among the proposed projects, the winning concept emerged as "WeAreHERe," a title that embodies a powerful dual meaning. It conveys the campaign's core message, emphasizing both "We are her" and "We are here" at Polito. This notion centers on the concept that the best advocates for enrolling new female students in engineering are the current female students themselves. This strategic approach integrates recruitment and retention actions, seamlessly combining them into a unified effort (see Table 3.10). By empowering and training current female students, the university reinforces its community and positions them as pivotal mentors in the recruitment phase. Moreover, this mentoring role indirectly supports the students' self-awareness, helping them recognize and appreciate their unique contributions and roles in the engineering field during the retention phase.

Rectruitment strategy

The recruitment strategy of the "We Are HERe" campaign focuses on attracting young girls in the 14–18 age group to pursue STEM studies, with a particular emphasis on engineering. The goal is to address the gender disparity early on and motivate high-school girls to consider STEM careers as viable and rewarding options. The strategy is informed by data analysis of admission test results, surveys, and feedback from female students already enrolled in engineering programs.

To effectively engage the target audience, the campaign leverages social media and organic communication. The use of liquid communicative language and relatable content is a key element in reaching young girls. Female students from various engi-

		Audience	Main actor	Action
Contemporary role-models				
One-to-one	Mentoring program	1-2y. BS	MS	Retention
	Study support	1y. BS	MS	Retention
	Calls	HS + 1y. BS	MS	Recruitment Retention
One-to-many	Daily storytelling on IG	follower	3y. BS + MS	Recruitment Retention
	High school Talk	HS	3y. BS + MS	Recruitment Retention
	Personality test	follower	/	Recruitment Retention
Orientation support				
Incoming	Summer schools	HS	Experts	Recruitment
	"How to TIL"	HS	3y. BS + MS	Recruitment
	"Notte prima del TIL"	HS	3y. BS + MS	Recruitment
Outgoing	"AperiSTEM"	3y. BS + 2y. MS	Workers	Vertical gap
	Mentoring program	3y. BS + 2y. MS	Workers	Vertical gap
Experiences				
	Annual "e.vent"	HS + BS + MS	Guests	Recruitment Retention Vertical gap
	Annual "SheHackPoliTo"	BS + MS	BS + MS	Retention
	"We are HERe meets"	1y. BS	1y. BS + prof	Retention

Table 3.10 Overview of the campaign (HS: High school students, BS: Bachelor students, MS: Master students)

neering courses serve as mentors and role models, sharing their personal experiences and stories through platforms like Instagram. These peer-to-peer interactions aim to challenge stereotypes and misconceptions about STEM careers, highlighting that barriers to pursuing engineering studies are not related to lack of skills but rather external factors.

The "We Are HERe" campaign employs multiple activities to attract high-school students to STEM fields. One-to-many activities, such as daily storytelling on Instagram, allow mentors to share their journey and experiences with a broader audience. High-school talks are organized to directly engage with students, providing insights into the possibilities and opportunities in engineering studies. Additionally, personality tests and orientation support activities help students discover their interests and passions related to STEM disciplines, making them more inclined to pursue further education in the field.

Furthermore, the campaign organizes incoming summer schools to provide students with hands-on experiences and exposure to the university environment. Next subsection presents an example of the summer schools provided. These immersive experiences allow prospective students to gain a deeper understanding of engineering and dispel any fears or doubts they may have about entering the field. Additionally, the campaign hosts events like "Notte prima del TIL," where female high-school students are invited to the campus for an evening of interactive sessions and discussions about engineering programs.

By focusing on experiences rather than formal events, the "We Are HERe" campaign creates meaningful connections with potential female engineering students. The combination of peer-to-peer mentoring, engaging storytelling, and interactive activities fosters a sense of community and belonging among the target audience. Through this recruitment strategy, Polito aims to attract more young girls to STEM studies, eventually leading to increased female representation in engineering programs.

Retention strategy

The retention strategy of the "We Are HERe" campaign is designed to support and empower female students who have already enrolled in engineering programs. The goal is to foster a gender-friendly environment that encourages female students to persist in their studies and successfully transition into the workforce. This strategy recognizes the importance of addressing the "leaky pipeline" phenomenon, where women in STEM fields often face challenges that lead to attrition.

One of the key elements of the retention strategy is the implementation of a one-to-one mentoring program. Female students in their second year and beyond are invited to become mentors for first-year female engineering students. These mentors provide support, guidance, and advice to their mentees, helping them navigate their academic journey and overcome any challenges they may encounter. The mentoring program not only assists first-year students in their academic pursuits but also creates a strong sense of community and camaraderie among female engineering students.

To ensure the effectiveness of the mentoring program, mentors undergo special training conducted by the Equality@Polito staff. This training includes raising awareness on gender equality and facilitating self-reflection among mentors to break down stereotypes and biases. By empowering female students to become mentors and role models, the campaign creates a supportive network that fosters a positive learning environment.

Additionally, the retention strategy includes study support programs for female students in their first and second years. These programs provide academic assistance and resources to help female students excel in their coursework and overcome any academic challenges. By offering tailored support, the campaign aims to reduce the first-year dropout rate among female students, ultimately contributing to higher retention rates.

The "We Are HERe" campaign also organizes a series of activities and events aimed at promoting vertical cohesion and reducing the gender gap in engineering programs. Events like "SheHackPoliTo" bring together female students from different academic years to share their experiences, exchange knowledge, and build a sense of belonging within the engineering community.

Moreover, the campaign actively engages with female students in their third year and beyond through the "WeAreHERe meets" initiative. This program connects these students with industry professionals and professors, providing networking opportunities and potential career insights. By exposing female students to successful women in the engineering field, the retention strategy aims to inspire and motivate them to pursue long-term careers in STEM.

The "We Are HERe" campaign's retention strategy also involves annual events like "e.vent," where female high-school students, current engineering students, and industry professionals come together to discuss and celebrate gender equality and inclusivity in STEM. These events help create a supportive ecosystem and encourage female students to persist in their studies, even in the face of challenges.

Overall, the retention strategy of the "We Are HERe" campaign o seeks to empower and retain female engineering students by providing them with the necessary support, resources, and opportunities for personal and academic growth. By fostering a gender-friendly and inclusive environment, the campaign aims to increase the percentage of female students graduating from engineering programs and bridge the gender gap in STEM fields.

Impact

The "We Are HERe" campaign at Polito has shown positive results in both recruitment and retention efforts. Within two years of the project, there was an 8% relative increase in the percentage of female engineering enrollment, with the potential to reach even higher percentages in the future. The retention rate also improved, with a reduction in first-year female dropout.

However, achieving the ambitious goal of 35% female enrollment in engineering by 2024 remains challenging. To further advance towards this goal, the campaign plans to expand its scope to attract international students, employing bilingual content and dedicated mentors from different countries.

In conclusion, Polito's "We Are HERe" campaign has demonstrated that a comprehensive approach that addresses both recruitment and retention is crucial to narrowing the gender gap in EE. By using experiences and female role models, the campaign effectively motivates and supports young girls to pursue STEM studies, thereby fostering a more inclusive and diverse engineering community at the university.

3.3.2 Approaching Gender Gap using Spatial Ability: SAperI

Spatial ability is a multifaceted cognitive skill that encompasses various intellectual competencies related to the representation, transformation, generation, and recall of nonlinguistic information (see Subsection 2.3.3). Historically, spatial ability has been associated with success in STEMM fields, making it a crucial factor for individuals aspiring to pursue careers in engineering, science, drafting, designing, and related disciplines [257, 258, 155, 259]. The proficiency in spatial ability is essential for tasks such as interpreting graphs, solving complex part-whole relations, and visualizing mathematical models in real-world scenarios, skills that are particularly crucial in STEMM careers [158, 157].

The existence of a strong association between spatial ability and success in STEMM disciplines has been supported by various studies. It has been shown that individuals who demonstrate high spatial ability tend to perform well in mathematics and scientific thinking [260–262], standardized tests (SATs) [263], and occupational aptitude tests, indicating its predictive validity for STEMM career paths [264]. Longitudinal studies have further confirmed this association, following participants from high school through university and their subsequent careers, revealing a consistent link between spatial ability and science and engineering career preferences [160].

However, despite the importance of spatial ability in STEMM fields, a significant gender gap has been observed in this cognitive domain. Robust gender differences exist in spatial ability, with males generally outperforming females on certain spatial tasks, particularly those related to mental rotation [265–272]. On the other hand, smaller gender differences are observed in spatial perception tasks [273, 155]. These gender disparities in spatial ability have raised important questions about their implications for the representation of women in engineering and other STEMM disciplines.

The gender gap in spatial ability has been a subject of extensive research, and multiple factors have been proposed to explain its existence. Among these are psychological factors, societal stereotypes, and environmental influences [274–276, 259, 277, 278]. For instance, girls may perceive spatial tasks as masculine and may be more intimidated by them due to prevailing gender stereotypes [278]. Additionally, the lack of support and encouragement from professors, families, and peers, as well as the absence of female role models and mentors in STEMM fields, might contribute to the persistence of the gender gap.

Addressing the gender gap in STEMM fields requires a comprehensive understanding of the role of spatial ability in career choices and success. Varoius initiatives have been designed to enhance girls' spatial ability and prepare them for future careers in engineering and related disciplines [183]. Such interventions aim not only to bridge the gender gap in spatial ability but also to create a supportive network that challenges stereotypes and prejudices in society, fostering an inclusive and diverse environment in STEMM fields.

In this subsection, we delve into the relationship between spatial ability and the gender gap in engineering. We explore the significance of spatial ability in STEMM disciplines, the impact of the gender gap on career choices, and the potential of interventions like Sorby course or the SAperI summer school to empower young women in pursuing engineering and other STEMM careers. By examining existing research and drawing insights from the SAperI initiative, we aim to shed light on the challenges and opportunities in addressing the gender gap through spatial ability enhancement programs in the field of engineering.

The Sorby course, developed by Dr. Sheryl Sorby and her colleagues, is a significant intervention designed to enhance spatial ability and promote diversity in STEMM disciplines, particularly in engineering and related fields. The course aims to address the gender gap in spatial ability by providing targeted training and support to female students, empowering them to pursue STEMM careers and challenging the stereotypes that hinder their participation in these fields.

The Sorby course represents a proactive intervention to address the gender gap in spatial ability and promote diversity in STEMM disciplines. The course was initially introduced as a 3-credit program called "Introduction to Spatial Visualization" at Michigan Technological University. A pilot course was ten weeks long, and required the participants to get engaged in hands-on construction activities, paper and pencil exercises, and computer-based tasks designed to develop their 3-D spatial skills. Then, maintaining the contents, a newly semester course was designed [183] along with the accompanying multimedia software. The RCT study reveals that is just as effective in improving spatial skills as the previous quarter system course that utilized traditional lectures.

The positive outcomes of the Sorby course extended beyond the improvement in spatial skills. Students who participated in the course performed significantly better in their subsequent engineering courses compared to their counterparts in the control group. Additionally, the course had a positive impact on retention rates in engineering. Students in the experimental group were retained in engineering at a higher rate than those in the control group.

An interesting observation from the evaluation is that the differences in retention rates for women in the experimental group were significantly higher than for women in the control group. This indicates that the Sorby course had a particularly empowering effect on female students, helping them stay engaged in engineering and increasing their representation in the field.

Following the Sorby course's positive impact on spatial abilities and engineering career outcomes, we now turn our attention to the "SAperI - Spatial Ability per l'Ingegneria" summer school [279](in English: Knowledge - Spatial Ability for Engineering), an intense summer school for 17 years-old girls. It was organized by Polito as part of the *We are HERe* campains. SAperI was a targeted initiative aimed at exploring the potential of interventions in improving spatial abilities, particularly among young women, and encouraging them to pursue engineering and

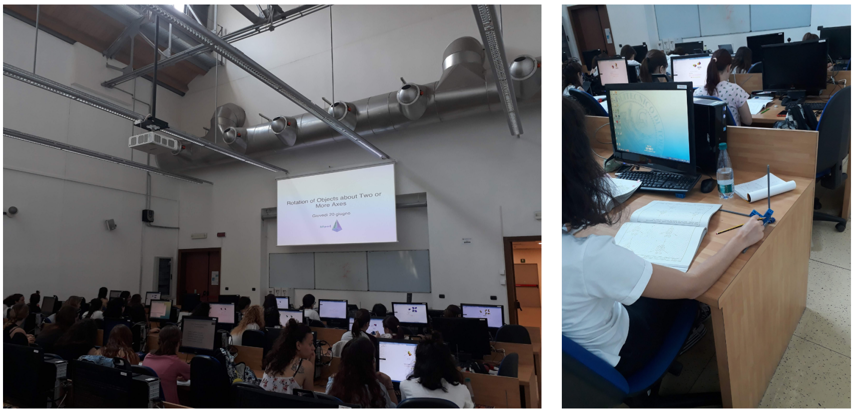


Fig. 3.30 Pictures of the SAperI summer school

other STEMM disciplines. In the meantime, from the research point of view, through the school we look at the effectiveness of an intense five-day training program in improving spatial abilities among the participants.

The summer school took place during the summer of 2019 and was open to female high school students in the Piedmont and Valle d'Aosta regions of Italy (Fig. 3.30). PoliTo leveraged its "Progetto Orientamento", a well-established network of high schools, to reach out to potential participants. Out of the 167 students from 11 high schools who expressed interest, 93 female students and 74 male students participated in the initiative.

After the selection process, 37 female students completed all phases of the SAperI summer school, making them the focus of the evaluation. The course was structured to be intensive and immersive, designed to improve spatial abilities through various engaging activities and exercises.

The SAperI summer school consisted of a carefully planned curriculum, covering five modules based on the course developed by Sorby [180]. Each module was introduced by a moderator, and the students engaged in pairs to explore the topics through computer-based exercises. They also completed workbook exercises, and alternative solution strategies were shared at the end of each session.

In addition to the morning sessions, which focused on the Sorby course modules, the afternoons were dedicated to "play and learn" activities. The participants were divided into homogeneous groups based on preliminary test results and named after female STEM role models. The afternoon activities included:

- Trail-O: A desk-based version of Orienteering, with 5 games of increasing difficulty.
- Graphical Problem Solving: Individual problem-solving exercises followed by a group competition.
- Origami e Touch Sketch: A lesson on technological origami followed by a final competition.

The evaluation of the SAperI summer school was based on three testing phases: the preliminary evaluation in May 2019 (Phase a), the evaluation at the end of the summer school in June 2019 (Phase b), and the final evaluation in September 2019 (Phase c). To assess the participants' spatial abilities, standardized testing instruments were utilized, including the Revised Purdue Spatial Visualization Tests (PSVT: R) [280], Modified Lappan Spatial Visualization Assessment (Lappan) [281], Santa Barbara Cross Section mental cutting test (SBCS) [282], and Paper Folding component of the Differential Aptitude Test (DAT)[283]. At the end of the series of tests, each student could see his/her personal score in each test. In general, males outperformed females in all four tests (Table 3.11). As the mean spatial ability score of the participants that actually took part at SAperI summer school (experimental group) is slightly higher than those who were selected, it seems that those who opted not to take the course had slightly lower SA.

	N	Revised PSVT:R	Lappan	SBCS	DAT
Males	74	M=19.15 SD=5.84	M=5.73 SD=2.46	M=19.47 SD=6.82	M=7 SD=2.55
Females	93	M=16.23 SD=4.78	M=4.45 SD=2.02	M=17.13 SD=7.72	M=6.62 SD=2.17
selected	46	M=16.61 SD=5.32	M=4.93 SD=2.13	M=18.15 SD=7.13	M=6.80 SD=2.33
who took part	37	M=17.14 SD=5.37	M=5.05 SD=2.21	M=18.46 SD=7.00	M=7.03 SD=2.17

Table 3.11 Descriptive statistics of the pre-test (Pahse a) considering the different populations involved in the SAperI evaluation

Table 3.12 presents the average test results for each evaluation phase (a, b, and c) in all four spatial ability tests. The data clearly indicate a substantial improvement in spatial abilities from the initial evaluation (Phase a) to the evaluation at the end of the summer school (Phase b) for all four tests. This trend of improvement persisted even in the final evaluation (Phase c), confirming the durable impact of the SAperI summer school on spatial abilities.

Test	Step (a)	Step (b)	Step (c)
Revised PSVT:R	Min=6 Max=27 M=17,49 SD=5,22	Min=13 Max=29 M=21,94 SD=4,07	Min=13 Max=29 M=22,77 SD=3,94
Lappan	Min=1 Max=9 M=5,2 SD=2,10	Min=2 Max=10 M=7,34 SD=1,85	Min=3 Max=10 M=7,97 SD=1,98
SBCS	Min=7 Max=29 M=18,77 SD=6,91	Min=14 Max=30 M=24,20 SD=3,78	Min=9 Max=30 M=24,69 SD=4,21
DAT	Min=3 Max=10 M=7,28 SD=1,92	Min=4 Max=10 M=8,51 SD=1,58	Min=5 Max=10 M=8,54 SD=1,44

Table 3.12 Descriptive statistics of the results achieved by the SAperI Summer School participants

The average gain scores for all four tests indicate a positive improvement from Phase (a) to (b). However, it is essential to note that for the SBCS and DAT tests, a small number of participants scored lower results from Phase (a) to (b). This observation may be attributed to the intensity of the morning sessions, which could have affected their performance during the afternoon evaluation. Another explanation couldbe that the flat pattern module was the last one to be taught and they could have hadless time to elaborate the content.

As mentioned by Sorby and Baartmans [180], considering the two-month gap between the tests, any gains in scores due to practice effects are expected to be minimal. To ascertain whether the score improvements are indeed attributed to the summer school rather than mere repetition of the tests, we can compare the ratios of the gain in points from Phase (a) to (b) (Table 3.13) and from Phase (b) to (c) (Table 3.14).

The previously specified ratio falls within the range of 0.72 to 1.30 for Phase (a) to (b) and 0.02 to 0.33 for Phase (b) to (c). Clearly, the ratio pertaining to the gain from the initial evaluation to the evaluation at the end of the summer school surpasses the latter. This observation provides compelling evidence that SAperI has significantly contributed to the improvement of participants' spatial abilities.

Moreover, the average test scores during Phase (c), along with the corresponding p-values for the data set of Phase (b) and (c), are all substantially higher than the significance level. This further validates the enduring impact of the SAperI summer school, indicating that the improvement in spatial abilities is sustained over time.

	Gain	Standard Deviation	t-value	p-value	Gain(in function of)
PSVT	4,457143	3,424332	3,985078	0,000175	1,301609
LAPPAN	2,142857	1,768064	4,536763	0,000024	1,211979
SBCS	5,428571	5,658340	4,077006	0,000155	0,959393
DAT	1,228571	1,699234	2,925381	0,004721	0,723015

Table 3.13 Average gain scores from phase (a) to phase (b)

	Gain	Standard Deviation	t-value	p-value	Gain (in function of)
PSVT	0,828571	2,479157	0,86493	0,390122	0,334215
LAPPAN	0,628571	1,415995	1,374526	0,173813	0,443908
SBCS	0,485714	3,08098	0,508172	0,612996	0,157649
DAT	0,028571	1,042782	0,079057	0,937221	0,027399

Table 3.14 Average gain scores from phase (b) and phase (c)

Beyond the quantitative evaluation, participants' feedback on the SAperI summer school was overwhelmingly positive. The survey conducted at the end of the program revealed that the majority of participants considered it an extremely positive or positive experience. Many of the girls stated that SAperI had influenced their university choices, motivating them to pursue STEMM degrees.

The long-term impact of the SAperI summer school was assessed through a follow-up survey in May 2020. Among the respondents, 87% were attending higher education, with 77% pursuing STEM degrees. Notably, 37% of the participants believed that SAperI had a direct influence on their university choice.

The evaluation of the SAperI summer school demonstrates its effectiveness in enhancing spatial abilities among young women and fostering interest in engineering and other STEMM disciplines. The significant improvements in spatial test scores, as well as the positive feedback from participants and their subsequent career choices, highlight the importance of targeted interventions to bridge the gender gap in STEMM fields.

The findings further reinforce the potential of spatial ability enhancement programs, such as the Sorby course-based SAperI summer school, in empowering young women and challenging gender stereotypes in engineering. By investing in such initiatives and creating inclusive learning environments, we can pave the way for a diverse and thriving future in engineering and other STEMM disciplines.

3.3.3 Investigating Gender Dimension in self-efficacy

In the previous subsection, we explored how enhancing spatial ability can play a pivotal role in addressing the gender gap. However, it is crucial to pay special attention to an ancillary phenomenon, especially during adolescence: self-efficacy. Research suggests that gender differences exist in self-efficacy, which refers to individuals' belief in their capabilities to perform specific tasks and achieve desired outcomes. Self-efficacy can significantly impact performance and career choices.

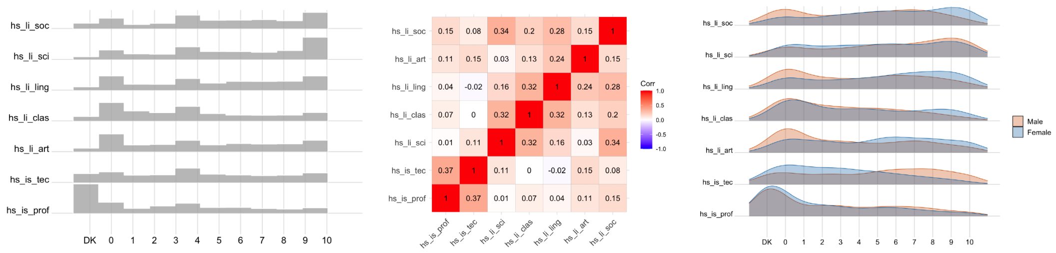
Several studies have investigated the relationship between gender and self-efficacy. Schmitt found that emotional stability and gender interact to influence self-efficacy, which, in turn, affects performance [284]. Chowdhury and Endres reported that men generally exhibit higher levels of self-efficacy across all education levels compared to women [285]. Additionally, McKay, Dempster, and Byrne observed that females tend to score lower in self-esteem and social self-efficacy but higher in emotional self-efficacy [286].

Within the context of the SMaILE project's RCT baseline (See Subsection 3.1.5)[219], we sought to investigate whether self-efficacy also exhibited gender bias in italian eleven years old students, with a particular focus on self-efficacy related to spatial abilities. Understanding the dynamics of self-efficacy and its potential gender-related variations can provide valuable insights into how young individuals perceive their spatial skills and the impact it might have on their career choices.

Here, we now present the findings from our examination of self-efficacy, with a particular emphasis on self-efficacy related to spatial abilities.

The baseline survey encompassed an impressive number of participants, with 57 classes from 20 schools joining the project. Among the students, 86.12% received consent to participate, resulting in a total of 1031 students in the second year of middle school, and the baseline survey registered a commendable participation rate of 94.86%.

Upon analyzing the data, we sought to understand the most prevalent high school choices among the participants, which included Liceo Socioeconomico, Liceo Scientifico, Liceo Linguistico, Liceo Classico, Liceo Artistico, Istituto Tecnico, and Istituto Professionale. It was evident from the findings that there was a significant variation in the level of interest displayed by the students in these different options (Fig. 3.31a e 3.31b).



(a) Distribution (b) Correlation (c) Gender distribution

Fig. 3.31 Analysing the students' intentions toward the different Italian High School tracks

The findings revealed significant gender-specific trends in high school choices, see (Fig.3.31c). Notably, female students displayed a strong negative correlation with Istituto Tecnico (-1.69; p < 0.001), indicating a pronounced aversion to this vocational track. Moreover, Liceo Scientifico showed a strong negative correlation with female gender (-0.75, p < 0.001), indicating a pronounced aversion to this scientific track among them. On the other hand, they exhibited a notable positive correlation with Liceo Linguistico (1.43, p < 0.001), reflecting a higher likelihood of choosing this linguistic-focused option. Similarly, female students displayed a strong positive correlation with Liceo Artistico (1.64, p < 0.001), indicating a significant inclination towards the artistic track. Additionally, Liceo Socioeconomico also showed a positive correlation with female gender (1.36, $p < 0.001$), suggesting a higher interest in this socioeconomic-oriented option.

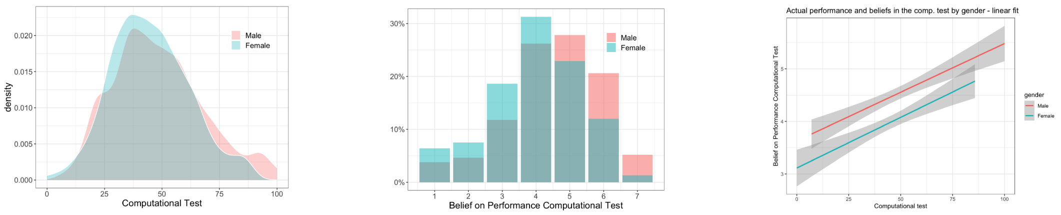
Conversely, male students exhibited a strong negative correlation with Liceo Linguistico (-1.43, $p < 0.001$), indicating a notable aversion to this linguistic-focused track. In contrast, they displayed a positive correlation with Istituto Tecnico (1.69, $p < 0.001$), reflecting a higher likelihood of choosing this vocational option.

The data also revealed intriguing patterns related to Liceo Classico and Istituto Professionale. Liceo Classico displayed a positive correlation with both female and male students, with a higher correlation observed for females (0.57, $p < 0.01$). This result suggests that while Liceo Classico attracts both genders, it might be slightly more appealing to female students. Conversely, Istituto Professionale showed a negative correlation with female gender (-0.50, $p < 0.05$), indicating a lower likelihood of female students choosing this vocational track.

These meticulous findings shed light on the gender-based variations in their intersections with students' career intentions confirming the literature. The observed correlations between high school choices and gender may reflect broader societal perceptions, stereotypes, and individual self-perceptions influencing career preferences, particularly in STEMM fields. Understanding these patterns can inform targeted interventions and support systems to encourage greater diversity and inclusivity in various professions and help bridge the gender gap in STEMM disciplines. Moreover, recognizing the variation in self-efficacy and career intentions among young students can enable educators and policymakers to design initiatives that promote a more inclusive and supportive learning environment for all as we will see in next subsection.

In the exploration of students' self-efficacy and its relationship with test performance, we focused on two distinct assessments: the Computational Thinking Test [287] and the 10-items Revised Purdue Spatial Visualization Test: Visualization of Rotation [280].

For the Computational Thinking Test, both male and female participants exhibited a relatively normal distribution of scores (Fig. 3.32a). Among male students, the mean score was 48.2 with a standard deviation of 19.52, while female students attained a mean score of 44.9 with a standard deviation of 16.7. When we inquired about their perceived performance in the test, we discovered that both genders had distributions centered around different levels (Fig. 3.32b). Male students' responses clustered around 5/7, whereas female students' responses clustered around 4/7. Intriguingly, only a small proportion of male students (5%) claimed to have achieved the maximum score of 7/7, in contrast to an even smaller proportion of female students (1%). Conversely, the minimum score of 1/7 was selected by 7% of female students and 4% of male students. A linear fit analysis comparing actual performance and perceived performance revealed that while the slopes of the two lines were the same, male students consistently rated themselves one point higher than their actual scores (FIg. 3.32c). Notably, the confidence intervals (25%-75%) of these lines did not overlap.

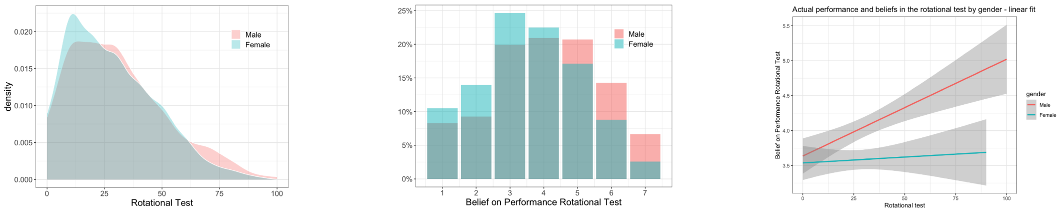


(a) Actual performance (b) Belief on performance (c) Self-efficacy

Fig. 3.32 Analysing the Computational Thinking Test results and belief

Turning to the 10-items Revised Purdue Spatial Visualization Test: Visualization of Rotation, we encountered a somewhat different scenario. The distribution of scores was less symmetrical, indicating a departure from a perfect normal distribution (Fig. 3.33a). Among male participants, the mean score was 30.4 with a standard deviation of 19.52, while female participants achieved a mean score of 27.6 with a standard deviation of 16.7. Notably, none of the female participants managed to score 100% on this assessment.

Examining the self-efficacy perceptions, distinct patterns emerged between male and female participants (Fig. 3.33b). The self-efficacy distribution for male students exhibited a relatively normal distribution, centered around 4/7, with approximately 57% of responses falling within the range of 3/7 to 5/7. About 7% of male students expressed the highest level of self-efficacy (7/7). In stark contrast, the self-efficacy distribution for female students showed a distinct pattern. Roughly 25% of female students rated their self-efficacy at 3/7, 22.5% at 4/7, and 17% at the lower levels of 1/7 or 2/7. Only a small minority (2.5%) of female students claimed the highest level of self-efficacy (7/7). When plotting a linear fit for actual test performance and perceived self-efficacy, significant differences in the slopes of the two lines were evident (Fig. 3.33c). The male line exhibited a steeper slope, starting at 3.6 at zero and reaching 5 at 100. In contrast, the female line started at 3.5 and only reached 3.6 at the 90% mark, indicating a more conservative estimation of their performance capabilities.



(a) Actual performance (b) Belief on performance (c) Self-efficacy

Fig. 3.33 Analysing the 10-items Revised Purdue Spatial Visualization Test: Visualization of Rotation

Male students exhibited slightly higher mean scores compared to their female counterparts, which aligned with the broader trend of gender disparities in spatial skills. Interestingly, male students expressed a more optimistic view of their performance, as indicated by their self-efficacy ratings. This discrepancy, with male students rating themselves consistently higher than their actual scores, suggests a level of overestimation, potentially influenced by societal perceptions or self-confidence biases. These findings underscore the importance of addressing not only the enhancement of spatial skills but also the alignment of self-efficacy estimations with actual performance, particularly among female students, to mitigate the potential impact of such disparities on academic and career decisions.

Therefore, these findings shed light on the dynamic interplay between self-efficacy perceptions and actual test performance, revealing gender-specific patterns that could significantly influence students' academic and career trajectories. The discrepancies observed between self-efficacy estimations and actual performance underscore the need for targeted interventions to bolster students' self-confidence, particularly among female participants, to ensure that self-efficacy aligns more closely with true capabilities. Such interventions could prove instrumental in fostering greater self-assuredness and encouraging students, regardless of gender, to pursue careers in STEMM fields.

3.3.4 Cultivating Comprehensive Perspectives in Engineering: A Global Paradigm for Matching Profiles

Achieving gender balance within STEM fields stands as a pivotal objective in Higher Education recruitment. Central to this mission is the recognition that addressing students' self-confidence and perception is fundamental. Self-efficacy, a cornerstone concept in this endeavor, represents one's belief in their capacity to conquer challenges and accomplish tasks. Within engineering disciplines, the influence of self-efficacy on students' choices and experiences is underscored by empirical evidence-based strategies [288]. The bedrock of self-efficacy beliefs lies in mastery experience, vicarious experience, social persuasion, and physiological reaction.

Of these sources, the vicarious experience holds particular significance, as it facilitates the creation of a network interlinking past, present, and future students, thereby fostering a tangible framework of role models. The efficacy of role models in driving positive behavioral outcomes surpasses gender boundaries and pivots on their perceived similarity to the observer [289, 290]. By strategically deploying role models, the potency of stereotypes is diminished, rendering them of marginal impact. This innovative approach substantially bolsters recruitment endeavors within the expansive realm of STEM [291].

The insights gleaned from prior research, as discussed in the previous subsection, illuminate the intricate interplay between self-efficacy perceptions and actual test performance. This revelation uncovers gender-specific patterns with substantial implications for students' academic and vocational trajectories. Discrepancies between estimated self-efficacy and actual performance underscore the urgency for targeted interventions. Such interventions, particularly vital for female participants, serve to fortify self-confidence and align self-efficacy more closely with authentic capabilities. Ultimately, these interventions hold the potential to nurture heightened self-assuredness, fostering a conducive environment for all students, regardless of gender, to embrace and pursue STEMM careers.

The *ATTRACT project*, an acronym for "Enhancing the Attractiveness of Studies in Science and Technology," was a significant initiative aimed at comprehensively understanding and enhancing the appeal of science and technology studies, particularly in the field of engineering. Conducted on a European level, this project focused on dissecting perceptions of science-related careers, scrutinizing student recruitment strategies for engineering and technological studies, and devising strategies to improve student retention rates.

One of the primary objectives of the ATTRACT project was to delve into the multifaceted challenges associated with attracting students to engineering disciplines and unravel effective strategies to address these challenges. The project's findings indicated that while female students tend to possess a reasonable awareness of the roles and career prospects within the engineering domain, they often encounter barriers that hinder their ability to envision themselves in these roles. These barriers encompassed issues like imposter syndrome, self-doubt regarding personal capabilities, limited availability of relatable role models, and apprehensions about fitting into a predominantly male-dominated environment.

As the ATTRACT project concluded, it became evident that a more profound exploration of the identified aspects was essential, prompting the project partners to escalate their efforts and elevate the exploitation of the project's outcomes to a more advanced stage. The project's insights not only shed light on the hurdles and intricacies of attracting female students to engineering but also laid the foundation for refining recruitment strategies and cultivating an environment that fosters inclusivity and gender balance within the STEM landscape [292]. By acknowledging and addressing these challenges head-on, the ATTRACT project set the stage for further advancements in EE, ensuring that both male and female students can envisage themselves as successful contributors to the field.

Building upon the insights from the ATTRACT project and driven by the mission to foster inclusivity in EE, the *INGDIVS project*, an acronym for "Increasing Gender DIVersity in STEM", embarked on a journey to develop a profiling tool with the goal of providing potential high school students with a broader perspective on engineering. Rooted in real engineering experiences, this innovative endeavor sought to bridge the gap between self-perception and career envisioning, particularly for female students who often encounter challenges in visualizing themselves within STEM roles. Recognizing the need to enhance the attractiveness of engineering studies across a diverse cross-section of society, the project formulated these key research questions:

- Is there a gender difference in self-perception between male and female students?

- How scalable are the instruments developed by the INGDIVS project to address the dissimilarity in self-perception?

The project aimed to address these questions through a multidimensional profiling tool known as the *"Anna tool"* [274]. This tool was meticulously crafted to enable high school students to connect with existing students and successful graduates, facilitating a sense of resonance and empowering female students to bridge the gap between understanding engineering as a career and envisioning themselves within it. The project unfolded in five work packages: defining key inputs for the profiling tool, developing resources and data gathering, pilot testing, finalizing the tool, and disseminating and implementing the tool.

During the development process, the project team made strategic choices to ensure the tool's effectiveness. Instead of focusing on psychometric data, the tool emphasized addressing apprehensions and stereotypes. Short profiles of alumni and current bachelor students were incorporated to offer an opportunity for high school students to explore the experiences and sentiments of engineers and engineering students. A comprehensive questionnaire was constructed to gather data for the tool, adhering to research ethics guidelines and data protection regulations.

The prototype of the Anna tool underwent rigorous testing, incorporating feedback from high school students to refine the interface and content. The final version of the tool was disseminated across partner universities, creating a valuable database containing records from both male and female respondents.

The Anna tool's significance lies in its role as a search engine that connects high school students with anonymized profiles shown in a postcard format of real engineers and engineering students (Fig. 3.34). Designed to be user-friendly and multilingual, the tool empowers students to explore engineering perspectives and career possibilities, aiding them in making more informed choices. Through a series of filtering modules and matching mechanisms, users can visualize their compatibility with engineering studies based on self-perception, thinking styles, and personality types.

The findings from the INGDIVS project's survey data analysis supported the hypothesis of gender-specific differences in self-perception among high school students. These insights provided quantitative evidence to guide communication and intervention strategies. Moreover, the Anna tool's database granted partner

Fig. 3.34 Anna tool profile example

universities an in-depth understanding of how students and graduates perceive the STEM university environment, paving the way for effective promotion of engineering studies.

The scalability of the Anna tool involves considerations of cultural nuances in data collection and the tool's language. The tool's design facilitates expansion to other institutions worldwide, requiring adaptations and translations to cater to diverse student populations. By offering a personalized glimpse into engineering careers and fostering connections between potential students and role models, the Anna tool not only supports gender equality in EE but also encourages exploration and informed decision-making.

A study related to INGDIVS project discerned nuanced STEM perceptions influenced by multifaceted factors, encompassing career objectives, individual preferences, and societal expectations. Gender differentials surfaced, elucidating that male students tend to prioritize career-focused attributes, whereas female counterparts emphasize social and familial dimensions. Regional disparities emerged, evidencing distinct STEM attitudes among EU countries. Academic status variations also materialized, with graduate students highlighting practical applicability and societal impact, while undergrad

uates exhibited curiosity about the expansiveness of their chosen disciplines. This investigation demonstrated the ANNA tool's adaptability in unearthing intricate trends within diverse STEM education environments. A complete discussion on the results of the ANNA tool inside the INGDIVS project can be found in the conference paper [274] and the journal article [293].

As the INGDIVS project advances and integrates new features, its impact is poised to extend beyond the European context. With a focus on spreading knowledge and fostering interaction among students in non-EU countries through the *Women in STEM (W-STEM) project*, the journey initiated by the ATTRACT project continues to unfold, enriching the landscape of EE globally.

In the W-STEM project, the Anna tool's application extended beyond the EU's borders, encompassing a broader international context that included both EU and Latin American and Caribbean (LAC) countries. This expansion facilitated a comparative analysis of STEM perceptions between diverse regions, gender groups, and academic statuses, showcasing the tool's versatility and adaptability.

This international adaptation of the Anna tool within the W-STEM project aimed to address pressing questions about gender disparities, regional influences, and academic trajectories in STEM education. By collecting data from universities across EU and LAC countries, the project aimed to gain insights into the factors shaping students' perspectives and experiences within STEM disciplines.

Findings mirrored those of the INGDIVS study, manifesting gender-oriented dissimilarities. Female students underscored social and familial motivations, while their male counterparts emphasized vocational aspirations. Regional distinctions persisted, underscoring socio-cultural and geographical determinants in shaping STEM attitudes. Graduates continued to emphasize pragmatic applications and societal impacts, while undergraduates maintained an inquisitive stance toward the breadth of their disciplines. Notably, the Anna tool seamlessly adapted to this broader context, eliciting insights that underscored the need for cross-regional collaboration to enhance STEM education inclusivity and diversity.

The journey embarked upon by the ATTRACT project has culminated in a visionary endeavor, supported by the INGDIVS and W-STEM projects, to cultivate a panoramic understanding of students' perceptions in STEM disciplines. The integration of the Anna tool within an international context via the W-STEM project has fortified the tool's versatility in capturing intricate nuances of STEM attitudes, transcending regional boundaries. Through the juxtaposition of findings from both projects, it becomes evident that gender, regional, and academic differentials influence the multifaceted tapestry of STEM perceptions. This holistic approach not only enriches our comprehension of students' aspirations and concerns but also underscores the significance of fostering diversity and inclusivity in EE. As we continue on this global trajectory of matching profiles, the collaborative synergy between projects catalyzes the evolution of engineering pedagogy towards a more equitable, engaging, and transformative future.

3.3.5 Gender perspective in Engineering in Short

The section on "Gender Perspectives in Engineering" delves into several key themes and projects aimed at addressing the gender gap within STEM fields, particularly in engineering. These themes highlight the intricate challenges and innovative strategies that contribute to fostering a more inclusive and diverse environment in EE.

The "We Are HERe" project takes a comprehensive approach to tackle the gender gap in engineering. By implementing targeted recruitment and retention strategies, including mentorship programs and supportive environments, the project aims to increase the representation of women in engineering disciplines. This approach recognizes that a holistic strategy is essential to not only attract but also retain female students in engineering programs.

The SAperI project introduces a novel perspective by examining the role of spatial ability in addressing the gender gap. The project acknowledges that spatial skills are crucial in engineering and aims to enhance women's spatial abilities through innovative training methods. By equipping female students with stronger spatial reasoning skills, the project seeks to bridge the performance gap in STEM fields that demand these capabilities.

Exploring the relationship between gender, self-efficacy, and academic performance, researchers investigate the dimensions of self-efficacy among male and female students. The findings emphasize gender-specific patterns, revealing that differences between perceived self-efficacy and actual performance are more pronounced among female students. This underlines the importance of targeted interventions to boost female students' self-confidence and align it with their actual capabilities.

The concept of role models and vicarious experiences emerges as a significant influencer in motivating students, particularly females, to pursue STEM careers.

Initiatives like the Anna tool, employed in the ATTRACT and INGDIVS projects, create connections between high school students and real engineering experiences. These tools play a pivotal role in helping students envision themselves in STEM roles, thereby increasing the attractiveness of engineering studies.

Projects such as the ATTRACT and INGDIVS initiatives exemplify a global paradigm for matching profiles. These projects utilize the Anna tool to address gender differences in self-perception among high school students. The tool provides insights into real engineering experiences and facilitates connections that empower students to make informed decisions about their academic and professional paths. This approach not only contributes to gender equality in EE but also encourages exploration and decision-making.

In conclusion, the section on "Gender Perspectives in Engineering" underscores the multifaceted nature of the gender gap in EE. Through projects that encompass recruitment strategies, spatial skill development, self-efficacy interventions, and profiling tools, the section emphasizes the need for holistic approaches to create a more diverse, inclusive, and equitable environment in STEM disciplines. These endeavors collectively contribute to shaping a transformative future for EE on a global scale.

4

Enhancing Engineering Education from the Lecturer's Perspective

> *"Three bricklayers are working hard to build a building. A passerby, curious, asked the three of them, 'What are you doing?' The first bricklayer, tired, annoyed, and sweaty, replied, 'I am building a wall.' The second bricklayer, sighing, answered, 'I am building a cathedral.' The third bricklayer, despite the heat, fatigue, and scorching sun, replied with a smile, 'I am building the house of God, where He will be glorified for centuries to come.' "*
>
> – Anonymous , *Parable*

In the dynamic field of Engineering Education (EE), the pivotal role of university lecturers cannot be overstated. These educators stand at the forefront of knowledge dissemination, inspiring the next generation of engineers, and shaping the trajectory of the field. As the driving force behind the learning experience, their commitment to innovation and professional development significantly influences the quality and effectiveness of EE.

This chapter delves into the multifaceted landscape of enhancing EE through the lens of the lecturer. Recognizing the critical role of educators, this chapter explores various facets of their development, methodologies employed to structure courses, and the wider international context in which they operate. The underlying theme underscores the importance of continuous improvement and adaptability in the face of evolving educational landscapes.

The chapter is structured to encompass a spectrum of topics, each contributing to a holistic understanding of the lecturer's role in shaping effective EE. It embarks on a journey through training opportunities that fortify both primary and secondary education, elucidating how educators at all levels play a collaborative role in nurturing engineering foundations. The journey then transitions to professional development for university-level educators, unveiling the tools and platforms designed to empower their pedagogical approaches. The exploration further extends to the integration of open educational practices and methodologies that optimize course delivery, ultimately culminating in a global perspective that highlights the cross-cultural exchange and adaptability necessary for the modern engineering educator.

As the chapter unfolds, it illuminates the interconnectedness of these components, reinforcing the understanding that effective EE is a synergy of several vital elements. Through this exploration, the chapter seeks not only to shed light on the challenges and opportunities faced by educators but also to celebrate the collective efforts that contribute to the advancement of EE as a whole.

In this pursuit, we embark on an exploration of the myriad ways in which EE can be nurtured, refined, and innovated from the lecturer's perspective. By delving into the training opportunities, instructional methodologies, and global influences that shape this multifaceted field, we aim to contribute to a comprehensive understanding of how educators play a pivotal role in molding the engineers of tomorrow.

Through these pages, we invite readers to delve into the intricacies of EE from a vantage point that is both pivotal and transformative – that of the dedicated educator. Join us on this journey as we navigate the realms of training, methodologies, and international perspectives, uncovering the threads that weave the tapestry of excellence in EE.

4.1 Training Opportunities and Professional Development

4.1.1 Reinforcing Engineering Prerequisites in K-12 Education

In the landscape of modern education, the significance of engineering as a cornerstone of innovation and societal advancement is widely acknowledged. An essential facet of fostering a skilled and informed cohort of future engineers lies in the systematic integration of EE at the primary and secondary levels. This subsection delves into the pivotal role of bolstering engineering prerequisites during the formative years of K-12 education and examines the empirical insights offered by recent research.

Within the context of K-12 education, the introduction of engineering concepts has emerged as a pivotal avenue for nurturing future engineers and fostering a culture of innovation. Notably, the studies conducted by Genalo[294] and Katehi, Pearson and Feder [295] emphasize the significance of early exposure to EE. Genalo advocates for the training of educators to craft engineering-infused learning experiences, underscoring its centrality to curricular enhancement. Katehi, Pearson and Feder's research expounds on the multifaceted benefits of integrating engineering into K-12 classrooms, ranging from improved student learning outcomes in science and mathematics to heightened awareness of engineering as a discipline and career path.

Numerous scholarly inquiries have further substantiated the value of early EE. The work of Olds [296] introduces a K-12 engineering outreach project with a twofold aim: benefiting both the recipients of instructional materials and the project developers. This duality underscores the reciprocal advantages of engineering exposure at a young age, fostering a symbiotic relationship between educational advancement and curriculum enhancement. Dornian, Moshirpour and Behjat's systematic literature review [297] extends the discourse by underscoring the preparatory role of K-12 digital education in equipping future engineering students with enhanced learning outcomes in the 21st century.

the studies conducted by Ghalia et al. [298], Guzey et al. [299], Porter et al. [300], and Singer, Ross and Jackson-Lee[301] converge on a crucial theme: the transformative potential of targeted professional development for educators. These investigations affirm that equipping teachers with the tools and pedagogical strategies to integrate engineering into their classrooms is a pivotal step towards strengthening engineering prerequisites. Ghalia and Guzey highlight the successful implementation of engineering design lessons by teachers who participated in professional development programs. Porter's research underscores the importance of training and guidance to seamlessly embed engineering concepts, while Singer's findings reveal the positive impact of professional development on high school STEM teachers' ability to enact design-based pedagogical practices associated with engineering curricula.

The Matabì training course exemplifies a paradigm of transformative professional development meticulously designed to equip primary school educators with the tools to enhance mathematics education while tackling gender disparities. Developed collaboratively by the Fondazione Agnelli and Politecnico di Torino (Polito), supported by Exor and The LEGO Foundation, the Matabì project's training course presents a holistic approach that elevates both educators' competencies and students' learning outcomes (see Subsection 3.1.3).

The Matabì training course is an intricately structured journey designed to empower primary school teachers with the skills and strategies required for fostering equitable mathematics education, transcending gender-based disparities. Now we delves into the granular details of the training's content and structure, revealing its transformative pedagogical framework.

Central to the Matabì training course is a meticulously designed curriculum, a compass guiding educators through the intricacies of spatial thinking enhancement and gender-equitable math instruction. The course unfolds over a comprehensive 10-hour trajectory, melding both face-to-face and online formats to optimize accessibility and flexibility for educators. This curriculum encompasses five pivotal modules, each dedicated to specific facets of pedagogical refinement:

Module 1: Understanding Gender Stereotypes and Mathematics Performance The journey commences with an exploration of gender stereotypes' impact on mathematics education. Educators engage in illuminating discussions, dismantling misconceptions and acknowledging the societal influences shaping performance disparities. This module lays the foundation for addressing implicit biases, fostering a pedagogical landscape grounded in inclusivity.

Module 2: The Significance of Spatial Skills in Mathematics Spatial skills take center stage in the second module, as teachers embark on a voyage into the world of spatial thinking. Hands-on exercises, curated akin to students' experiences, beckon educators to refine their spatial abilities. This introspective journey fosters empathy and a deeper understanding of spatial challenges, laying the groundwork for enhanced teaching methodologies.

Module 3: Introducing the Matabì Kit The third module introduces the Matabì kit, an innovative tool bridging spatial exploration and mathematics instruction. Educators familiarize themselves with the kit's components, unraveling its potential to infuse classrooms with experiential learning. This hands-on engagement primes teachers to weave spatial exploration into their pedagogical repertoire.

Module 4: Strategies for Teaching with Matabl Module four delves into pedagogical strategies that harmonize the Matabì kit's potential with instructional efficacy. Educators are immersed in best practices, understanding how to seamlessly integrate spatial exploration into existing curricula. This module unfolds strategies tailored to each grade, empowering teachers to catalyze transformative learning experiences.

Module 5: Personal Skill Development and Empowerment The final module circles back to personal skill development. Here, educators undergo training akin to students, grappling with spatial challenges and enhancing their own spatial skills. This introspective journey fortifies teachers' spatial acumen, instilling confidence and a nuanced perspective that transcends traditional pedagogy.

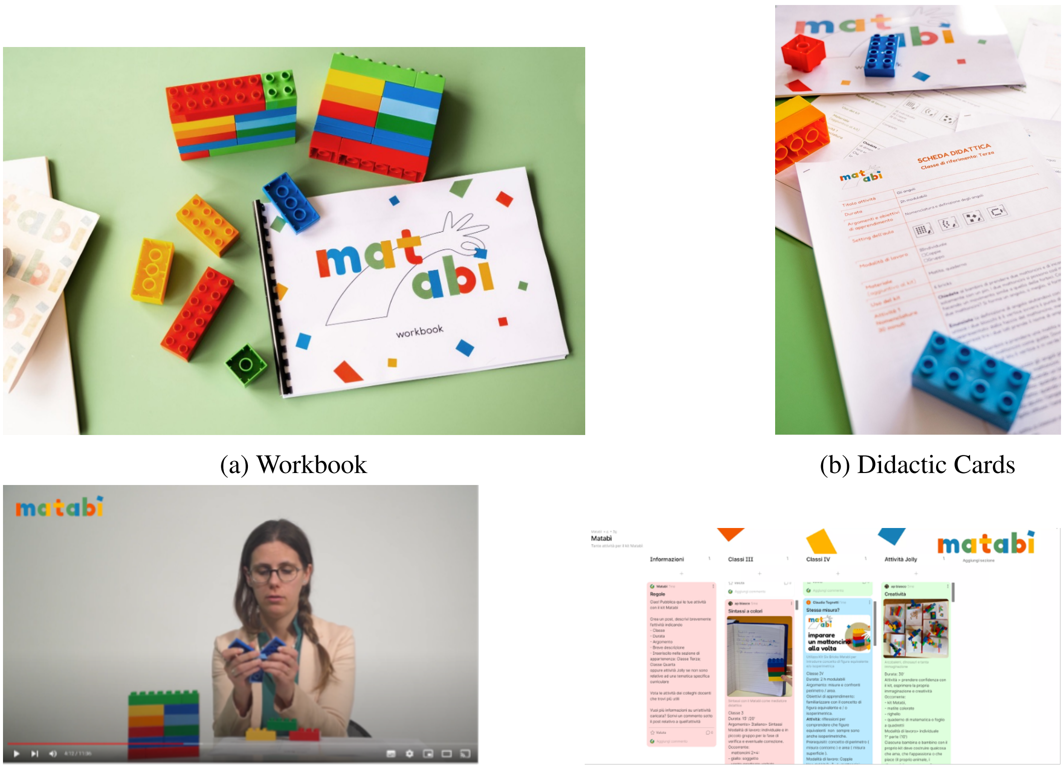
Workshops in class The culmination of the training is manifest in workshops and classroom implementation. Educators embark on a series of workshops, each meticulously curated to empower teachers in distinct aspects of spatial mathematics:

1. Geometry and Angles: A tutor-led workshop that boosts educators' confidence in using Matabì for geometric concepts.
2. Measurements and Equivalences: Teachers take the lead in this workshop, concentrating on measurements, areas, and equivalences, harnessing the Matabì kit's power.
3. Spatial Mathematics with Isometries: A teacher-led exploration delving into symmetry, translations, and rotations through hands-on brick activities.

Additionally, teachers create and execute an additional workshop, shaping personalized learning experiences for their students, echoing the core principle of Matabì's transformative journey.

The Matabì training course harmonizes face-to-face and online modalities, ensuring a flexible and comprehensive learning experience. The initial pilot phase involved 15 teachers and prioritized direct interaction, fostering immediate feedback and dynamic idea exchange. Transitioning to an online format in subsequent editions, with 69 teachers, introduced flexibility and accessibility, making instructional materials, video lectures, and interactive sessions available via a digital platform. The online format allows teachers to engage at their own pace, supplemented by virtual tutoring meetings and emails for ongoing support and engagement.

Central to the Matabì teacher training is a rich repository of supplementary didactical materials that empowers educators with a diverse toolkit for pedagogical transformation. These materials extend beyond the conventional lecture-centric approach, fostering an immersive and interactive learning experience for teachers.



(a) Workbook (b) Didactic Cards

(c) Video Clip (d) Padlet

Fig. 4.1 Variety of materials available

One cornerstone of this arsenal is the bespoke "Workbook" meticulously curated to hone teachers' spatial skills (Fig. 4.1a). This compendium of exercises orchestrates a deliberate journey towards enhancing spatial thinking, acknowledging the educators as learners in their own right. Through these exercises, teachers navigate spatial challenges akin to those encountered by their students, fostering empathy, deeper understanding, and personal growth.

Complementing the Workbook are the "Didactic Cards," strategically tailored to suit the distinct learning trajectories of third and fourth-grade students (Fig. 4.1b). These cards orchestrate engaging activities that intertwine with the workshop sessions, offering teachers a dynamic toolkit to infuse spatial ability development within their classrooms. This interactive pedagogical resource empowers teachers to orchestrate hands-on spatial explorations, equipping students with cognitive skills that transcend the confines of traditional learning paradigms.

The Matabì training course is an immersive odyssey that empowers educators with the knowledge, skills, and transformative strategies required to reshape the contours of mathematics education. By unraveling nuanced modules, fostering personal growth, and nurturing hands-on implementation, Matabì emerges as a beacon of innovation, poised to ignite transformative learning environments grounded in gender equity and spatial acumen. Acknowledging the multifaceted nature of modern education, the Matabì project strategically integrates multimedia elements into its training arsenal. Video clips, replete with comprehensive explanations, elucidate the nuances of workshops and activities involving the distinctive LEGO Duplo bricks (Fig. 4.1c). These visual aids serve as navigational beacons, guiding teachers through the intricacies of pedagogical execution.

Furthermore, the project leverages the dynamic capabilities of the digital world with the creation of a dedicated Padlet (Fig. 4.1d). This virtual platform nurtures collaboration and knowledge exchange among educators, facilitating the sharing of materials, insights, and innovative teaching strategies. The Padlet serves as an intellectual crossroads, catalyzing a dynamic community of educators vested in reshaping mathematics pedagogy.

The empirical outcomes of the Matabì training course reverberate with transformation, both quantifiable and qualitative. Notably, the project's efficacy becomes palpable through observed improvements in teachers' spatial abilities despite their non-voluntary involvement in the training program. The baseline assessment using the Revised PSVT:R [280] involved 76 teachers, who achieved an average score of 10.09 (SD=6.18), aligning with existing literature that locates the education community as the poorest one on spatial ability [160]. The end-line assessment included 52 teachers, with an increased average score of 12.94 (SD=5.88). Notably, 47 teachers completed both the pre and post-tests, ena-bling a direct comparison of their performance. The two-sample t-test with equal vari-ances revealed a significant improvement in spatial ability, with a mean increase of 2.57 ($t(92)=2.14$, $p=0.035$) in the number of correct answers in the post-test, corre-sponding to 25% increase in the score.

The observed improvement in spatial ability highlights the effectiveness of the Matabì project's interventions and training programs in enhancing teachers' spatial thinking skills. This indicates the project's potential to positively impact teachers' professional development and subsequently improve students' learning outcomes.

Moreover, our sample composition, which includes teachers who may not have been initially motivated to participate, strengthens the generalisability of the findings, providing a realistic portrayal of the broader teaching community. Additionally, com-paring the baseline results with existing literature on spatial ability in STEM domains further reinforces the significance of spatial thinking skills in mathematics education.

Furthermore, examining two pilot editions, one conducted face-to-face with deeper spatial learning and the other conducted online, revealed noteworthy differences. The face-to-face pilot exhibited a baseline mean of 9.08 and a post-test mean of 13.02, while the online pilot showed a baseline mean of 10.28 and a post-test mean of 12.88. Although the analysis is limited due to the difference in the number of teach-ers between the editions, it is evident that face-to-face training yielded better results. This advantage can be attributed to the facilitation of physical presence, which fosters collaboration, interaction, and longer-duration engagement for personal improvement.

A study presented at the TEEM conference 2023 [302] focused solely on teachers' spatial ability and did not explore other potential outcomes or factors that may influence the effectiveness of the Matabì project. Future research should aim for a more comprehensive understanding of the impact.

Overall, our findings suggest that the Matabì project effectively enhances teachers' spatial ability, contributing to their professional development and potentially benefiting students' learning outcomes. These positive results underscore the potential of incorporating playful learning and LEGO-based activities in mathematics education to foster spatial thinking and promote a deeper understanding of geometric and spatial concepts. The Matabì training course is an immersive odyssey that empowers educators with the knowledge, skills, and transformative strategies required to reshape the contours of mathematics education. By unraveling nuanced modules, fostering personal growth, and nurturing hands-on implementation, Matabì emerges as a beacon of innovation, poised to ignite transformative learning environments grounded in gender equity and spatial acumen.

In addition to the Matabì training course, another exemplary initiative that underscores the transformative potential of teacher training is the course inside the SMaILE project. SMaILE is designed to pioneer game-based tools for teaching Artificial Intelligence (AI) concepts through a "learning-by-doing" approach (See subsection 3.1.5). The couse run with the support of Ufficio Scolastico Regionale Piemonte, presents twofold objectives: to foster a deeper understanding of AI concepts and to empower young students to not only consume AI technology but also create it. Through a series of engaging sessions, the SMaILE teacher training unfolds as a unique educational journey, integrating digital resources, teaching practices, unplugged activities and student digital competence development. The SMaILE teacher training program operates within digital competence education, encompassing multiple focus areas:

- Digital Resources (Area 2): The program taps into digital resources to explore innovative teaching methods and AI concepts.
- Teaching and Learning Practices (Area 3): Through hands-on activities, the training promotes interactive teaching and learning practices centered around AI education.
- Student Digital Competence Development (Area 6): The training contributes to fostering students' digital competence by equipping educators with tools to facilitate meaningful AI learning experiences.

The program is tailored to novices with an entry-level of A1, ensuring accessibility to educators at various stages of digital competence. The training spans 8 hours in total, providing an immersive and engaging educational experience.

The SMaILE teacher training program is organized into four dynamic sessions, each delving into distinct aspects of AI education through engaging and practical activities:

Classification of Images and IoT Applications In this two-hour session, educators explore the classification of images as a means to convey narratives and construct applications involving the Internet of Things (IoT). The emphasis is on hands-on engagement, fostering an understanding of AI concepts through tangible experiences and storytelling. This activity bridges the digital and physical worlds, allowing educators to guide students in the classification of images while illuminating the concept of IoT. By manipulating real-world objects and images, students grasp the significance of AI's role in categorization and automation.

Autonomous Machines Through Unplugged Activities The second session, also spanning two hours, immerses educators in the realm of autonomous machines. Unplugged games like the challenge 15 are employed to illustrate the concept of machines operating independently, shedding light on AI's role in creating self-sufficient systems. Teachers are guided through hands-on tasks that mirror the decision-making processes of machines, fostering an intuitive understanding of AI's capacity for independent operation.

AI Functionality: Research Systems and Winning Strategies The focus shifts to the functionality of AI. Educators delve into research systems and strategies that contribute to successful AI outcomes, enriching their understanding of AI's intricacies.

SMaILE App in the Classroom: Heuristics and Reinforcement Learning The final session revolves around the integration of the SMaILE app within classroom settings. Educators explore heuristic techniques and reinforcement learning, applying them to educational contexts through the app.

The SMaILE teacher training program culminates in educators being equipped with the knowledge, tools, and strategies needed to foster meaningful AI education. By delving into the intricacies of AI through experiential learning, educators become transformative facilitators, inspiring young minds to engage with AI not just as consumers but as creators of technology. The program's structure reflects a commitment to cultivating digital competence, fostering innovative teaching practices, and shaping the next generation of digitally literate learners, poised to navigate the complexities of AI with enthusiasm and competence.

The SMaILE app serves as a dynamic gateway to AI education. Through interactive sessions, educators acquaint students with the app's functionalities, enabling them to explore AI concepts in an engaging and accessible manner. The app's gamified exercises create an immersive learning environment, ensuring concepts are not just understood but experienced. Leveraging the SMaILE app's features, educators craft gamified exercises that reinforce AI concepts. Through interactive challenges and scenarios, students navigate AI principles, solidifying their understanding while enjoying the educational journey. The SMaILE app opens avenues for dynamic discussions and explorations. Educators prompt students to critically analyze AI's role in various domains, fostering conversations that nurture curiosity and informed perspectives.

The integration of unplugged and plugged activities within the SMaILE teacher training program underscores its comprehensive approach to AI education. Unplugged activities bring abstract concepts to life, grounding them in tangible experiences that cater to diverse learning styles. These activities lay the groundwork for plugged activities, where the SMaILE app emerges as a versatile tool for concept introduction, reinforcement, and discussion.

Through this integrated approach, educators cultivate AI enthusiasts who not only comprehend AI's intricacies but also possess the confidence to navigate its multifaceted landscape. The SMaILE teacher training program empowers educators to guide students through meaningful AI learning experiences, leveraging both traditional and digital pedagogies to inspire a generation of technology-savvy learners. As educators harness the potential of unplugged and plugged activities, they spark curiosity, facilitate exploration, and set students on a trajectory of AI understanding that extends beyond the classroom.

4.1.2 Faculty Development for Higher Educational Lecturers

In the dynamic landscape of higher education, the role of university lecturers has evolved beyond the conventional boundaries of knowledge dissemination to encompass the cultivation of critical thinking, problem-solving, and collaboration skills among students. To effectively navigate these changing pedagogical demands, it has become essential for educators to continuously refine their teaching methodologies, embrace innovative approaches, and remain responsive to emerging educational paradigms. The concept of "Provide Opportunity in Teaching" (POT) developed inside Polito emerges as a strategic initiative aimed at nurturing the professional growth of higher education lecturers through diverse training opportunities and experiential engagements [303].

POT, in essence, embodies a multifaceted framework designed to empower lecturers with a spectrum of pedagogical tools, experiences, and insights that extend beyond traditional classroom practices. As the educational landscape evolves and diversifies, lecturers are not only expected to adapt to evolving learning needs but also to proactively contribute to the transformative process of higher education. In this context, POT acts as a catalyst, fostering an environment where educators can engage in continuous professional development, fostering innovation, refining teaching skills, and engaging in constructive dialogue on pedagogical best practices.

POT emphasizes a holistic approach to faculty development that transcends disciplinary boundaries, enabling educators to holistically engage with pedagogical theories, innovative technologies, and novel methodologies. Through a rich array of training activities, educators are encouraged to explore new frontiers of teaching, critically reflect on their instructional practices, and collaborate with peers to collectively elevate the quality of higher education. From methodological training to leveraging advanced teaching technologies and embracing pedagogical experiences, POT equips educators with the tools to not only navigate the present educational landscape but also contribute to its evolution.

Here we delve into a comprehensive exploration of the POT framework, elucidating its components, methodologies, and transformative potential. By championing a culture of continuous professional development, POT addresses the complex demands placed on modern higher education lecturers, allowing them to proactively adapt and contribute to the ever-evolving pedagogical ecosystem. Then, we delve into the intricate details of various training activities encompassed within the POT framework, with a particular focus on the Teach2Teach program.

The Provide Opportunity in Teaching (POT) framework is a comprehensive and dynamic approach to faculty development tailored to the evolving landscape of higher education, particularly within the realm of EE. POT serves as a strategic response to the multifaceted challenges faced by university lecturers, empowering them with a versatile toolkit to enhance their pedagogical proficiency, incorporate innovative methodologies, and enrich student learning experiences. This framework operates on the premise that teaching effectiveness is an ongoing process that requires engagement, adaptation, and continual learning.

This innovative framework serves as a strategic response to the intricate challenges faced by university lecturers, equipping them with a versatile toolkit to enrich their pedagogical practices, embrace inventive methodologies, and elevate the overall quality of student learning experiences. In a rapidly changing environment marked by technological advancements, burgeoning knowledge domains, and evolving pedagogical philosophies, the POT framework embodies a continuous journey of engagement, adaptability, and relentless learning.

Analysing the POT Framework we can identify three components: Methodological Training, Integration of Teaching Technologies, and Incorporating Methodological Experiences.

At the core of the POT framework lies the cultivation of methodological training, a pivotal element that immerses educators in an array of diverse teaching methodologies, instructional strategies, and learner-centric approaches. By delving into this spectrum of methodologies, educators acquire indispensable skills that enable them to harmonize their instructional goals with the varied learning needs of their students. From unraveling the intricacies of flipped classrooms to embracing the dynamism of project-based learning, methodological training not only fuels pedagogical innovation but also ensures the alignment of instructional practices with the evolving educational landscape.

Two quintessential offerings under this umbrella are the "English as a Medium of Instruction (EMI)" and the "Learning to Teach in Higher Education" courses. The EMI course, an intricate tapestry of four units, aspires to fortify the mastery of technical English for the transmission of scientific knowledge. This course is meticulously designed to foster linguistic competency on par with both Italian and English, enabling educators to seamlessly interact with students, elucidate concepts through multifaceted approaches, and wield the art of assessing expectations within a non-native language milieu. The course provides an additional layer of support through one-on-one consultancy services, ensuring a personalized growth trajectory for each participant.

In parallel, the "Learning to Teach in Higher Education" course unveils its array of five units, each encapsulating diverse themes that embrace the holistic essence of pedagogical mastery. By traversing the terrain of student-centric perspectives, learning outcomes, didactic methodologies, active learning paradigms, and comprehensive learning assessment, this course is meticulously orchestrated to infuse educators with a treasure trove of teaching tools, insights, and contemplative pathways for growth [304].

In an era dominated by digital advancements, the assimilation of cutting-edge teaching technologies becomes imperative to craft engaging and interactive learning environments. The POT framework introduces educators to a gamut of educational technologies, empowering them to seamlessly integrate online platforms, virtual laboratories, simulation tools, and collaborative platforms into their pedagogical repertoire. This integration effectively bridges the gap between traditional pedagogy and the realm of digital engagement, fostering personalized and impactful learning interactions.

Here, a conference christened "Esperienze PoliTo" flourishes as a podium to disseminate best practices and monitor ongoing pursuits within the PoliTo community. This gathering accentuates the strides made in e-learning and MOOC, creating a platform for educators to showcase their innovations and collectively shape the trajectory of digital learning. Simultaneously, the concept of "Pillole Online" germinates from the need to bolster effective communication between the university and its student community. Educators are empowered to craft succinct yet impactful dissemination videos, traversing realms from scientific expositions to illuminating the diverse spectrum of services the university proffers. The inherent open disposition of the PoliTo community further fuels these initiatives, with the anticipation of forthcoming Open Education Resources (OER) courses adding another layer of potency to the narrative [305]. This aspect with be further discuss in the following subsection 4.1.3.

The third dimension of the POT framework underscores the value of experiential learning that transcends conventional classroom boundaries. Through hands-on workshops, immersive seminars, and collaborative projects, educators are encouraged to experiment with novel teaching approaches, participate in peer mentoring, and share best practices. Methodological experiences stimulate reflective thought processes, empowering educators to fine-tune their pedagogical techniques based on real-world classroom dynamics and constructive feedback.

Dissemination conferences come to the forefront as emblematic instances of knowledge exchange. The array of typologies woven into these conferences speaks to the diverse avenues through which innovation is seeded and nurtured. Events like "Costruire il futuro – da un'idea di Piero Angela" beckon educators into futuristic dialogues, fostering exchanges with international experts and paving the way for innovative trajectories. The "TeatroScienza" platform magnifies scientific themes through theatrical performances, weaving entertainment and education into an exquisite tapestry. "GiovedìScienza," a weekly symphony of conferences orchestrated by professors, embraces the intricate realms of technical and innovative subjects, unraveling intellectual horizons for the broader community. Hybrid moments dedicated to nurturing the talents of the top 4% of students serve as exceptional learning junctures, wherein educators experiment with pioneering methodologies in the company of a responsive student cohort. Equally significant, the mentoring of student teams emerges as an avenue to recalibrate knowledge exchange with a strong undercurrent of scientific profundity.

The journey within the POT framework commences with a meticulous analysis of learners' distinct requirements, institutional objectives, and the evolving demands within the engineering domain. This comprehensive analysis serves as the bedrock for the discerning selection of appropriate teaching methodologies and strategies that seamlessly align with desired learning outcomes. Regular assessments and structured feedback mechanisms empower educators to iteratively refine their approaches based on student performance and active engagement.

Collaborative learning serves as the heartbeat of the POT framework, cultivating a vibrant community of educators who partake in insightful discussions, immersive workshops, and interdisciplinary dialogues. This collaborative network enriches educators' pedagogical repertoire by fostering the exchange of collective wisdom, thereby enhancing the overall tapestry of teaching practices.

Central to the POT framework is the practice of introspective reflection, wherein educators critically assess their teaching experiences and distill invaluable lessons to inform subsequent iterations. This reflective practice cultivates a growth mindset, compelling educators to adapt their strategies in response to evolving educational paradigms and the ever-evolving needs of learners.

The POT framework underscores the paramount importance of perpetual professional development within the realm of EE. In a dynamic landscape characterized by shifting educational dynamics, educators are entrusted not only with imparting technical knowledge but also with nurturing essential competencies such as critical thinking, problem-solving, and adaptability. By actively engaging with the diverse components and methodologies of the POT framework, educators amplify their teaching efficacy, ensuring that their pedagogical practices harmoniously align with industry requisites and the broader shifts in society.

Moreover, the POT framework heralds a paradigmatic shift, repositioning faculty development as a cornerstone of institutional excellence. This framework fosters a culture of lifelong learning within educational institutions, where faculty members ardently embrace innovative pedagogy, actively participate in continuous skill enhancement, and collectively contribute to the profound transformation of the education landscape.

In summation, the POT framework envelops educators in a realm of exploration, expansion, and excellence. The courses, initiatives, and experiences enshrined within this framework become conduits through which educators navigate the multidimensional landscape of pedagogical enhancement, technological integration, and transformative learning. By embedding methodological training, teaching technologies, and experiential learning, the POT framework unveils a tapestry that not only empowers educators but also orchestrates a symphony of educational evolution within the dynamic domain of EE.

The training activities are the lifeblood of continuous professional development for university lecturers, equipping them with the skills and knowledge needed to deliver effective and innovative teaching experiences. These activities not only enhance pedagogical techniques but also foster a vibrant culture of learning and improvement. Among these activities, the Teach2Teach program stands out as a remarkable exemplar of a comprehensive and impactful training initiative.

Workshops form the bedrock of lecturer training, offering immersive experiences that delve into diverse teaching methodologies. These sessions provide educators with insights into pedagogical theories, active learning techniques, and student-centered approaches. Through methodological training, lecturers learn to craft effective lesson plans, design engaging activities, and foster inclusive classroom environments. Such workshops empower educators to adapt their instructional styles to cater to the varied learning preferences of modern students.

In an era characterized by rapid technological advancements, the integration of technology in education is paramount. Training activities centered on teaching technologies enable lecturers to harness digital tools that enhance engagement and learning outcomes. These activities introduce educators to interactive platforms, virtual labs, multimedia presentations, and learning management systems. Through technology integration, university lecturers can create dynamic and immersive learning experiences that resonate with the digital-native generation of students.

Methodological experiences offer a hands-on approach to continuous professional development by immersing lecturers in real-world teaching scenarios. These experiences often involve collaborative projects, teaching demonstrations, and peer observations. Through these interactions, educators have the opportunity to share best practices, exchange innovative ideas, and receive constructive feedback. Peer collaboration not only enriches the learning process but also fosters a sense of camaraderie and collective growth among educators.

A critical aspect of continuous professional development is the ability for lecturers to engage in introspection and self-assessment. Training activities that encourage reflective practice empower educators to critically evaluate their teaching methods, identify areas for improvement, and set goals for personal growth. By engaging in reflective dialogue, lecturers refine their instructional strategies and align their practices with the evolving needs of students and the educational landscape.

The Teach2Teach program emerges as a beacon of innovation and excellence within lecturer training. Rooted in the principles of lifelong learning and transformative education, the program embodies a holistic approach to continuous professional develoment. Its foundation rests on the acclaimed ADDIE model (Analyze, Design, Develop, Implement, Evaluate), which guides educators through a systematic process of methodological refinement.

The program's structure encompasses five comprehensive workshops delivered over the course of a week, supplemented by asynchronous self-paced activities. With English as the primary language of instruction and material, the program fosters cross-cultural engagement and international collaboration. Each workshop is meticulously designed to address key facets of effective teaching, including student-centered approaches, constructive alignment, active teaching strategies, assessment practices, and the integration of cutting-edge technologies.

Integral to the Teach2Teach program is the emphasis on learner-centered pedagogy, where lecturers learn to place students at the heart of the learning process. By understanding student backgrounds, needs, and objectives, educators design learning experiences that resonate with diverse cohorts of learners. Additionally, the program advocates for continuous self-evaluation, cultivating a culture of introspection and growth among participants.

The Teach2Teach program extends its impact beyond the classroom. It forges collaborative partnerships and a community of practice among lecturers, enabling the exchange of insights and ideas that transcend disciplinary boundaries. As lecturers refine their teaching methodologies, the ripple effect extends to their institutions, elevating the quality of education and contributing to institutional excellence.

In conclusion, the myriad training activities available for university lecturers collectively contribute to a dynamic ecosystem of continuous professional development. From workshops that instill effective teaching strategies to technology integration, methodological experiences, and reflective practice, these activities empower educators to continually evolve and enrich their instructional practices. Among these activities, the Teach2Teach program shines as a model of comprehensive continuous professional development, embracing learner-centered pedagogy, cross-cultural engagement, and community collaboration. As higher education evolves, the commitment to lecturer training remains integral to nurturing a generation of educators who can adeptly navigate the complexities of modern education and inspire the next generation of engineers and innovators.

4.1.3 Embracing Open Educational Practices (OEP)

Open Educational Practices (OEP) have emerged as a transformative force, reshaping the traditional paradigms of teaching, learning, and knowledge dissemination. The integration of digital technologies, coupled with the principles of openness and collaboration, has ignited a paradigm shift that extends far beyond the confines of conventional classroom settings. This subsection delves into the profound implications of Open Educational Practices, exploring their significance within the realm of EE at Polito.

At its core, Open Educational Practices encompass a range of activities that leverage open principles and digital technologies to enhance the creation, sharing, and use of educational resources and knowledge. OEP encourages educators to collaborate, innovate, and engage in a dynamic exchange of ideas, transcending geographical and disciplinary boundaries. As educators harness the power of open licenses, online platforms, and collaborative methodologies, they unlock the potential to transform traditional education into a participatory and inclusive experience.

The relevance of Open Educational Practices within higher education cannot be overstated. Today's higher education landscape is characterized by an unprecedented proliferation of information and a growing demand for flexible, accessible, and learner-centered educational experiences. Traditional pedagogical approaches, while invaluable, often face limitations in meeting these evolving demands. This is where OEP emerges as a catalyst for change.

By embracing Open Educational Practices, institutions of higher learning can address several critical imperatives simultaneously:

Access and Equity OEP breaks down barriers to education by providing open access to resources and knowledge. This democratization of education empowers learners from diverse backgrounds to engage with high-quality content, regardless of geographical location or socioeconomic status.

Innovation and Collaboration OEP fosters a culture of innovation and collaboration among educators. It encourages the creation and sharing of open educational resources, enabling educators to co-design courses, experiment with novel teaching methodologies, and collectively advance pedagogical approaches.

Customization and Engagement Through OEP, educators can tailor content to meet the unique needs of their students. This customization enhances student engagement and active learning, leading to deeper understanding and improved retention.

Professional Development OEP offers educators opportunities for continuous professional development. By participating in open communities, educators can share experiences, learn from peers, and refine their teaching practices based on collective wisdom.

Global Impact The open nature of OEP transcends institutional borders, enabling educators to contribute to the global knowledge commons. This interconnectedness facilitates the exchange of best practices and innovative ideas, driving educational advancement on a global scale.

Open Educational Practices have the potential to reshape education at Polito. By investigating the incorporation of OEP within the institution, we uncover not only the challenges and opportunities it presents but also the unique ways in which educators navigate the open landscape to enhance EE. The following exploration draws from an in-depth interview study conducted at Polito, shedding light on how OEP is being harnessed and its impact on EE within the institution.

The Open Educators Factory (OEF) framework, depicted in Figure 4.2, serves as a comprehensive framework to assess educators' fluency in working with open approaches across various domains of their work. This framework encompasses four fundamental columns: design, content, pedagogy, and assessment [306]. Its aim is to offer a holistic view of the open educator's role, recognizing the diverse paths to openness and providing educators with a roadmap for their open journey.

The OEF framework is the culmination of an extensive literature review on open education. It draws from insights found in definitions, conceptual frameworks, and guidelines geared toward university educators aiming to enhance their open fluency. This framework was further refined through discussions with experts in the field of open education.

The OEF framework classifies educators into distinct profiles within each domain. In terms of design, three typologies emerge: the Open designer, who shares course design ideas and curriculum openly through social media; the Collaborative designer, who engages in collaborative course design with colleagues from the same or international subject-related teams; and the Individual designer, who independently designs courses based on their knowledge and experience.

Within the resources domain, educators are categorized into profiles based on their engagement with Open Educational Resources (OERs). The OER expert re-shares openly reused resources, uses resources created by others, and actively contributes to OER repositories. The OER novice creates and shares resources under open licenses, while the "New to OER" educator leverages digital resources from the web to enhance teaching.

In the realm of teaching, profiles are differentiated based on their approaches. The Open teacher fosters co-creation of knowledge among students, encourages contribution to public knowledge resources, and shares teaching practices openly. The Engaging teacher adopts interactive strategies, such as seminars and flipped-classroom methodologies, to enhance student engagement. The Traditional teacher adheres to traditional transmissive pedagogy.

Areas of activity

	A. Design	B. Content	C. Teaching	D. Assessment
Open Collaboration	**3. Open designer** Shares her course design ideas and curriculum openly through social media, including with colleagues and with students.	**3. Expert OER user** Re-shares resources she has reused openly through social media and OER repositories. Uses resources created by others. Searches for OER through social media and repositories. Shares links and resources beyond the classroom, through an open online identity.	**3. Open teacher** Encourages participation from non-enrolled students in her courses. Implements methods that foster co-creation of knowledge by students. Fosters students to contribute to public knowledge resources. Encourages learners to access freely available online content. Shares examples of teaching practice in open subject-related communities.	**3. Open evaluator** Uses open assessment practices such as peers assessment or e-portfolios. Engages communities of practices to assess students' work.
Second transition phase: becoming an Open Educator				
Bilateral collaboration/Small groups	**2. Collaborative designer** Collaborates in designing her courses with close colleagues, either from the same university or from international subject-related teams.	**2. Familiar with OER** Re-shares resources she has reused among close colleagues. Produces and share one's own resources under open licences. Reuses resources recommended by trusted people.	**2. Engaging teacher** Adopts seminars-like strategies, either offline or through restricted online spaces (Chats, Discussion forums). Uses "flipped-classroom" methodologies. Uses the university LMS, to share links and resources with the students of her courses.	**2. Innovative evaluator** Experiments with peers-based assessments methods.
First transition phase: becoming aware about openness in education				
Individual work	**1. Individual designer** Designs her courses on her own, based on her knowledge and experience.	**1.New to OER** Might use digital resources found on the web to enhance teaching and learning. Does not produce openly-licensed content.	**1. Traditional teacher** Adopts traditional trasmissive pedagogy	**1. Traditional evaluator** Uses traditional assessment methods such as tests or classwork.

Fig. 4.2 The Open Educators Factory Framework

In the area of assessment, educators are grouped by their assessment methods. The Open evaluator employs open assessment practices like peer assessment and e-portfolios, while the Innovative evaluator experiments with peer-based assessment methods. The Traditional evaluator relies on conventional assessment methods such as tests or classwork.

The OEF framework served as a foundational tool to guide an extensive study at Polito. A total of 173 teachers from various academic fields participated in the study by filling out a questionnaire on the OEF platform [305]. The participants comprised a diverse demographic, including different ranks, disciplines, ages, and gender distribution.

The findings illustrated a comprehensive snapshot of the openness capacity and gaps within the institution's teaching staff. Notably, the framework's holistic approach allowed for a nuanced understanding of openness across the dimensions of design, content, pedagogy, and assessment.

Learning Design

A substantial number of educators (116) collaborated with colleagues to design their courses. Seven educators were identified as open designers, who openly shared their ideas and curriculum through social media even before their courses commenced. This early openness demonstrates a commitment to fostering an open attitude from the outset of the teaching cycle.

Teaching Resources

A significant majority (100) of respondents demonstrated awareness and use of Open Educational Resources (OERs), including applying open licenses to their materials and sharing resources among colleagues. Notably, 22 educators were categorized as OER experts, showcasing their fluency in searching, adapting, and sharing resources openly through repositories and social media.

Teaching Methods

While traditional frontal teaching remained predominant (94 respondents), a notable proportion (80) engaged students through offline and online collaborative methods. Eight educators were classified as Open teachers, who not only fostered co-creation of knowledge but also shared their teaching practices in open communities, indicating their readiness to lead by example.

Assessment

The majority of educators (162) adhered to traditional assessment methods, reflecting the established norm. However, a noteworthy group of 13 educators implemented innovative open assessment methods, signifying a willingness to experiment and embrace openness even in areas with normed practices.

Using this study [305] as starting point, an in-depth interview study was conducted [307]. This new study aimed to uncover the perspectives of educators regarding their understanding of OEP, its practical implementation, and the challenges and opportunities it presents within the university's unique setting.

The study revealed two distinctive groups among the interviewed educators: those who primarily perceive OEP as teaching with Open Educational Resources (OERs), and those who embrace a broader ethos of open teaching practices. The former group, referred to as Group A, emphasized the importance of organizational conditions, human resources, and collaboration with colleagues. These educators recognized how specific teaching obligations could serve as opportunities for innovation, particularly with technological tools such as the polling system provided by Polito.

On the other hand, educators in Group B saw OEP as a comprehensive approach that extends beyond OERs, where student engagement and collaboration play pivotal roles. Their teaching decisions were guided by interaction with students and the desire to enhance teaching practices progressively. This group identified challenges related to institutional incentives, resources, and the need for structurally avant-garde classrooms that support open teaching practices effectively.

Both groups highlighted the need for enhanced support from trained human resources in OEP and acknowledged the industry's role in fostering openness. Additionally, they expressed a shared interest in tailoring teaching approaches and resources to suit the needs of different student cohorts, leveraging the potential of OEPs to facilitate this process.

The findings of this study have substantial implications for the training opportunities and professional development of educators at Polito. The insights gained from educators in both Group A and Group B highlight the importance of fostering a culture of openness that transcends the use of resources alone. It is evident that OEPs can serve as catalysts for pedagogical innovation, enabling faculty members to collaboratively access each other's materials and approaches, thus enriching the teaching experience.

As we delve deeper into training opportunities and professional development, it is crucial to recognize the different perspectives and motivations within the educator community. By addressing the barriers identified by educators, such as the time required for OEP implementation and the need for tailored support, Polito can facilitate the integration of open practices into various educational contexts.

4.1.4 Training Opportunities and Professional Development in Short

The role of university lecturers has expanded to include fostering critical thinking, problem-solving, and collaboration skills. The "Provide Opportunity in Teaching" (POT) framework [303] at Polito empowers educators with a diverse range of training activities to navigate these evolving demands. POT comprises three components: Methodological Training, Integration of Teaching Technologies, and Incorporating Methodological Experiences. The framework promotes continuous professional development, collaboration, and introspection.

POT immerses educators in diverse teaching methodologies, enabling them to harmonize instructional goals with students' learning needs. Notable offerings include the "English as a Medium of Instruction" course and the "Learning to Teach in Higher Education" course. These courses empower educators with linguistic competency and comprehensive pedagogical insights.

In an era of digital advancements, the integration of teaching technologies becomes vital. Polito employs platforms like "Esperienze PoliTo" and "Pillole Online" to disseminate best practices and enhance communication. The integration of educational technologies bridges traditional pedagogy and digital engagement, fostering personalized learning experiences.

POT encourages experiential learning beyond conventional classroom boundaries. Through workshops, seminars, and collaborative projects, educators experiment with novel teaching approaches and engage in reflective processes. Dissemination conferences and mentoring student teams serve as avenues for knowledge exchange and scientific profundity.

The Teach2Teach program exemplifies a comprehensive training initiative. Its structured approach, rooted in learner-centered pedagogy and the ADDIE model, offers workshops that enhance pedagogical techniques and technology integration. The program fosters a community of practice and contributes to institutional excellence.

Moreover, Open Educational Practices (OEP) have emerged as a transformative force. OEP leverage open principles and digital technologies to enhance education's creation, sharing, and use. OEP addresses challenges in access, equity, innovation, and customization. An extensive study at Polito explored educators' fluency in working with open approaches across dimensions like design, content, pedagogy, and assessment.

The study revealed distinct groups of educators, showcasing different perceptions of OEP. Some educators emphasized OEP as teaching with Open Educational Resources (OERs), while others embraced a broader ethos of open teaching practices. This diversity highlights the importance of fostering a culture of openness that extends beyond resource use and integrates student engagement and collaboration.

In conclusion, the POT framework and Open Educational Practices collectively contribute to a vibrant culture of continuous professional development and innovation among educators at Polito. These initiatives propel higher education toward a dynamic future where collaboration, adaptability, and open principles drive the evolution of teaching and learning.

4.2 Course Development and Methodologies

4.2.1 The Role of Instructional System Design

Where the pursuit of knowledge intersects with the demands of rapidly evolving industries, the role of instructional design emerges as a guiding light to illuminate the path of effective learning. Instructional design, as a systematic and strategic approach, plays a pivotal role in shaping educational experiences that transcend traditional paradigms. This subsection delves into the heart of instructional design, elucidating its essence and exploring why it holds particular significance in the realm of EE.

At its core, instructional system design can be envisioned as the art and science of crafting intentional learning journeys. It involves the orchestration of diverse components, such as content, pedagogical strategies, assessments, and technologies, into a harmonious symphony that resonates with learners' cognitive processes. In this age of information abundance, instructional design acts as a discerning curator, meticulously selecting and arranging educational elements to foster engagement, comprehension, and mastery.

In EE, where the fusion of theory and application underpins the curriculum, instructional design emerges as a powerful ally. The intricacies of engineering concepts and practices demand an approach that not only imparts knowledge but also cultivates problem-solving prowess and innovation. This subsection navigates through the facets of instructional design methodologies, exploring how they bolster the effectiveness of teaching and learning within the engineering domain.

The pages ahead unravel the significance of instructional design in EE, drawing insights from scholarly contributions that illuminate its transformative potential. As Ng et al. [98] contends, instructional design principles possess the ability to enhance the pedagogical value of learning objects and activities, enabling learners to navigate the complexities of engineering disciplines with acumen and confidence. Little and Cardenas [308] further underscores the value of active learning methodologies, accentuating the symbiosis between hands-on design projects and the cultivation of design-oriented thinking.

Amidst the discourse, the essence of instructional design intertwines with the evolution of EE paradigms. Minichiello and Caldwell [309] explores the synergy between design-based research and the modern tools of technology, accentuating how instructional design methodologies can catalyze innovation and address contemporary challenges. Morris and McAdams [310], in turn, shines a light on the practical integration of design projects into engineering courses, fostering an immersive and experiential understanding of engineering design principles.

The application of instructional design methodologies has emerged as a pivotal approach to enhance the quality and effectiveness of teaching and learning processes. The significance of incorporating instructional design principles lies in their capacity to synergize pedagogical strategies with the distinct demands of EE. By systematically structuring course content and activities, these methodologies address the unique challenges posed by complex technical subjects and equip both educators and students with a comprehensive framework for success.

The role of instructional design methodologies extends beyond theoretical insights, as evidenced by Morris's practical insights into design integration methods. Such methods permit the seamless infusion of design projects into established engineering courses, empowering students to engage with the learning process actively. Notably, this active engagement aligns with Thom, Crossley and Thom's work [311], which illustrates how structured engineering design tools can holistically transform curricula, ensuring their relevance and alignment with evolving industry needs.

In a broader context, the discourse on instructional design methodologies in EE has evolved to encompass various perspectives. Sukacke et al. [312] champions a paradigm shift from traditional teacher-centered education towards instructor-led instructional design, mirroring the trend towards active learning methods.

Collectively, these scholarly contributions underscore the pivotal role of instructional design methodologies in EE. Beyond mere theoretical significance, these approaches hold the potential to reshape the landscape of teaching and learning in engineering. Through the systematic alignment of pedagogical principles with the intricate demands of engineering disciplines, instructional design methodologies emerge as catalysts for enhanced educational experiences and improved learning outcomes.

In the realm of instructional system design, various systematic models have emerged to guide the creation of effective learning experiences. These models provide structured frameworks that streamline the process of developing instructional materials and strategies. Let's explore a selection of these widely recognized models, each offering unique approaches to crafting meaningful educational content.

ADDIE Model

The ADDIE Model, a cornerstone of instructional design, offers a comprehensive approach to crafting impactful learning experiences. Standing for Analysis, Design, Development, Implementation, and Evaluation, ADDIE provides a structured framework for systematically designing instruction. While it has been pictured in several ways, the model below shows one popular way [313]) (Fig. 4.3). The process begins with a meticulous analysis of the learning context and target audience, facilitating the identification of learning objectives and needs. In the design phase, instructional strategies, content, and assessments are carefully crafted to align with these objectives. Development involves creating the actual instructional materials and resources, translating design concepts into tangible learning tools. The implementation phase brings these resources to learners, ensuring the instructional plan is put into action. Finally, the evaluation phase assesses the effectiveness of the instruction through formative and summative evaluations, allowing for iterative improvements and refinements. The ADDIE Model's iterative nature fosters continuous enhancement, making it a versatile and widely employed framework in the field of instructional design.

Dick and Carey Model

This model emphasizes careful analysis, alignment, and evaluation of instructional elements. It provides a structured framework for designing effective learning experiences, ensuring that the instruction is well-aligned with desired outcomes. It involves identifying instructional goals, conducting detailed task analysis, specifying performance objectives, designing assessments, selecting appropriate instructional strategies, and evaluating the instruction. Its structured approach helps ensure that instruction is well-aligned with desired outcomes. The model comprises several stages that guide instructional designers through the process: Instructional Goals, Learner and Context Analysis, Task Analysis, Performance Objectives, Instructional Strategy, Instructional Materials Development, Formative Evaluationl, Summative Evaluation (Fig. 4.4). The Dick and Carey Model's structured approach ensures that

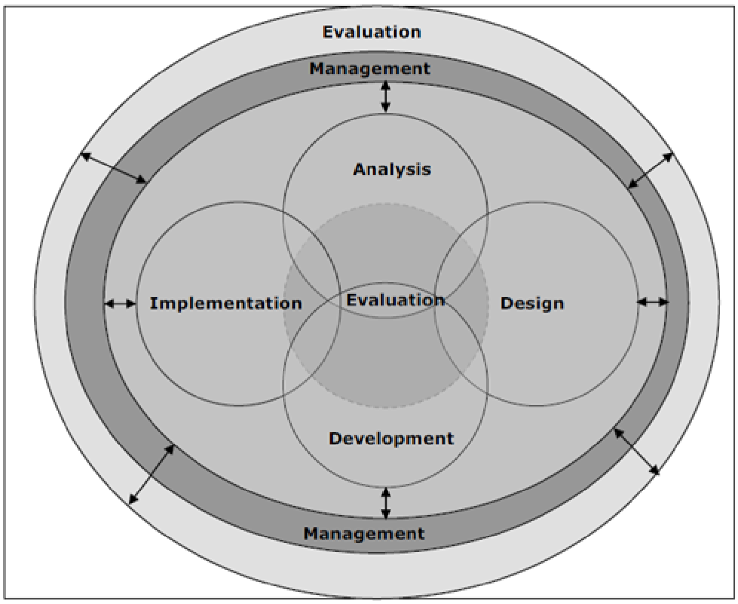


Figure 6-1. The non-linear ADDIE process

Fig. 4.3 ADDIE model

the design process is thorough and aligns with the learning goals. By systematically analyzing the context, breaking down tasks, and aligning objectives, this model supports the creation of instruction that is effective, efficient, and meaningful for learners.

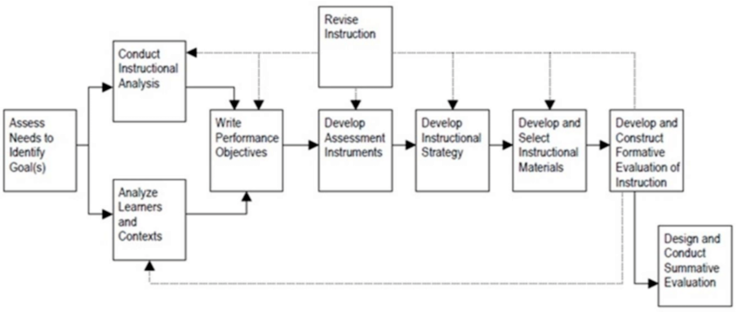


Fig. 4.4 Dick and Carey model

SAM Model (Successive Approximation Model)

The SAM model focuses on rapid prototyping and iterative design through collaboration. SAM deviates from the traditional linear design process and instead focuses on creating effective instruction through a series of iterations. The model is particularly well-suited for projects where flexibility and responsiveness to learner needs are essential. It involves three main phases: Preparation, Iteration, and Implementation (Fig. 4.5). In the first phase, the design team collaborates with stakeholders, including subject matter experts and learners, to gather information about the learning goals, content, and desired outcomes. The team defines project constraints, identifies the target audience, and outlines the project's scope and objectives. The iteration phase involves a series of cycles, each comprising three steps: Design, Develop, and Review. During the Design step, the team creates a prototype of the instruction, focusing on key content and interactions. In the Develop step, the prototype is developed into a functional instructional module. This module is then reviewed by stakeholders, including learners, to gather feedback. In the final phase, the instructional materials are refined based on the feedback received in the previous phase. The refined materials are then fully implemented for a wider audience. This phase can involve instructor training, learner orientation, and the actual delivery of instruction. The SAM Model's iterative approach is its core strength. It allows for rapid testing and refining of instruction, ensuring that learner feedback and changing needs are promptly incorporated. This flexibility is particularly valuable when dealing with complex subjects, evolving content, or situations where the learning environment may change.

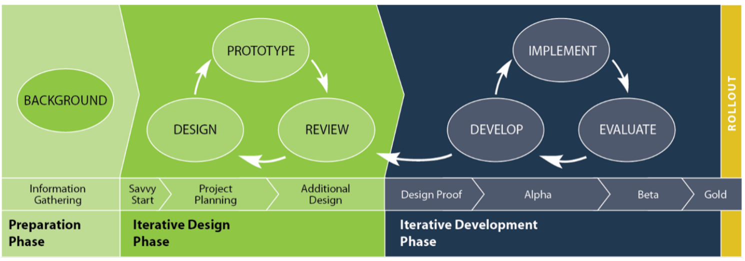


Fig. 4.5 SAM model

Gagne's Nine Events of Instruction

Gagne's Nine Events of Instruction is a widely recognized instructional design model developed by Robert Gagne. in 1965. It outlines a sequence of nine events that enhance the effectiveness of learning experiences by engaging learners, promoting understanding, and facilitating retention. Each event serves a specific purpose in guiding learners through the learning process. It starts with gaining learners' attention, informing them of the learning objectives, presenting the content, providing guidance and practice, eliciting learner performance, providing feedback, assessing performance, and enhancing retention and transfer of knowledge (further details are available in Fig. 4.6).

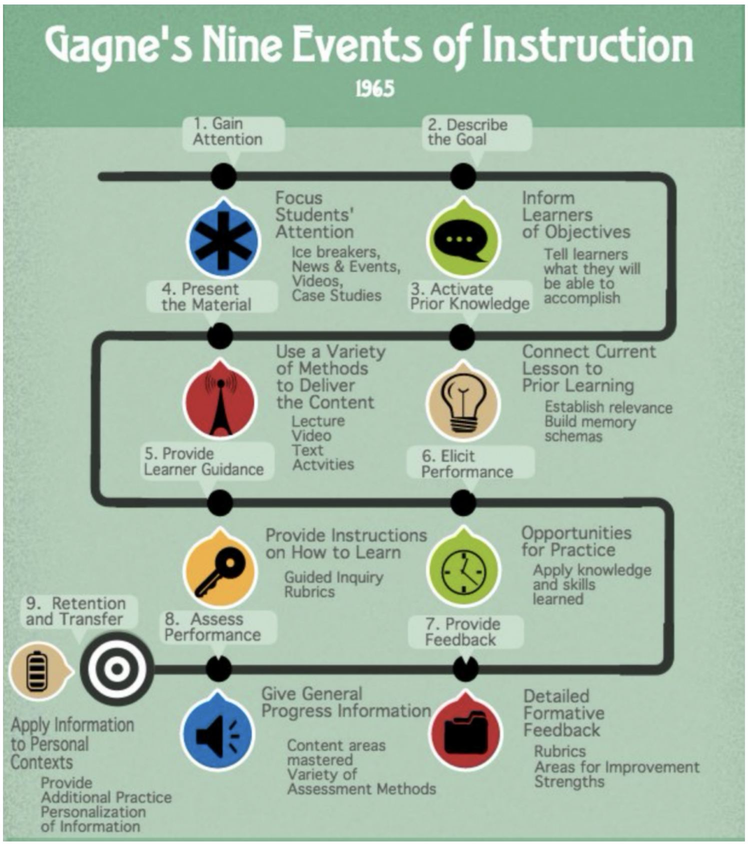


Fig. 4.6 Gagne's nine events of instruction model

ASSURE Model

This model provides a structured approach for planning and implementing effective instruction. Developed by Heinich, Molenda, Russell, and Smaldino, the model is designed to ensure that instructional materials and strategies are well-aligned with learning objectives and learner needs. The acronym "ASSURE" stands for the steps involved in the process: Analyze Learners, State Objectives, Select Methods, Media, and Materials, Utilize Media and Materials, Require Learner Participation,

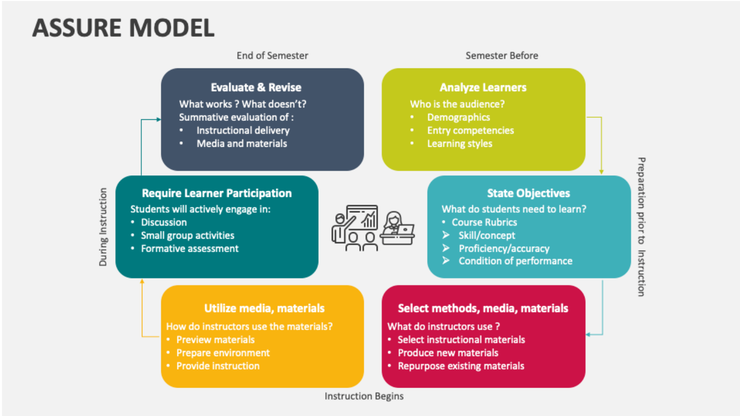


Fig. 4.7 ASSURE model

and Evaluate and Revise (see Fig. 4.7). The ASSURE model’s strength lies in its systematic approach to instructional design. By emphasizing learner analysis, alignment with objectives, and active learner participation, the model ensures that instruction is learner-centered and effective. It also encourages the use of various media and materials to cater to diverse learning styles and preferences. The model’s iterative nature, through the evaluation and revision step, promotes ongoing improvement in instructional design based on learner feedback and performance data.

ARCS Model

The ARCS Model of Motivational Design, developed by John Keller, is an instructional design framework that focuses on enhancing learner motivation and engagement throughout the learning process. The model aims to create instruction that captures learners’ attention, demonstrates the relevance of the content, builds their confidence, and ensures their satisfaction with the learning experience. The ARCS acronym represents the four key components of the model: Attention, Relevance, Confidence, Satisfaction (Fig. 4.8). The ARCS Model provides a strategic framework for designing instruction that appeals to learners’ intrinsic motivations and encourages active engagement. By addressing these four motivational factors, instructional designers can create learning experiences that are more enjoyable, meaningful, and effective. The model recognizes that motivated learners are more likely to stay engaged, retain information, and apply their learning beyond the instructional setting.

Attention	Relevance	Confidence	Satisfaction
Perceptual Arousal Provide novelty and surprise	***Goal Orientation*** Present objectives and useful purpose of instruction and specific methods for successful achievement	***Learning Requirements*** Inform students about learning and performance requirements and assessment criteria	***Intrinsic Reinforcement*** Encourage and support intrinsic enjoyment of the learning experience
Inquiry Arousal Stimulate curiosity by posing questions or problems to solve	***Motive Matching*** Match objectives to student needs and motives	***Successful Opportunities*** Provide challenging and meaningful opportunities for successful learning	***Extrinsic Rewards*** Provide positive reinforcement and motivational feedback
Variability Incorporate a range of methods and media to meet students' varying needs	***Familiarity*** Present content in ways that are understandable and that related to the learners' experiences and values	***Personal Responsibility*** Link learning success to students' personal effort and ability	***Equity*** Maintain consistent standards and consequences for success

Fig. 4.8 ARCS model

RID Model

The RID (Rapid Instructional Design) Model is an instructional design approach that emphasizes efficiency and speed in the creation of instructional materials. It is particularly useful when there is a need for quick development of instruction due to time constraints, changing content, or other factors. The RID Model streamlines the design process to expedite the creation of effective learning experiences. While not as detailed as some other instructional design models, RID focuses on key elements that contribute to rapid development: Analysis, Design, Development, Implementation, and Feedback. The RID Model is particularly suited for situations where immediate instruction is required, such as in rapidly changing work environments, emergency training, or short-term projects. It is not as comprehensive as other models but offers a pragmatic approach to developing instruction quickly while still maintaining a focus on learning outcomes. While speed is a key aspect, it's important to strike a balance between speed and ensuring that the instructional materials are effective and aligned with the desired outcomes.

These models offer structured frameworks for designing instruction and ensuring effective learning experiences. The choice of model depends on factors such as the nature of the content, the target audience, available resources, and the desired level of detail and planning.

Using the ADDIE model in EE offers several benefits that contribute to the effective design and delivery of instruction. The systematic approach of the ADDIE model aligns well with the complex and technical nature of engineering disciplines, resulting in improved learning outcomes and overall student satisfaction. As evidenced by Swain and Sahoo[314] and Peterson [315], the following benefits can be observed:

Enhanced Learning Effectiveness The ADDIE model's emphasis on thorough analysis, clear objectives, and aligned instructional strategies ensures that engineering content is presented in a structured and coherent manner. This approach promotes a deeper understanding of complex concepts and fosters critical thinking skills among engineering students.

Improved Student Satisfaction The systematic design process of the ADDIE model results in well-organized and engaging learning experiences. As a result, students are more likely to find the instruction meaningful, relevant, and enjoyable, leading to higher levels of satisfaction with the course.

Adaptation to Technical Content EE often involves intricate technical content that can be challenging to present. The ADDIE model allows instructors to break down complex topics into manageable modules, select appropriate instructional methods, and develop materials that cater to various learning styles.

Tailored Instruction Through the analysis phase, the ADDIE model encourages instructors to understand the specific needs, prior knowledge, and learning preferences of engineering students. This enables them to customize the instruction to suit the diverse backgrounds and abilities of the learners.

Effective Assessment Strategies The ADDIE model's inclusion of assessment design ensures that engineering students' progress and understanding are regularly measured. This enables instructors to identify areas of improvement and provide targeted feedback to enhance learning.

Time Management Engineering departments often have a rigorous curriculum, and the structured approach of ADDIE helps streamline the development and delivery of instructional materials, reducing the time needed to create effective courses.

Continuous Improvement The ADDIE model's iterative nature supports continuous improvement. By evaluating the effectiveness of instruction through the evaluation phase, educators can gather feedback from students and make necessary adjustments for future iterations, resulting in ongoing enhancement of the course.

Alignment with Industry Standards The ADDIE model's structured approach aligns well with engineering industry practices, where systematic design, analysis, and evaluation are critical. Students who experience instruction designed using the ADDIE model are better prepared for the demands of the engineering field.

In summary, implementing the ADDIE model in EE offers a structured, adaptable, and effective approach to designing and delivering instruction. The model's systematic phases ensure that learning objectives are met, student satisfaction is high, and instructional materials are tailored to the technical and conceptual challenges of engineering disciplines.

4.2.2 Engaging Students in Course Redesign: ThinkLab

The "ThinkLab: IDEA (Instructional Design Elementary Application) Workshop" is a transdisciplinary teaching course that was designed and conducted within the University College of Merit "Collegio Universitario Renato Einaudi" in Torino, Italy. The workshop aimed to review and redesign the first-year engineering courses offered by Polito under the central theme of "resilience" during the academic year 2020/21 [316]. The workshop's instructional design is closely aligned with the ADDIE model, which stands for Analysis, Design, Development, Implementation, and Evaluation. This model serves as a guiding framework to facilitate the course redesign process, incorporating the essential stages required for effective instructional design.

Analysis

In the context of the ThinkLab: IDEA Workshop, the Analysis phase aligns with the initial theoretical moment of the workshop. During this phase, the instructors present and explain the ADDIE model to the participating students. Groups are formed, each linked to a specific first-year engineering course subject. This phase involves analyzing the needs of the course, understanding the learners' characteristics, evaluating the learning context, and considering the existing content and infrastructure. The Hodges et al. [317] framework is utilized to guide the analysis of needs, learners, context, environmental scan, infrastructure, and content-task relationship. This phase facilitates a comprehensive understanding of the course's current state and informs subsequent design decisions.

Design and Development Phases

The Design and Development phases of the ADDIE model align with the macro-level and micro-level design workshops within the ThinkLab: IDEA Workshop. The macro-level design workshop, spanning four hours, engages students in a guided ADDIE cycle. Students are provided with reference materials, including slides, guidelines, and course descriptions. This workshop is structured into three assignments: Analysis (1 hour), Design, Development, and Implementation (2 hours), and Course Description (1 hour). During the Analysis assignment, groups systematically address questions related to instructional needs, learning objectives, interactions, skills, knowledge, and assessment strategies.

The Design, Development, and Implementation assignment delves into defining the strategy and technological solutions for the course redesign. Students identify learning objectives, activities, interactions, required skills, knowledge, and assessments for each course week. The micro-level design phase focuses on the detailed preparation of specific topics to ensure alignment with the course description. Bates's [318] features, including outcomes, overview, reading, discussion, practice, assessment, and more, serve as a framework to structure the implementation.

Implementation and Evaluation Phases

The Implementation and Evaluation phases are realized through the workshop's various components, including the macro-level and micro-level design workshops and the final presentation. Students, guided by the ADDIE model, actively engage in role-play methodologies, experiencing the teaching and design process from the perspective of a lecturer. This experiential approach helps them understand the implications of their design decisions and fosters a more meaningful learning experience.

The ADDIE model's iterative nature is reflected in the workshop's progression, promoting continuous improvement. The evaluation of the ThinkLab: IDEA Workshop is facilitated through feedback and surveys provided by the participants. The workshop's impact on student learning experiences and the integration of resilience concepts into course redesigns can be assessed, providing valuable insights for further refinement.

The ThinkLab: IDEA Workshop's alignment with the ADDIE model demonstrates a systematic and comprehensive approach to instructional design. The workshop leverages the ADDIE framework's strengths by integrating its phases into various activities, role-playing, and collaborative design efforts. Through this alignment, the ThinkLab: IDEA Workshop effectively guides students through the process of designing resilient and effective course experiences for first-year engineering students, showcasing the adaptability and applicability of the ADDIE model in addressing contemporary educational challenges.

The innovative approach employed by the "ThinkLab: IDEA Workshop" lies in its active engagement of students as co-designers in the process of course redesign. Traditionally, instructional design has primarily been driven by educators and administrators. However, this workshop introduces a paradigm shift by placing the students at the forefront of the redesign process. By immersing students in the role of instructors and encouraging them to re-envision the curriculum from an educator's perspective, the workshop harnesses their fresh insights, diverse perspectives, and intimate understanding of their own learning needs. This student-centric approach resonates with contemporary pedagogical principles, empowering learners to take an active role in shaping their educational experiences. Moreover, the workshop cultivates essential skills such as critical thinking, collaboration, and problem-solving, which are indispensable in today's rapidly evolving educational landscape.

The results of the "ThinkLab: IDEA Workshop" have been successfully integrated into the first-year engineering courses at Polito, exemplifying the workshop's tangible impact on curriculum enhancement. The insights and innovative ideas generated by students during the workshop have informed a comprehensive redesign of the first-year courses, ensuring alignment with the central theme of resilience and best practices in instructional design.

4.2.3 Enhancing Efficiency Through Competition: TEACH-GYM

The significance of instructional system design in shaping the quality and outcomes of courses within the educational landscape cannot be overstated. The choice and application of appropriate teaching methodologies are instrumental not only in engaging and enlightening students but also in optimizing the efficiency and effectiveness of the overall educational process. In the relentless pursuit of enriching and impactful learning experiences, the integration of innovative teaching methods has become an imperative for educational institutions.

In the pursuit of elevating instructional practices and nurturing a culture of perpetual advancement, an innovative initiative has emerged — TEACH-GYM: Grow Your Methodology. This visionary framework heralds a transformative shift in how educational institutions approach the design of instructional systems. By amalgamating the principles of gamification with the aspiration for pedagogical excellence, TEACH-GYM seeks to not only elevate the efficiency and effectiveness of courses but also to foster a dynamic and captivating learning environment. The initiative forms a profound and enduring connection between Polito, a distinguished European university, and Turin Polytechnic University in Tashkent, a prominent institution in Central Asia. The distinctive educational needs and disparities between these two regions have catalyzed a stimulating contest of ideas, designed to revamp teaching methodologies and recalibrate course content within bachelor programs. On one front, the contest prompts the creation of more specialized courses that cater to the specific demands of undergraduate education in Uzbekistan. On the other, it paves the way for the transfer of expertise and methodologies to the Italian university.

At its core, TEACH-GYM symbolizes a collaborative endeavor aimed at reshaping the conventional teaching methodologies prevalent within educational establishments. It transcends conventional approaches by leveraging the potential of competition to stimulate innovation, endorse experimentation, and engender tangible enhancements in course design and delivery. This framework provides educators with a platform to innovate within their instructional approaches, experiment with novel teaching strategies, and cultivate a learner-centric environment in sync with the ever-evolving requirements of students and the educational domain.

TEACH-GYM is guided by several key principles and objectives:

Innovation Through Collaboration TEACH-GYM fosters a sense of collaboration among educators and instructional designers. By encouraging the exchange of ideas and experiences, the competition creates an environment where innovative teaching methodologies can flourish.

Student-Centered Approach The competition places students at the forefront. Participants are challenged to develop teaching strategies that cater to diverse learning styles, promote active participation, and enhance overall comprehension and skill acquisition.

Continuous Improvement TEACH-GYM underscores the importance of continuous improvement in education. Participants are inspired to critically assess existing teaching methods and propose enhancements that adapt to the evolving needs of learners.

Impactful Learning Outcomes The ultimate goal of TEACH-GYM is to enhance learning outcomes. Educators are motivated to design methodologies that not only impart knowledge effectively but also foster critical thinking, problem-solving skills, and a passion for lifelong learning.

The inaugural TEACH-GYM call witnessed remarkable participation and outcomes. Italian lecturers teaching at Turin Polytechnic University in Tashkent actively engaged in the initiative, submitting proposals to reshape their courses to meet the educational demands of the region. The results were promising: a total of 23 proposals were received, each reflecting innovative adaptations of instructional methods tailored to the diverse learning preferences of students. These proposals underscored the commitment of educators to enhancing the educational experience and achieving impactful learning outcomes (Fig. 4.9).

Furthermore, TEACH-GYM introduced a call inviting Italian lecturers at TTPU to review and reshape their courses in the context of the distinct educational environment. This initiative exemplifies the commitment to cross-cultural collaboration and adaptive teaching practices, ensuring that the courses remain responsive to the evolving academic landscape and the diverse needs of learners. Informed by the shared realization that at TTPU merely 10% of students choose to pursue Master of Science degrees and that students often juggle part-time jobs alongside their studies due to the cost of graduate education, TEACH-GYM propels a rethinking of pedagogical methods. Recognizing the necessity of adapting teaching methodologies

Fig. 4.9 Poster section of the winning proposals during the celebration for the 10th years of TTPU

to meet these multifaceted demands, TEACH-GYM presents an arena of change where innovation flourishes.

The inception of TEACH-GYM [230] saw initial trials in courses employing experiential learning and simulations, yielding remarkable outcomes. The adoption of these innovative methods led to a notable increase in student attendance and engagement, alongside elevated success rates and academic achievements. These encouraging results provided the foundation for the project's expansion, driving forward the vision of reshaping courses and instilling job-oriented skills.

The impact of TEACH-GYM extends beyond student outcomes, permeating the academic fabric of both institutions. The initiative bridges Polito and Turin Polytechnic University in Tashkent in a symbiotic manner. While Polito gains insights for refining its courses based on concrete feedback from TTPU implementations, the Uzbekistan institution benefits from enhanced teaching methodologies and invaluable experiential learning for its faculty members.

The response to the call for proposals underlines the resonance of TEACH-GYM's objectives, with 14 submissions spanning diverse scientific domains. A testament to its adaptability, the project has garnered interest from various disciplines, reflecting a collective eagerness for pedagogical reinvention. The range of proposals, from interdisciplinary experiential projects to focused teaching method enhancements, emphasizes a comprehensive approach to course transformation.

TEACH-GYM's trajectory hinges on continuous evaluation, and preliminary insights are promising. The revitalization of teaching methodologies at both institutions signifies a dynamic shift in pedagogical paradigms, fostering skills that align with industry demands. The project's unfolding impact heralds the emergence of a win-win relationship, where academic institutions collaborate for mutual growth and educational excellence. As TEACH-GYM continues to unfold, the ongoing implementation of innovative strategies promises a landscape where education transcends conventional boundaries.

Among the winning proposals that emerged, one that stands out is the creation of the REAL Lab, an acronym for Remote Automatic Control Laboratory, which embodies a remarkable collaborative endeavor with far-reaching implications for EE. It represents an innovative and collaborative initiative that bridges geographical distances to provide students with valuable educational opportunities. The lab's inception and its subsequent impact from the perspective of the lecturer highlight the dedication and transformative teaching approach that went into its creation. Its purpose was to establish a remote platform accessible to students, particularly those from Uzbekistan, enabling them to engage in practical learning experiences in the field of automatic control (further details on the students' point of view are available in the Subsection 3.2.7).

From the lecturer's point of view, the REAL Lab signified a significant shift in educational paradigms. It required the exploration of novel pedagogical approaches to effectively deliver content and facilitate experiential learning in a virtual environment. The lecturer's role evolved from being a traditional source of knowledge to a facilitator of interactive and hands-on learning experiences. This transformation demanded not only technical expertise but also the ability to adapt to the dynamics of remote learning.

The REAL Lab's establishment called for a multidisciplinary approach, necessitating collaboration between educators, engineers, and technology specialists. Overcoming technological barriers, designing remote experiments, and ensuring seamless communication across continents were among the challenges that the lecturer, alongside their collaborators, faced. The lecturer's commitment to this endeavor was driven by the belief in the educational value it could offer to students, as well as the potential to enhance cross-cultural exchange and collaboration.

The development and implementation of the REAL platform required a phased approach, involving iterative design, testing, and refinement. The collaborative effort between TTPU and PoliTo ensured that the platform's design and functionalities aligned with the educational objectives and pedagogical practices of both institutions. This joint effort fostered a strong sense of ownership and investment from the educators and students, creating a shared commitment to the success and continuous improvement of the remote laboratory.

By collaborating with TTPU and extending the REAL platform to Italian courses, PoliTo demonstrated its commitment to promoting internationalization in EE. The collaboration not only enriched the educational experience for students at both institutions but also fostered a deeper understanding and appreciation of different cultural and educational contexts. Furthermore, the partnership between TTPU and PoliTo served as a model for future collaborations, emphasizing the value of knowledge exchange and cooperation in enhancing EE globally.

The REAL Lab's impact was felt in multiple dimensions. It not only empowered Uzbek students with access to resources and learning opportunities that were previously unavailable but also enriched the educational experience of students at Polito. The lab's success exemplified the potential of technology-mediated education to transcend geographical limitations and create a global learning community.

This collaborative effort marked a significant step forward in leveraging technology for education, fostering intercultural understanding, and nurturing a sense of global citizenship among students. As the REAL Lab continues to evolve, its legacy serves as an inspiration for educators and institutions worldwide to explore innovative ways to enhance education and create meaningful connections across borders.

4.2.4 Innovation in Course Delivery: some examples

The integration of innovative teaching approaches, including the incorporation of remote labs, has marked a transformative shift in lecturers and students' life. As traditional educational paradigms continue to evolve, educators are exploring dynamic methods to enhance student learning experiences and foster deeper engagement with complex concepts. This evolution is particularly evident through initiatives like the REAL Lab, where the convergence of advanced technology and pedagogy is revolutionizing the educational landscape. By seamlessly combining theoretical knowledge with practical applications, remote labs offer students a unique opportunity to engage in hands-on experiments and collaborative learning, transcending geographical boundaries and traditional classroom limitations.

The REAL project stands as a groundbreaking testament to the transformative potential of remote labs in EE. By seamlessly amalgamating theory with practice, transcending geographical constraints, and fostering collaborative global learning, this initiative illuminates the path forward for modern pedagogy. As we delve further into the exploration of innovative teaching approaches, the REAL project serves as an emblem of how technology and education can converge to revolutionize the very essence of learning.

Another offspring of the TEACH-GYM initiative, which has yielded transformative results, is the revitalized Structural Analysis course at Polito [232, 233]. Inspired by the insights garnered from the TEACH-GYM experience, the lecturer spearheading the course undertook a comprehensive redesign, driven by a resolute commitment to aligning the curriculum with the dynamic demands of the contemporary educational landscape. The endeavor to infuse the course with the spirit of student-centered pedagogy, sparked by TEACH-GYM's ethos, led to a comprehensive redesign that bore testament to the lecturer's unwavering commitment to fostering enhanced learning outcomes. This section delves into the profound redesign of the Structural Analysis course, underscored by the integration of Problem-Based Learning (PBL) principles, and navigates through the challenges encountered in this pedagogical transformation.

The lecturer's participation in the TEACH-GYM initiative served as a pivotal catalyst that kindled a fervent desire to extend the boundaries of innovation within the educational landscape. Encountering the synergistic blend of interactive teaching methodologies, the lecturer gained a profound appreciation for the transformative potential of student-centered pedagogy. Inspired by the rejuvenating spirit of TEACH-GYM, the lecturer envisioned a similar pedagogical metamorphosis for the traditional Structural Analysis course, aimed at fostering deeper engagement and more comprehensive understanding among students.

Central to the overhaul of the course was the integration of Problem-Based Learning (PBL), a pedagogical approach known for its ability to cultivate critical thinking, collaboration, and real-world problem-solving skills. Recognizing the need to bridge the gap between theoretical concepts and their practical applications, the lecturer skillfully infused authentic, real-world challenges into the curriculum. Through PBL, students were not merely passive recipients of knowledge but active participants in constructing their learning journey (see further details in the students perspective in subsection 3.2.8).

Undoubtedly, the transition from a traditional instructional model to a PBL-infused curriculum was not without its challenges. One prominent hurdle was the need to strike a delicate balance between structured content delivery and the open-ended, exploratory nature of PBL. The lecturer grappled with aligning the learning objectives with the dynamic nature of project-based exploration, ensuring that while students delved into real-world problems, they remained firmly grounded in theoretical foundations.

Moreover, the heterogeneity of the student cohort posed both opportunities and challenges. Tailoring PBL experiences to cater to diverse learning styles and prior knowledge levels necessitated a flexible approach to instruction. The lecturer adeptly employed various scaffolding strategies, leveraging peer collaboration and individualized guidance, to ensure that every student could derive meaningful insights from the PBL process.

In conclusion, the reconstruction of the Structural Analysis course exemplifies the lecturer's bold initiative to revolutionize education. Guided by the spirit of TEACH-GYM and fortified by the principles of PBL, the course's redesign stands as an opportunity to the educator's resolute commitment to nurturing the holistic development of students. Despite challenges, the lecturer's dedication to navigating uncharted pedagogical terrain paved the way for a more enriching, relevant, and transformative learning experience within the context of structural analysis education.

4.2.5 Course Approach and Methodologies in Short

The evolving landscape of teaching is marked by innovative approaches and transformative methodologies designed to enhance learning experiences and prepare students for the challenges of the modern world. This comprehensive overview explored three notable initiatives within this domain: the ThinkLab: IDEA Workshop, the TEACH-GYM framework, and the integration of Problem-Based Learning (PBL) principles into the Structural Analysis course.

The discussion of Instructional System Design underscores its significance in shaping the quality and outcomes of courses. The choice and application of appropriate teaching methodologies are instrumental in optimizing the efficiency and effectiveness of the educational process, as demonstrated by the initiatives discussed. The convergence of pedagogy and innovation in these initiatives reflects a collective commitment to nurturing holistic development and preparing students for a dynamic future. The choice of model depends on factors such as the nature of the content, the target audience, available resources, and the desired level of detail and planning.

The ThinkLab: IDEA Workshop exemplifies a transdisciplinary effort that leverages the ADDIE model to guide students through the process of redesigning first-year engineering courses. By analyzing needs, aligning learning objectives, and fostering collaboration, this workshop empowers students as co-designers, driving course enhancements and aligning curriculum with contemporary pedagogical principles.

The TEACH-GYM framework introduces gamification into instructional system design, sparking collaboration and innovation among lecturers. By focusing on a student-centered approach, continuous improvement, and impactful learning outcomes, TEACH-GYM propels pedagogical innovation, transcending geographical boundaries and fostering cross-cultural exchange.

The REAL Lab initiative stands as a groundbreaking testament to the transformative potential of remote labs in EE. Seamlessly blending theory with practice and transcending geographical constraints, REAL Lab offers students a unique opportunity to engage in hands-on experiments and collaborative learning, revolutionizing the essence of modern learning.

The integration of Problem-Based Learning (PBL) principles into the Structural Analysis course underscores the shift towards active learning and real-world application. By infusing authentic challenges, fostering critical thinking, and adapting to diverse learning styles, this approach transforms students from passive recipients of knowledge to active explorers and problem solvers.

These initiatives collectively represent a paradigm shift in EE: an era defined by collaboration, technology integration, and student-centered approaches. As educators and institutions embrace these innovative methodologies, the engineering landscape evolves to produce graduates equipped not only with technical expertise but also with the adaptable skills and mindset needed to excel in a rapidly changing world.

Through the convergence of pedagogy and innovation, EE paves the way for a future of continuous growth and excellence.

4.3 Global Perspectives in Engineering Education

4.3.1 Adapting to Educational Challenges: Online Solutions

It is imperative to underscore the pivotal role played by cross-fertilization across disciplinary boundaries in augmenting the efficacy of teaching and enhancing the overall learning experiences. The insightful exploration and implementation of the TEACH-GYM initiative have distinctly illuminated the profound impact that the integration of diverse knowledge domains can exert on pedagogical paradigms. By transcending the conventional confines of individual disciplines, TEACH-GYM has engendered a transformative synergy that not only encourages the convergence of multifaceted perspectives but also fosters an environment conducive to innovative instructional methodologies. This discernible confluence has, without a doubt, precipitated a substantial elevation in the quality of pedagogy and the resultant learning outcomes. As we delve further into this discourse, it becomes unequivocally evident that the fusion of boundaries indeed emerges as a catalyst for a noteworthy advancement in the educational landscape, fundamentally reshaping the contours of contemporary engineering instruction.

The outbreak of the COVID-19 pandemic catalyzed an unprecedented upheaval in global higher education systems, compelling institutions to urgently reimagine their instructional methodologies and swiftly transition to remote teaching modalities. The Polito, in sinergy with the Turin Polytechnic University in Tashkent (TTPU), stands as a prominent exemplar in this transformative narrative, where the convergence of proactive partnerships, technology-enabled infrastructure, and pedagogical adaptability played a pivotal role in shaping a dynamic response to the crisis [319].

While TTPU had already initiated forays into online education through initiatives like the TEACH-GYM, the onset of the pandemic ushered in an accelerated paradigm shift. Prior groundwork facilitated a seamless transition, evidenced by the incorporation of innovative tools such as the "BigBlueButton" for real-time collaboration and the "Respondus" proctoring system for remote exams. These technological assets not only ensured the continuity of education but also reaffirmed the power of cross-disciplinary collaborations.

The international perspective underscores the broader ramifications of this shift, with parallels observed in higher education institutions globally. The pandemic compelled universities to transcend geographical boundaries, leveraging technology to bridge the gap between instructors and students dispersed across diverse locations. As depicted by Remote Laboratory, distance ceased to be a deterrent to engaging in experiential learning, as students thousands of kilometers apart accessed and manipulated laboratory instruments through virtual interfaces.

Additionally, TTPU's experience highlights the intricate interplay between administrative preparedness and students' connectivity. While Uzbekistan's internet penetration rate presented a potential obstacle, TTPU's adaptability and students' resourcefulness emerged as potent mitigating factors. This resonates with a broader trend where institutions worldwide faced the challenge of ensuring equitable access to online resources, exposing disparities in digital infrastructure.

The feedback collected from TTPU's students underscores the significance of student-centered learning in the online domain. Positive responses underscored not only the accessibility of teaching materials but also the potential for enriched interactions with professors, transcending geographical barriers. This accentuates the need for educators to embrace novel pedagogies that harness technology's potential to facilitate personalized learning experiences and foster active engagement.

In conclusion, the sinergy between Polito and TTPU's proactive response to the COVID-19 crisis reverberates within the broader context of global higher education. The institution's pioneering efforts to integrate technology, adapt curriculum, and foster international partnerships have unveiled a new opportunities.

4.3.2 Broadening Horizons: Mobility, Training and Networking

In a world characterized by dynamic shifts driven by globalization, technological advancements, and the imperative for interdisciplinary collaboration, the significance of international mobility, comprehensive training, and robust networking mechanisms stands prominently at the forefront of curricular and pedagogical considerations. TRecognizing the significance of equipping educators with the tools to navigate this evolving terrain, the European Union (EU) has meticulously orchestrated a suite of initiatives under the Erasmus program and the Cost Action framework. These initiatives, tailored for university teachers, embrace mobility, training, and networking as pivotal components, engendering a holistic enhancement of pedagogical efficacy and research acumen both within the EU's geographic bounds and beyond. This subsection delves into an intricate exploration of these opportunities, elucidating their underpinnings, objectives, and outcomes, thus illuminating their contributions to the holistic development of EE.

The Erasmus program, a seminal pillar of the EU's commitment to enhancing education, propels a comprehensive assortment of initiatives aimed at nurturing internationalization and cross-cultural exchange within higher education. Rooted in the Erasmus+ framework, these initiatives encapsulate a diverse range of actions, with a profound emphasis on mobility, training, and networking. Within the realm of EE, the Erasmus+ program offers tailored opportunities such as student and staff mobility, enabling learners and educators to embark on enriching journeys across institutions, fostering a global perspective and cross-pollination of knowledge. Moreover, the Erasmus Mundus Joint Master Degrees further exemplify the EU's dedication to fostering mobility, equipping engineering aspirants with transnational experiences and a multifaceted skill set. The thematic networks, such as the European Society for Engineering Education (SEFI), provide a robust platform for stakeholders to engage in collaborative discourse, thereby fortifying the foundation of EE through the exchange of pedagogical best practices and research insights.

Concomitant with the Erasmus+ program, the EU's Cost Action initiative constitutes a multifarious spectrum of actions devoted to scientific and technological cooperation across the European research landscape. This initiative, inherently interdisciplinary, underscores the importance of mobility, training, and networking as conduits for augmenting education. Through its capacity building mechanisms, the Cost Action framework endeavors to extend the realms of educational efficacy by strengthening cross-border collaborations and knowledge transfer. The interconnectedness between the program's activities serves as a catalyst for transcending institutional boundaries, culminating in synergistic endeavors that refine pedagogical methodologies and equip educators with novel didactic approaches.

The COST Action 15221, entitled 'Advancing effective institutional models towards cohesive teaching, learning, research and writing development' or 'We ReLaTe,' stands as an exemplar of collaborative synergy and transformative outcomes, focusing on the imperative theme of writing, research, learning, and teaching support within the higher education milieu.

The WeReLaTe Action was conceived to tackle the intricate challenge of unifying specialized and centralized supports for four fundamental higher education facets: research, writing, teaching, and learning. Often confined within their silos, these domains possess shared territories and common ground that remain underutilized. This initiative sought to capitalize on the interplay among these areas, and it did so through two pivotal objectives. The first objective entailed classifying the commonalities in terms of purposes, processes, knowledge, values, and skills among central institutional supports for the aforementioned aspects, thereby enabling the harnessing of synergies. The second objective revolved around identifying optimal models and practices for supporting these domains, adapting to the evolving landscape of technology and assessments, and engendering transformative shifts in institutional support paradigms.

The collaborative nature of the Action was underscored by the participation of colleagues from diverse academic backgrounds across Europe and beyond. The author of this dissertation is the Italian Member substitute for this Cost Action. The initial endeavor involved establishing a shared comprehension of central support for writing, research, learning, and teaching. Building on this foundation, the Action partners delineated the existing and desirable scenarios pertaining to centralized support in these realms. Subsequently, through focused deliberations, key informants - esteemed colleagues proficient in writing, research, learning, and teaching - were identified. These informants contributed their insights through focus groups and a comprehensive questionnaire, shedding light on the multifaceted aspects that underpin their professional success. The acquired data was meticulously analyzed, culminating in the formulation of support models grounded in empirical observations and insights.

The potency of the WeReLaTe Action emanates from its engagement with diverse networking tools, including meetings, working groups, training schools, short-term scientific missions, and conference grants. These mechanisms facilitated the synthesis of collaborative efforts, enabling the crystallization of the Action's outcomes, lessons learned, and scholarly publications. Beyond the accomplishment of research objectives, the Action fostered a vibrant milieu for cross-cultural and multidisciplinary learning. By navigating the complexities of collaboration and partnership, participants gleaned insights that transcended disciplinary boundaries.

Another International Project in which Polito played an active role was the W-STEM project, an European Union ERASMUS+ Capacity-building in Higher Education Programme, that recognize the exigency of addressing the gender gap in STEM. Indeed, the underrepresentation of women remains a pressing concern, manifesting as lower participation rates and limited representation in senior positions. This transformative initiative encompassed a consortium of fifteen Universities from ten different countries, converging their efforts to devise effective strategies and tools for mitigating gender disparities in STEM disciplines.

The project has many different deliveries, like the profilling tool discussed in Subsection 3.3.4 and an illuminating course tailored for educators, administrative staff, and teachers seeking to become change agents in advancing gender equality within STEM education. The course, meticulously designed based on the project's outputs, empowers participants with the knowledge, skills, and resources to drive progressive transformations in their academic institutions. This course is not merely a didactic endeavor; rather, it serves as a gateway for catalyzing tangible change by providing comprehensive insights, actionable strategies, and pragmatic solutions.

The W-STEM course boasts a robust array of learning outcomes, each poised to cultivate an enriched understanding and proactive approach to addressing gender inequalities in STEM programs:

Contextual Analysis and Critical Reflection Participants will adeptly describe and critically analyze the contextual dynamics surrounding women's participation in STEM programs. This foundational insight equips them to match gender equality action plans with their unique institutional contexts, fostering informed dialogue with decision-makers while fostering a holistic grasp of women's involvement in STEM programs.

Strategic Evaluation and Enhancement Through a rigorous evaluation of existing self-assessment and gender equality action plans, participants will acquire the acumen to critically evaluate these frameworks for enhancing women's engagement in STEM programs. This evaluative prowess bolsters their ability to refine these plans for maximum efficacy.

Institutional Self-Reflection Participants will engage in profound introspection, reflecting upon the significance of self-assessment and gender equality action planning in their own institutions. This introspective journey prompts them to recognize the pivotal role of institutional commitment in driving transformative change.

Personal Agency and Impact Empowered by newfound insights, participants will contemplate their roles as change agents within the sphere of self-assessment and gender equality action planning. This introspective reflection culminates in the application of acquired resources to implement activities fostering women's participation in STEM programs, effecting tangible change.

Tools Utilization and Resource Contribution A cornerstone of the W-STEM initiative, participants will delve into the utilization and evaluation of tools, applications, and designs forged through the project's collaborative efforts. Additionally, participants will actively contribute to the W-STEM resource catalogue, thereby perpetuating the virtuous cycle of knowledge dissemination and innovation.

The W-STEM course transcends conventional boundaries, igniting a transformative journey for educators, administrative staff, and teachers committed to propelling gender equality within STEM education. Through a meticulously crafted curriculum, participants are poised to emerge as proactive change agents, armed with the insights, strategies, and resources necessary to forge a more inclusive, equitable, and diverse STEM landscape. By partaking in this course, participants are poised to initiate profound ripples of change within their academic institutions, amplifying the visibility of women in STEM disciplines and championing the cause of gender balance in decision-making and leadership. The W-STEM course is more than an educational endeavor; it is a clarion call to reshape the future of STEM education through the prisms of inclusivity, empowerment, and progress.

Speaking about internationalization, in collaboration with the Union for the Mediterranean (UfM), the Mediterranean Universities Union (UNIMED) undertook a comprehensive study to investigate mobility trends, academic exchange programs, strategic partnerships, and other key factors influencing the internationalization of higher education institutions within the Euro-Mediterranean region [320]. This study sought to investigate mobility trends, academic exchange programs, strategic partnerships, and other key factors influencing the internationalization of higher education institutions within the region. As an external expert, the author of this dissertation had the privilege to contribute to this research initiative by providing insights and methodological support. This collaborative effort between UNIMED and UfM aimed to shed light on the opportunities, challenges, and best practices associated with internationalization, and to formulate recommendations that could pave the way for further integration and advancement of higher education in the diverse and dynamic Euro-Mediterranean context. In this section, we will explore the methodology and key findings of this study, highlighting the pivotal role played by UNIMED and UfM in shaping the discourse on internationalization in the region.

The study concentrates on unraveling the dynamics of internationalization within the Euro-Mediterranean region, with a special emphasis on academic mobility and cross-border education trends. The investigation spans across ten countries: Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Mauritania, Morocco, Palestine, and Tunisia. These countries represent a diverse range of socio-cultural and geopolitical contexts, providing a comprehensive lens to understand the broader internationalization landscape.

The overarching objectives of the study are multifaceted. First and foremost, it seeks to examine the contours of internationalization in higher education, spotlighting available resources and opportunities at both national and regional levels. Within this exploration, the study aims to identify persistent challenges and obstacles impeding the internationalization process. In addition, the study endeavors to extract valuable insights from successful practices and experiences, offering a range of transferable and inspiring models for consideration. Ultimately, the study aspires to formulate a set of strategic recommendations, tailored to foster enhanced regional integration under the auspices of the UfM.

In constructing the research design, two prominent methodological frameworks have been interwoven. Firstly, the comprehensive approach to internationalization proposed by the Centre for Internationalization and Global Engagement (CIGE) at the American Council on Education (ACE) has been adopted. This framework, consisting of six interrelated dimensions—Institutional Commitment & Policy, Leadership & Structure, Curriculum & Co-curriculum, Faculty & Staff Support, Mobility, and Partnerships and Networks—provides a holistic lens through which to examine the intricate layers of internationalization.

Algeria		Egypt	
Jordan		Lebanon	
Libya		Mauritania	
Morocco		Palestine	
Tunisia			

Table 4.1 Dynamic infographic for each country in the study

Secondly, the methodological approach articulated by the European Association for International Education (EAIE) Barometer has guided the selection and engagement of stakeholders. This approach ensures a balanced and representative sampling of actors engaged in higher education internationalization, facilitating a nuanced analysis of internal and external factors influencing internationalization efforts.

To comprehend the multifaceted landscape of internationalization, a range of data collection methods have been implemented. A survey was administered to teaching and administrative staff, as well as students, across universities within the ten target countries. Interviews with international and regional stakeholders have been conducted to glean insights from diverse perspectives. Focus groups have been established within universities covered by the study, facilitating in-depth discussions and information exchange. Moreover, desk research has been employed to augment the qualitative analysis with comprehensive secondary sources.

A quick infographic for each country for Administrative Staff, Teachers and Students is available on the qrcode below.

Within the context of this young and dynamic region, brimming with enthusiasm for collaboration, the study exposes both challenges and openings. It brings into focus the vulnerabilities of higher education systems in the South-Mediterranean region, such as research quality deficiencies, bureaucratic hindrances, capacity limitations, language barriers, and visa policies, culminating in a relatively diminished appeal of the regional higher education institutions. Paradoxically, the study also underscores the active participation of universities and international stakeholders, illustrating their readiness to forge connections and embark on novel collaborative trajectories.

While Europe stands as the predominant partner and key higher education arena, it is essential to acknowledge the emerging roles of other actors like Turkey, China, India, Saudi Arabia, and Malaysia. Yet, European countries remain the primary destinations for students, faculty, and administrative staff from the countries under study. Rather than viewing this as an endpoint, it should be perceived as an initial phase. To recalibrate our perspective and relinquish an Orientalist lens, it is imperative to reinforce the principle of reciprocity, ushering in a new era of bidirectional cooperation and collaboration. The collective and resolute aspiration to enhance the internationalization of higher education across the Euro-Mediterranean region serves as an encouraging indicator that our trajectory is indeed aligned in the right direction.

In essence, the examination of mobility, training, and networking within the context of higher education reveals a complex tapestry of interconnectedness and transformation. As institutions increasingly embrace internationalization, the intricate dynamics of academic mobility unfold as a powerful catalyst for broadening horizons. The experiences of students, faculty, and administrative staff crossing borders enable the cultivation of a global perspective that transcends traditional academic boundaries. Moreover, training and capacity-building initiatives elevate the capabilities of individuals and institutions alike, fostering sustainable growth and mutual understanding. In parallel, networking amplifies collaboration, harnessing the collective wisdom and expertise of diverse stakeholders for addressing shared challenges and envisioning innovative solutions. As the study underscores, the Euro-Mediterranean region teems with potential and aspiration, poised to harness these opportunities to navigate the global higher education landscape. The findings illuminate both the imperatives and promises of internationalization, beckoning institutions to continue their journey toward enhanced cross-border engagement, fortified competencies, and interconnected futures.

4.3.3 Global Perspective in Engineering Education in Short

The section encapsulates the pivotal role of internationalization, adaptability, and innovative collaboration in shaping the landscape of EE. This discourse has delved into two profound facets: Adapting to Educational Challenges through Online Solutions, and Broadening Horizons through Mobility, Training, and Networking.

In the wake of the COVID-19 pandemic, the educational realm underwent a seismic shift, prompting the exploration of online solutions. The TEACH-GYM initiative showcased the transformative power of multidisciplinary integration, redefining pedagogical paradigms. The Polito's partnership with the Turin Polytechnic University in Tashkent (TTPU) exemplified the fusion of technology, proactive collaboration, and pedagogical adaptability in navigating the crisis. The outbreak necessitated a shift, accentuating the global nature of educational challenges, and the imperative to ensure equitable access to online resources, while highlighting the significance of student-centered, personalized learning experiences.

Simultaneously, the chapter illuminated the significance of international mobility, comprehensive training, and networking mechanisms in cultivating a holistic EE landscape. The Erasmus program and the Cost Action framework, embodiments of the European Union's commitment, underscored the power of transnational collaboration. TTPU's participation in projects like TEACH-GYM and WeReLaTe underscored the potential for cross-disciplinary collaboration to drive transformative shifts in institutional support paradigms. Furthermore, the W-STEM project emerged as a beacon of change, addressing gender disparities in STEM education through a multifaceted approach, including specialized tools, courses, and resources for educators and administrators. The study conducted by UNIMED and UfM delved into the dynamics of internationalization within the Euro-Mediterranean region, revealing both challenges and the enthusiasm for cooperation.

In summary, the section offers a panoramic view of the evolving dimensions within EE's global perspective. The resonance of themes across diverse initiatives underscores the intertwined nature of pedagogical innovation, cross-disciplinary collaboration, technology integration, equitable access, and fostering inclusive environments. This synthesis serves as a testament to the transformative potential of intercultural exchanges, innovative strategies, and collaborative endeavors, ushering in a new era of EE that is adaptive, inclusive, and globally interconnected.

5

Discussion

"The fishermen know that the sea is dangerous and the storm terrible, but they have never found these dangers sufficient reason for remaining ashore."

– Vincent van Gogh , *Letter to Theo van Gogh 14/05/1882*

The role of Engineering Education Researchers (EERs) extends far beyond the boundaries of traditional teaching and research. Their commitment is profound, aiming to elevate the educational experience for both students and faculty members. The central question guiding this dissertation has been: "What role does an EER play within an esteemed Italian technical university like Politecnico di Torino (Polito), and how does their work positively impact both students' understanding and lecturers' roles?" This research inquiry has served as a compass throughout our exploration of the multifaceted contributions of EERs.

As the author of this dissertation, I had the privilege of serving as the inaugural EER at Polito. Supported by esteemed full professors, I embarked on a journey to function as an academic scholar in the field of Engineering Education (EE). My role transcended disciplinary boundaries, bridging the gap between pedagogical innovation and engineering practice. Through rigorous research endeavors, I sought to scrutinize and refine pedagogical methods, curriculum design, and the overall learning experience within the realm of engineering.

My work encompassed several critical domains:

- **Pedagogical Innovation**: Collaborating tirelessly, I continuously sought innovative teaching approaches and strategies to enhance the effectiveness of

EE. Together with fellow educators, we explored novel methodologies, technologies, and active learning techniques that resonated with the ever-evolving needs of our students.

- **Curriculum Enhancement**: Active participation in curriculum development and improvement was essential. We endeavored to ensure that our engineering programs aligned seamlessly with industry demands, emphasizing interdisciplinary learning and incorporating contemporary knowledge and skills.

- **Assessment and Evaluation**: In the role of an EER, I learned to rigorously evaluate the outcomes of educational initiatives. Employing evidence-based assessment practices, I gauged student learning, retention, and success, facilitating data-driven improvements in our educational strategies.

- **Faculty Development**: My engagement with lecturers and professors was marked by providing unwavering support and valuable resources to enhance their teaching capabilities. We carefully planned and facilitated professional development opportunities, fostering a culture of continuous improvement among our esteemed educators.

Notably, the inception of the EER role at Polito marked a transformative period. Building a robust network of Politecnico professors and lecturers was pivotal, as it allowed us to bridge theory and practice effectively. Table 5.1 presents a comprehensive overview of the direct interactions and collaborations established by the EER. The data is organized by academic departments within Polito and includes the number of individuals reached directly by the EER, their respective career stages, and the count of publications with co-authors associated with each department. The EER's co-authorship is not included in the count for her department. This collaborative spirit within our academic community was instrumental in applying the theoretical role that an EER can play in practice. Simultaneously, the support and insights from the international EER community provided valuable guidance, shaping our understanding of this innovative role within the academic landscape.

As we journey through this dissertation, we will explore the multifaceted role of EERs in greater detail, examining their contributions to the enhancement of EE from various perspectives—student, lecturer, and the broader educational community at Polito.

Table 5.1 Interactions and Collaborations within the Engineering Education Researcher's Academic Network (*) the total number of publications with at least one co-author affiliated with Politecnico di Torino. It is important to note that this count does not represent the sum of the row above, as a single publication may involve co-authors from multiple departments within the institution. Legend: RF-Research Fellow, L-Lecturer, RTD-Researcher, PA-Associate Professor, PO-Full Professor

Department	People Directly Reached						Number of publications
	RF	L	RTD	PA	PO	Total	with at least one co-authors
DAD - Dip. Architettura e Design					2	***2***	1
DAUIN - Dip. Automatica e Informatica				1		***1***	1
DENERG - Dip. Energia				1	2	***3***	
DET - Dip. Elettronica e Telecomunicazioni				3	4	***7***	5
DIATI - Dip. Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture			1	2	2	***5***	
DIGEP - Dip. Ingegneria Gestionale e della Produzione			1		1	***2***	1
DIMEAS - Dip. Ingegneria Meccanica e Aerospaziale				2	2	***4***	
DISAT - Dip. Scienza Applicata e Tecnologia				5	1	***6***	5
DISEG - Dip. Ingegneria Strutturale, Edile e Geotecnica				2		***2***	2
DISMA - Dip. di Scienze Matematiche "G. L. Lagrange"	2	2		6	5	***15***	20
Totale	***2***	***2***	***2***	***22***	***19***	***47***	***20****

5.1 Fostering Engineering Excellence: Nurturing Student Potential

In this section, we delve into the student side of EE, examining the significance of spatial ability, the challenges posed by prerequisite mismatches, and the role of the scientific method. Throughout our discussion, we emphasize the transformative influence of EERs in nurturing students' potential and enhancing their understanding. From recognizing the significance of spatial ability to addressing prerequisite gaps and fostering critical thinking, this subsection provides a comprehensive overview of how EERs contribute to creating an environment where students thrive, excel, and develop the skills necessary for success in engineering and beyond.

Central to the essence of education is the fundamental truth that students are the driving force behind the roles and responsibilities of lecturers. Without the presence of students, the very purpose and significance of lecturers cease to exist. It is in this recognition that we firmly advocate for the paramount importance of adopting a student-centered approach in education, particularly within the realm of technical subjects. Placing students at the heart of the educational process not only acknowledges their pivotal role but also underscores the essential nature of tailoring teaching methods and curricula to meet their needs, aspirations, and intellectual growth. In embracing the student-centered approach, we aim to foster an educational environment that prioritizes the holistic development of learners, empowering them to excel in their academic journey and contribute meaningfully to the field of engineering.

The essence of education can be traced back to its Latin origins in the word 'educere,' meaning to lead out or bring forth. This fundamental etymology holds a profound truth for the entire education system. It reminds us that education's overarching purpose is to guide and facilitate the unfolding of students' innate skills, talents, and aptitudes. As such, the education system should be a beacon of support, nurturing an environment where students are empowered to discover, harness, and express their unique potential. It is in this transformative process of 'leading out' that education fulfills its most profound and noble mission—to enable individuals to illuminate their talents, contribute meaningfully to society, and embark on a journey of lifelong learning and growth.

5.1.1 Spatial Ability in Engineering Education

In earlier chapters, we have already delved into the pivotal role played by spatial ability within the context of EE (see subsecions 2.3.3, 3.1.3, and 3.3.2). However, recognizing the profound impact of spatial ability is only the first step. As EERs, we bear the responsibility of actively collaborating with educators at various levels to cultivate robust spatial ability among our students. This collaborative effort begins by engaging with teachers at lower grades, where the foundation of spatial understanding is laid.

During my tenure at Polito, we had the privilege of engaging in spatial ability training across diverse educational environments. Notably, the SAperI summer school initiative [279] aimed at empowering young girls through direct and intensive spatial training yielded compelling results. Participants demonstrated statistically significant improvements in their spatial ability compared to their peers who did not participate in the program, alongside a remarkable reduction in math anxiety. This reduction in anxiety proved pivotal, as it motivated some of these young students to pursue STEM careers, with the summer school experience serving as a key catalyst for their decisions.

Furthermore, the Matabì project provided a unique platform for integrating various spatial variables. Here, we developed a Lego Duplo set that facilitated spatial ability training. Moreover, teacher training programs were established, effectively enhancing their spatial reasoning skills, particularly in mental rotation. This, in turn, equipped educators to incorporate indirect spatial training techniques in their classrooms, positively influencing the spatial abilities of young learners.

The engagement in spatial training, whether through direct or indirect methods, emerges as a powerful tool for educating students, making it particularly advantageous for females pursuing STEM disciplines. The effectiveness of spatial training initiatives received further validation through collaboration with the CREATE research group at TU Dublin. Our engagement with Dr. Sheryl Sorby and her pioneering approach to training freshman engineers, which fosters inclusivity and challenges gender biases [183, 182], has been transformative. Initiatives like the Sorby course "Developing Spatial Thinking" empower young women to confidently pursue STEMM careers, helping to bridge the gender gap in spatial ability and encourage greater gender diversity within engineering and related STEMM fields.

In conclusion, spatial ability training initiatives in EE have emerged as a potent means to educate and empower students, particularly women, fostering inclusivity, and mitigating gender disparities. Collaborative efforts among EERs, educators, and researchers both within and beyond our academic institutions have the potential to reshape the landscape of engineering and STEMM fields, driving progress, innovation, and social equity. To attain greater gender diversity and inclusivity, continued dedication to targeted interventions and the creation of inclusive learning environments remains imperative.

As we delve into the research question of the role played by an EER within Polito, we recognize that a critical dimension of this inquiry revolves around our students—the primary beneficiaries of the educational ecosystem. Our research objectives include not only understanding this role but also seeking ways to enhance students' understanding and learning experiences. From the students' perspective, the incorporation of spatial ability development emerges as a pivotal factor. By embracing the insights and initiatives of EERs, students can expect to encounter enriched teaching methods, thoughtfully designed curricula, and a heightened emphasis on nurturing their spatial ability starting from early age education. This, in turn, equips them with a profound understanding of engineering principles and the problem-solving skills vital to their educational journey and future careers. Thus, the research objectives find resonance in empowering students with the cognitive tools they need to thrive in the world of EE, as facilitated by the collaborative efforts of EERs and educators.

5.1.2 Addressing Gaps in Prerequisite Knowledge

Directly related to the cognitive tools needed to access EE, addressing prerequisite mismatches emerges as a critical concern. This challenge extends beyond the conventional curriculum, as it significantly influences students' readiness and proficiency in technical subjects. One key observation is that students may possess a certain level of confidence in their technical abilities but often overlook fundamental gaps in their mathematical prerequisites.

These gaps in mathematical knowledge can manifest as a formidable barrier to student success, particularly in their early coursework. It is not uncommon for students to grapple with the intricate mathematical concepts required in engineering courses, which they might have underestimated during their initial self-assessment. Consequently, it is often the prerequisites, rather than the core course content, that pose the primary challenge.

Recognizing the need for proactive intervention, institutions like Polito have implemented innovative measures. The admission test, for instance, serves as a valuable tool in guiding students through a process of self-evaluation. By highlighting specific areas of mathematical deficiency, it empowers students to identify and address these gaps. Importantly, the Test In LAiB (TIL) at Polito offers students the flexibility to take the assessment multiple times, ensuring a comprehensive evaluation of their readiness.

In tandem, initiatives like the CIAO! (Corso Interattivo di Accompagnamento Online) and !OAIC (Online Accompanying Interactive Course) provide essential support for freshmen in reviewing and reinforcing fundamental mathematical concepts. These gamified approaches not only make the learning process engaging but also bridge the gap in mathematical prerequisites, equipping students with the essential knowledge required for their engineering journey.

Furthermore, the active role of an EER is pivotal in fostering innovative strategies to help students fill these gaps effectively. EERs can explore intriguing and engaging methods, such as gamification, to make the learning experience enjoyable while addressing prerequisite mismatches. Moreover, EERs can collaborate closely with teachers at lower grade levels to create a seamless network of support, ensuring a smoother transition for students as they progress through their educational journey.

In essence, addressing prerequisite mismatches in EE necessitates a holistic approach, with EERs actively contributing to the development of creative solutions. By navigating these challenges proactively and fostering collaboration with educators at all levels, educational institutions like Polito strive to enhance the overall preparedness and success of their engineering students.

5.1.3 The Scientific Study Method in Engineering Studies

EE is not solely about the acquisition of theoretical knowledge; it is equally concerned with nurturing a fundamental approach that underpins success— the scientific method. At its core, the scientific study method is a structured and systematic approach to inquiry, experimentation, and problem-solving. In engineering, it serves as a guiding philosophy that empowers students to tackle complex challenges, fostering critical thinking and problem-solving skills that are indispensable in the field.

The study method provides students with a structured framework for understanding and solving real-world problems. It begins with observation and curiosity, encouraging students to question the world around them. This initial phase is followed by hypothesis formulation, where students propose educated guesses to explain observed phenomena. Importantly, the scientific study method demands experimentation, inviting students to design and conduct experiments to test their hypotheses rigorously.

This approach is invaluable in engineering, where theoretical concepts are inextricably linked to practical applications. Engineering students often find themselves at the intersection of theory and practice, where the ability to apply knowledge to real-world scenarios is paramount. By emphasizing the study method, students are equipped with the tools to methodically approach engineering challenges, breaking them down into solvable components.

The scientific method's integration into EE is more than a pedagogical choice; it is a strategy for enhancing critical thinking and problem-solving skills. Engineering, by nature, deals with multifaceted problems that require analytical prowess. The scientific study method instills a disciplined and systematic approach to dissecting these problems.

Moreover, it encourages students to embrace failure as an essential component of learning. In engineering, not every experiment yields the desired outcome, and not every hypothesis proves correct. However, these perceived failures serve as valuable learning experiences, teaching resilience and adaptability.

Beyond academia, the scientific method equips engineering students with a mindset tailored for the professional world. In their careers, engineers will encounter complex challenges with no predetermined solutions. The scientific study method provides a structured approach to approaching these challenges, fostering the adaptability and creativity required for innovation.

In summary, the emphasis on the scientific study method in EE transcends theoretical knowledge. It empowers students with the tools to inquire, hypothesize, experiment, and critically analyze, all of which are indispensable skills in engineering practice. This emphasis underscores the transformative potential of EE in nurturing problem solvers, critical thinkers, and innovative professionals who are well-prepared for the challenges of the real world.

EERs wield significant influence in shaping the educational landscape by facilitating the seamless integration of the scientific study method into EE. EERs play a transformative role in nurturing students' analytical thinking and problem-solving abilities.

EERs understand that the scientific study method is not merely a theoretical concept but a practical approach with profound implications for students' development. They champion a pedagogical shift that places the scientific method at the heart of EE. By doing so, they recognize its transformative potential in nurturing students as effective problem solvers and critical thinkers, essential attributes in the engineering profession.

One hallmark of EER-led initiatives is their commitment to innovative curriculum design. They meticulously craft educational pathways that incorporate the scientific method as an integral component. EERs understand that students benefit most when they experience the scientific method in action.

For instance, initiatives like the "DayByDay" program illustrate EERs' dedication to supporting students in developing effective study methodologies. In this program, students are guided through their first Mathematical course, receiving ongoing support that helps them adapt their study perspectives as the semester progresses. This hands-on guidance instills a sense of metacognition, enabling students to recognize the applicability of the scientific method in their learning journey.

EERs go beyond theoretical discussions of the scientific method; they facilitate its practical application. By introducing students to real-world engineering challenges that demand systematic inquiry, hypothesis formulation, and experimentation, EERs allow students to experience the scientific study method's effectiveness firsthand. For example the REAL experience or the introduction of the PBL into a Structural Analysis course.

This approach empowers students to engage actively in problem-solving, fostering not only a deep understanding of engineering principles but also a mindset that embraces challenges as opportunities for growth. EER-led initiatives inspire students to view setbacks as stepping stones toward innovation and creative problem-solving.

Furthermore, EERs contribute to the development of a culture of analytical thinking within EE. By instilling the scientific method as a core approach, they create an environment where students are encouraged to question, experiment, and refine their understanding continuously.

EERs act as catalysts for change, influencing pedagogical practices, and faculty development to align with the principles of the scientific study method. Their collaborative efforts bridge the gap between theory and practice, ensuring that students graduate not only with theoretical knowledge but also with the ability to apply this knowledge effectively. Just to recall some initiative like STEMM games or Math Games Without Frontiers.

In essence, EERs' influence on integrating the scientific study method into EE embodies their commitment to preparing students for the challenges of the engineering profession. Through innovative curriculum design, practical application, and the cultivation of analytical thinking, EERs empower students to become agile problem solvers and critical thinkers who are poised to make meaningful contributions in their engineering careers.

5.2 Empowering Engineering Educators: A Cross-Fertilization Action

In this subsection, we explore the complex relationship between teaching and research within the academic landscape of Polito. Emphasizing the crucial role of EERs, we discuss how they empower engineering educators to balance teaching and research effectively. Through their initiatives and insights, EERs play a pivotal role in shaping the professional development of lecturers.

5.2.1 The Duality of Teaching and Research

In the landscape of Italian academia, as in many other countries, engineering educators often find themselves navigating the intricate duality of teaching and research. This duality is marked by the simultaneous responsibilities of imparting knowledge to students while engaging in research activities that contribute to the advancement of their respective fields. While these roles are undeniably interconnected, they also present unique challenges that necessitate careful balance and strategic management.

One of the primary challenges that educators face is the significant time investment that teaching demands. Preparing courses, delivering lectures, engaging with students, and assessing their progress all consume a substantial portion of their workdays. These commitments, while crucial for nurturing the next generation of engineers, can sometimes leave limited time and energy for engaging in meaningful research activities.

Additionally, academic roles often come with administrative duties and responsibilities within their institutions. These may include serving on committees, participating in departmental meetings, and taking on various administrative tasks. While these responsibilities are essential for the functioning of academic institutions, they further reduce the available time for research endeavors.

Italian universities typically set high expectations for research productivity among their faculty members. This includes publishing scholarly articles, securing research funding, and actively contributing to academic discourse. Meeting these expectations can be particularly challenging when teaching responsibilities occupy a significant portion of an educator's schedule.

Despite these challenges, educators are committed to delivering high-quality teaching to their students. They continually seek ways to improve their pedagogical approaches, stay updated on the latest educational methods, and adapt to the evolving needs of their diverse student populations. Maintaining this commitment to teaching excellence while juggling research demands adds another layer of complexity to their roles.

This is where EERs enter the picture as invaluable allies. EERs are experts in the field of education, and they bring a wealth of knowledge and resources to support lecturers in managing the duality of teaching and research.

EERs are actively engaged in researching innovative teaching methodologies, technology integration, and curriculum design. Their findings and insights provide educators with practical strategies to enhance the efficiency and effectiveness of their teaching practices. By implementing these research-based approaches, educators can potentially reduce the time demands associated with teaching while delivering an even more impactful educational experience to their students.

Furthermore, EERs offer professional development opportunities tailored to the needs of lecturers. Workshops, seminars, and training programs led by EERs equip educators with the skills and knowledge required to balance their teaching and research responsibilities effectively. Initiatives like the POT [303] and TEACH2TEACH experiences have demonstrated how these programs can empower educators to excel in both domains.

EERs also serve as mentors and collaborators, offering guidance on how to align research interests with teaching activities. This mentorship encourages synergy between the two roles, enabling educators to integrate research into their teaching practices. It promotes a holistic approach to academia, where research informs teaching, and teaching informs research, creating a mutually beneficial relationship. Notably, the revision of the Structural Analysis course [232, 233], a collaborative effort between an EER and a lecturer, exemplifies how this synergy optimizes effort and time in course development.

In addition to these roles, EERs play a pivotal role in introducing the research dimension into teaching. In some technical fields, it is increasingly recognized that teaching-related projects can be considered as research endeavors. EERs guide educators in defining these projects as research and assist in the publication process. This approach expands the educator's scholarly portfolio while enriching the educational experience.

Furthermore, the dedication of educators to teaching varies with their career stage. As revealed in semi-epistemological interviews conducted during the OEP investigation [307], career-stage-related factors influence their teaching efforts. For instance, junior educators may focus on refining their teaching methods through iterative improvements, driven by student interactions and outcomes. In contrast, more experienced educators may engage in strategic teaching decisions guided by a deep understanding of their students' needs and broader educational goals.

In conclusion, the duality of teaching and research is a central aspect of the Italian academic context for engineering educators. While it presents significant challenges, EERs play a crucial role in addressing these challenges. Their contributions through pedagogical innovation, professional development, mentorship, and advocacy empower lecturers to navigate this duality effectively. In doing so, educators enrich the educational experience for their students while advancing knowledge in their respective fields, regardless of their career stage.

The comprehensive data presented in Table 5.1 underscores the tangible impact of EER in bridging the gap between teaching and research. With direct interactions with 47 individuals, including a majority of senior-level faculty (Associate Professors [22] and Full Professors[19]), it becomes evident that the career stage of educators influences their willingness and interest in dedicating time to teaching innovation. Furthermore, the collaboration on 20 publications involving faculty members from 7 out of the 11 departments at Polito highlights the extensive reach and influence of EERs in fostering research-integrated teaching practices.

Please consider that some fields have started to witness the emergence of reputable technical journals that prioritize the educational perspective, such as IEEE. This shift further underscores the growing recognition of the importance of educational research within engineering disciplines.

This collaborative effort between educators and EERs fosters a thriving academic ecosystem where teaching and research coexist harmoniously.

5.2.2 Course Approach and Methodologies

The design of courses and the methodologies used for teaching are of paramount importance. These elements not only shape the learning experiences of students but also significantly impact their success in mastering complex engineering concepts. Within this context, EERs serve as guiding lights, illuminating pathways to innovative course design and teaching methodologies that empower both educators and learners.

Instructional system design is the art and science of crafting an educational experience that optimally aligns with learning objectives. It sets the foundation for effective teaching and learning. EERs bring their wealth of expertise to this endeavor, enhancing the overall quality of education.

EERs champion the philosophy of student-centered learning. This transformative approach places students at the heart of the educational process, recognizing their unique needs and the importance of active engagement. Collaborating closely with lecturers, EERs aid in the development of curricula that prioritize student needs, leading to the creation of learning environments that nurture active participation and deep comprehension. At Polito, we embrace this philosophy through initiatives like GYM (Grow Your Methodology) where lecturers transition toward student-centered learning.

Active learning has emerged as a powerful pedagogical approach, fostering critical thinking and problem-solving skills. EERs actively research and advocate for the integration of active learning strategies within engineering courses. Together with lecturers, they design activities such as group discussions, problem-solving sessions, and hands-on projects. These activities encourage students to become active participants in their own learning journeys. An illustrative example of this approach is the "We have an IDEA" course, which prompts students to role-play as lecturers and engage in the entire ADDIE instructional design process.

In today's digital age, technology is a valuable tool in education. EERs are at the forefront of researching and recommending effective ways to integrate technology into EE. They guide lecturers in selecting appropriate tools and platforms that enhance the learning experience. From online simulations to virtual laboratories, EER-led research informs the strategic use of technology to facilitate concept comprehension and skill development. As an example, the SMaILE app was developed within the SMaILE project, offering an engaging and interactive platform to teach complex AI algorithms.

EERs place a strong emphasis on formative assessment and timely feedback. They collaborate with lecturers to develop assessment strategies that not only gauge students' understanding but also provide constructive feedback for improvement. This iterative process of assessment and feedback contributes to more effective learning outcomes and helps students reinforce their study method, akin to the "daybyday" approach.

A fundamental aspect of instructional system design is ensuring that course objectives align seamlessly with desired learning outcomes. EERs work closely with lecturers to define clear and measurable learning objectives. These objectives serve as the foundation for designing assessments and selecting appropriate teaching methods, ensuring that the educational journey is purposeful and coherent.

In essence, EERs serve as educational consultants, infusing evidence-based practices into the heart of course design. Their collaboration with lecturers results in courses that are not only well-structured but also finely tuned to cater to the unique needs of students. This, in turn, enhances the quality of EE, creating an environment where students can thrive and reach their full potential.

Engagement is the cornerstone of effective teaching. It's not merely about transmitting knowledge but also about igniting students' curiosity and fostering their active involvement in the learning process. EERs play a pivotal role in inspiring and guiding lecturers to embrace innovative approaches that captivate students' interest.

- **Active Learning Strategies**: EERs advocate for active learning as a transformative approach. They collaborate with lecturers to incorporate strategies such as peer teaching, problem-based learning, and flipped classrooms. These methods encourage students to actively participate in discussions, collaborate with peers, and apply theoretical knowledge to real-world scenarios. Through this active engagement, students gain a deeper understanding of engineering concepts.
- **Inquiry-Based Learning**: Inquiry-based learning is a student-centered approach that fuels curiosity and critical thinking. EERs work hand in hand with lecturers to design courses that encourage students to ask questions, investigate problems, and seek solutions. This approach not only enhances students' problem-solving skills but also instills a sense of curiosity and intellectual exploration.
- **Project-Based Learning**: Project-based learning is a cornerstone of EE. It challenges students to apply their knowledge to real engineering problems, fostering practical, immersive learning experiences. For example, at Polito, we have witnessed the transformative impact of project-based learning in the Structural Analysis course. Students work on real-world engineering projects, deepening their understanding and preparing them for future engineering challenges.
- **Multimodal Resources**: Diverse learning resources play a vital role in accommodating various learning styles and enhancing comprehension and retention. EERs highlight the importance of incorporating multimedia, visual aids, and interactive materials into courses. Initiatives like CIAO/OAIC! exemplify how these resources make concepts more accessible, leading to improved student outcomes.
- **Community and Industry Engagement**: Connecting students with the broader engineering community and industry is invaluable. EERs facilitate partnerships between universities, students, and industry professionals. This collaboration includes guest lectures, internships, and industry projects, providing students with practical insights and real-world experiences that bridge the

gap between academia and industry. The "Percorso Talenti" initiative serves as a prime example of this industry-academia collaboration.

- **Illustrative Case Studies**: Illustrative case studies provide students with practical examples that deepen their understanding of engineering principles. EERs introduce real-world engineering challenges, allowing students to apply their knowledge to solve complex problems. These case studies serve as powerful learning tools, preparing students for the rigors of the engineering field. In GYM several proposals were in this direction.

- **Game-Based Learning**: Game-based learning is an innovative teaching method championed by EERs. It engages students by transforming education into an interactive and immersive adventure. EERs collaborate with lecturers to harness the engaging power of games to enhance the learning experience. For instance, the SMaILE app revolutionizes the teaching of AI by making learning interactive and enjoyable. Through gamified experiences, students not only acquire knowledge but also develop problem-solving and critical thinking skills while having fun.

In conclusion, EERs are catalysts for change, inspiring lecturers to adopt innovative approaches that captivate students' interest and foster active engagement. These approaches breathe life into traditional classrooms, creating dynamic learning environments where students become active participants in their education. By embracing these innovative teaching methods, students not only acquire essential engineering knowledge but also develop critical skills that prepare them for the ever-evolving challenges of the field.

These diverse methodologies, coupled with EER-led initiatives, enrich the educational landscape, empowering students to thrive in their engineering journeys and become the problem solvers and innovators of the future.

5.2.3 Impact Evaluation: Navigating the Complex Terrain of Teaching Research

Teaching is at the heart of EE, and understanding the impact of teaching activities is essential for ensuring students receive the best possible learning experiences. In this subsection, we delve into the world of impact evaluation within teaching research, exploring not only its significance but also the challenges faced and strategies employed in this complex endeavor.

At the core of EE research lies the pursuit of effective teaching methodologies and strategies. Evaluating the impact of teaching activities is not merely an academic exercise; it is a critical process that serves multiple vital purposes.

First and foremost, impact evaluation is a powerful tool for continuous improvement in teaching. It provides educators with insights into the effectiveness of their instructional methods and curricula. By systematically gathering evidence on student performance, engagement, and satisfaction, educators can identify areas for enhancement and refinement. This iterative process enables them to tailor their teaching approaches to better align with learning objectives.

Moreover, as educational institutions face growing demands for accountability, impact evaluation becomes instrumental in justifying educational investments. It offers concrete data that demonstrate the value and effectiveness of teaching practices. Policymakers, administrators, and stakeholders rely on these findings to make informed decisions regarding resource allocation and educational policies.

Additionally, impact evaluation is an indispensable component of research in EE. It allows researchers to investigate the efficacy of various teaching methodologies, interventions, and innovations. By rigorously examining the impact of these elements, researchers contribute valuable knowledge to the broader field of EER. This, in turn, supports evidence-based decision-making in education.

Conducting research on teaching activities presents a set of intricate challenges, particularly within the academic context. These challenges are rooted in the dynamic nature of educational settings and the multifaceted nature of teaching.

Resource constraints often top the list of challenges. Traditional research designs, such as Randomized Controlled Trials (RCTs), while highly rigorous, can demand significant resources. Implementing RCTs, which involve randomly assigning students to treatment and control groups, can be logistically challenging within the framework of regular courses.

Ethical considerations also play a pivotal role. In some cases, ethical concerns may limit the feasibility of certain research designs. For example, withholding a potentially beneficial teaching intervention from a control group may raise ethical dilemmas.

Time constraints pose another substantial challenge. Balancing the demands of teaching responsibilities with those of research activities can be demanding. Engaging in data collection, analysis, and interpretation within the confines of academic schedules can be daunting.

Furthermore, the variability in student populations within engineering courses introduces complexity when evaluating the impact of teaching methods. Diverse student backgrounds, levels of prior knowledge, and learning styles must be accounted for in research design and analysis.

To overcome these challenges and conduct rigorous impact evaluations in teaching research, educators and researchers employ a range of innovative strategies.

Quasi-experimental designs offer a practical alternative to RCTs. In these designs, researchers carefully match treatment and control groups based on relevant characteristics, minimizing potential bias. While not as robust as RCTs, they can provide valuable insights.

Longitudinal studies extend the evaluation horizon, tracking student progress over an extended period. This approach allows researchers to assess the long-term impact of teaching activities, providing insights into the sustainability of educational interventions.

Mixed-methods research combines quantitative and qualitative data collection methods. This holistic approach yields a comprehensive understanding of teaching impact. Qualitative data, such as student interviews and observations, can capture nuanced insights that quantitative data alone may miss.

Collaboration and networking prove invaluable in sharing the workload and resources needed for impact evaluation. Partnering with colleagues and educational researchers within and outside institutions facilitates the exchange of best practices and research methodologies.

Additionally, implementing a culture of continuous improvement in teaching acts as a form of impact evaluation in itself. Regular feedback from students, self-assessment, and peer reviews inform ongoing improvements in teaching practices, aligning them with learning objectives.

In summary, assessing the impact of teaching activities in EE is a multifaceted endeavor with significant implications for both educators and researchers. While challenges exist, innovative research designs, collaborative approaches, and a commitment to continuous improvement pave the way for meaningful insights into the effectiveness of teaching practices. The goal is to ensure that engineering students receive high-quality education that prepares them for successful careers in the field.

5.2.4 Global Perspectives in Engineering Education

EE thrives on the exchange of ideas, best practices, and international collaborations. As we explore the significance of cross-fertilization in this context, it becomes evident that EERs play a pivotal role in facilitating international connections and fostering global perspectives in Italian academia.

EERs serve as catalysts for faculty mobility and training, enabling Italian lecturers to explore and learn from educational practices around the world. This mobility is not limited to physical relocation but extends to virtual collaborations, exchange programs, and training opportunities.

Faculty networking opportunities allows lecturers to immerse themselves in different educational systems and cultures, gaining fresh insights and perspectives. It opens doors to international collaborations and partnerships, enriching their teaching and research endeavors.

EERs actively promote international training initiatives, encouraging lecturers to participate in workshops, seminars, and conferences abroad. For instance, programs like the school dedicated to young research within the Cost Action offer excellent opportunities, especially for lecturers in the early stages of their careers, to connect with the EER community and enhance their research skills. These training experiences expose educators to cutting-edge pedagogical methods and the latest advancements in EE, equipping them to bring global best practices back to Italian classrooms.

EE is a global community, and EERs recognize the value of international networking. They actively facilitate opportunities for Italian lecturers to connect with their counterparts worldwide.

EER-led initiatives often involve collaborative projects with international research groups. These collaborations transcend geographical boundaries, fostering the exchange of ideas and expertise. For instance, joint research projects, co-authored publications, and shared resources become avenues through which global perspectives are infused into Italian EE. A good example is the REAL remote laboratory [231] that is used from TTPU students from Tashkent (Uzbekistan) and Polito students for a win-win in the economical and resourses perspective.

Furthermore, EERs play an instrumental role in advocating for and securing funding from entities such as the European Union and private foundations. These funding opportunities support faculty mobility, international research partnerships, and cross-cultural initiatives within EE. That was the case for some of the international Erasmus+, Capacity Building or Cost Action projects brefly described in Section 4.3.

By embracing international experiences and collaborating with educators from diverse backgrounds, Italian lecturers and students gain exposure to a broad spectrum of engineering practices and perspectives. This exposure prepares them to thrive in an increasingly interconnected and multicultural world.

Global perspectives foster adaptability and innovation. They encourage lecturers to explore innovative teaching methods, draw inspiration from global best practices, and adapt their approaches to better serve the needs of a diverse student body.

Additionally, students benefit immensely from a curriculum that incorporates global perspectives. Exposure to different cultures, engineering challenges, and problem-solving approaches equips them with a broader skill set and a more holistic understanding of their field. That is why for the PBL Structural Analysis course [232] we choose as inspirational project a bridge design in Australia and the designer took part at the project assessment.

In conclusion, the role of EERs in promoting cross-fertilization and global perspectives in EE cannot be overstated. They serve as bridges that connect Italian academia with the rich tapestry of EE practices around the world. Through faculty mobility, international networking, and a commitment to global perspectives, EERs contribute to the cultivation of well-prepared, adaptable, and globally aware engineers in Italy.

5.3 Technology's Transformative Role

In this subsection, we delve into the transformative role of technology in EE. Of particular importance is the role of EERs at Polito in rigorously evaluating the impact of educational technology on both students' understanding and lecturers' roles. We will explore how EERs contribute to ensuring that technology adoption leads to positive outcomes in teaching and learning.

5.3.1 Evaluating Educational Technology

In the ever-evolving landscape of EE, technology stands as a catalyst for transformative change. The integration of educational technology has the potential to enhance teaching methodologies, engage students in novel ways, and ultimately elevate the quality of education. However, realizing this potential requires careful evaluation and assessment. This subsection delves into the crucial role of EERs at Polito in rigorously evaluating the impact of educational technology on both students' understanding and lecturers' roles.

EERs recognize that the adoption of technology in education transcends the introduction of the latest gadgets or software. It involves the strategic harnessing of technology to achieve specific educational goals. This understanding is rooted in the belief that technology should serve as a means to an end, enhancing the teaching and learning process in purposeful ways. To illustrate, consider the case of the Virtual Escape Room, a pioneering self-assessment game designed to address mathematical prerequisites. This innovative approach leverages gamification techniques to serve a specific educational objective, namely, increasing students' engagement in self-assessment and addressing potential knowledge gaps before embarking on their courses.

One fundamental aspect of EERs' work at Polito is to ensure that the integration of technology in EE leads to positive outcomes. This involves a multifaceted approach that begins with defining clear objectives for technology adoption. These objectives are aligned with pedagogical goals and the needs of both lecturers and students. Notably, Polito boasts an in-house developed platform known as the 'Portale della Didattica,' meticulously organized to centralize all educational and administrative information. Within this platform, each course is allocated a dedicated section featuring comprehensive descriptions, assessment details, and regularly updated course materials provided by the lecturers. Additionally, forums and video-recorded lessons are readily accessible to enhance the learning experience. Many courses also leverage Moodle integration, offering students access to exercises, tests, and course assessments. Moreover, Polito's classrooms are fully equipped with cutting-edge technology, including dual blackboards, smartboards, projectors, and the capability to record live sessions. Laboratories, designed to accommodate smaller groups, present no technological barriers, fostering a seamless and enriched learning environment.

EERs rigorously evaluate the impact of educational technology through a variety of assessment methodologies. These methodologies encompass quantitative and qualitative research, surveys, classroom observations, and in-depth interviews. By employing a mix of these methods, EERs gain a comprehensive understanding of how technology influences student learning and lecturers' roles.

One key area of assessment revolves around student understanding. EERs examine how technology-supported teaching methods affect students' comprehension of complex engineering concepts. This includes analyzing data on student performance, their engagement with technology-enhanced resources, and their feedback on the learning experience. An illustrative example of this assessment process is the revision of the Algebra and Geometry course, which underwent refinement based on valuable feedback from students participating in the Progetto Talenti.

Simultaneously, EERs explore the impact on lecturers' roles and teaching practices. They investigate how technology influences lecturers' pedagogical approaches, workload, and overall effectiveness. By conducting OEP interviews with lecturers, EER gained insights into the challenges and opportunities technology presents from an educator's perspective. These interviews revealed that once lecturers become familiar with technology, it often serves as a facilitator. However, it can require some time for adaptation and this is a big limitation.

The findings generated through these assessments guide the iterative process of technology integration. EERs collaborate closely with lecturers to refine and optimize the use of technology in engineering courses. This iterative approach ensures that technology aligns with the unique needs of both students, lecturers and labour market needs.

5.3.2 Supporting Teaching Through Technology

EERs at Polito are at the forefront of developing pedagogical innovations that leverage technology to enhance teaching practices. These innovations are driven by a deep understanding that technology should be strategically harnessed to achieve specific educational goals. The development of the SMaILE app is a perfect example in which EERs helped to properly match the type of technologies and games that suit the purpose of the project's objective, which is to teach AI to Generation Z.

Another exemplary case study, not yet discussed in the dissertation because developed before the EERs started collaborating at Polito, is the project designed by Prof. Stefano Grivet, which has revolutionized the examination process and student support in courses such as Elettrotecnica. Considering its pioniring design, it is here shortly described.

Prof. Grivet's project originated from a desire to streamline and enrich the examination experience for both students and lecturers. The project aimed to:

- Generate exam questions and exercises swiftly and efficiently.
- Provide students with tools for autonomous practice and self-assessment.
- Motivate students to stay on track with lessons and exercises.
- Offer a platform for students to experiment with various problem-solving methods and develop critical thinking skills.

For instance, in the field of Circuit Theory, where students are required to analyze circuits and calculate currents and voltages, Prof. Grivet's project introduced automated exam paper generation. This system employs randomized graph generation, assigns circuit elements to edges, and categorizes elements based on analysis type and difficulty. It also generates values for circuit elements, unknowns to be solved, and circuit diagrams using a combination of tools, including BLAG/OGDF and LaTeX (PSTricks+pscirc). The result is a diverse set of exam papers with solutions provided, eliminating the need for manual exam preparation.

Additionally, the project expanded to create www.autoCircuits.org, a web service offering:

- The generation of exam questions with solutions, ensuring diversity and appropriate difficulty levels.
- The generation of exercises with solutions, available anytime and anywhere.
- A user-friendly web interface for students and lecturers.
- Integration with the Moodle platform for easy access and management (this service is installed on a separate server dedicated to lecturers only).

Furthermore, the system includes icircuits, a feature that allows students to generate problems and receive guided step-by-step solutions. This feature empowers students to enhance their problem-solving skills and deepen their understanding of course materials.

The impact of Prof. Grivet's project has been substantial, with thousands of student requests (7852 requests from 543 unique IP addresses during the first six months of deployment) and a 68% positive response rate in student surveys. Furthermore, the project's integration into the university's Moodle system has made it accessible to a broader range of lecturers, maximizing its utility for the teaching community.

Implementing technology-supported teaching solutions, such as the SMaILE app and AutoCircuits, requires a significant investment of effort, energy, time, and technological knowledge. These projects are internally developed and represent a substantial commitment from educators and institutions to enhance the educational experience.

However, it's essential to recognize that technology integration in education is not limited to such extensive projects. There are simpler yet effective ways to leverage technology, such as the use of platforms like Kahoot for real-time student engagement and feedback during lessons. These options provide opportunities for enhanced interaction and active learning without the need for extensive development efforts.

In addition to facilitating exams, EERs at Polito harness technology to enhance student engagement and improve learning outcomes through innovative assessment practices. One of the notable achievements is the seamless integration of technology for the creation of randomized tests within the Moodle platform.

This technology-driven approach ensures the fairness and effectiveness of assessments, allowing lecturers to design exams that are dynamic, diverse, and tailored to individual student needs. The key to this success lies in the extensive item dataset available for each course.

With a vast repository of exam questions, lecturers can effortlessly create randomized tests that cover a wide range of topics and difficulty levels. Moodle's capabilities enable the distribution of questions in a balanced and unbiased manner, ensuring that each student receives a unique set of questions. This approach promotes fairness by preventing predictability and cheating, ultimately leading to more accurate evaluations of students' understanding.

For instance, in the context of Mathematical Analysis I, the availability of a substantial item dataset means that questions are labeled with the various mathematical concepts and organized in boxes depending on the competence required. This ensures that no two students receive identical exams manteining the same topic distribution and difficulty level, enhancing the credibility of the assessment process.

Similarly, the Test in Laib (TIL), which serves as an entrance exam for engineering programs, benefits from this technology-driven approach. The TIL's effectiveness in assessing students' aptitude and prior knowledge is amplified by the sheer volume of questions available. This enables the creation of randomized tests that accurately evaluate each student's readiness for their chosen engineering program.

By leveraging technology to create randomized tests with vast item datasets, EERs at Polito are not only enhancing the fairness of assessments but also streamlining the examination process. This approach encourages students to view the university as a preferred institution for higher education, where innovative assessment practices are utilized to ensure a level playing field for all.

In conclusion, while developing sophisticated technological solutions demands substantial resources, the effort pays off in improved teaching practices and enhanced student engagement. It's essential for educational institutions to strike a balance between investing in substantial projects and adopting readily available technological tools to create a dynamic and effective learning environment.

5.3.3 The Strategic Role of Technology Developers

EER at Polito play a pivotal role in guiding the effective integration of technology into EE. Her unique perspective as experts in EE research enables them to provide valuable insights into how technology can be harnessed to enhance the teaching and learning experience.

One remarkable example of this collaboration between EER and technology developers is the development of the SMaILE app (see Subsection 3.1.5). In this project, EER took a lead role in translating educational objectives into a gamified experience. She worked closely with technology developers to ensure that the game's design aligned seamlessly with the intended learning outcomes. This harmonious partnership resulted in a highly effective educational tool that engages students while facilitating their learning of complex topics, such as Artificial Intelligence.

Another illustrative case is the REAL laboratory (see Subsection 4.2.4), where EERs collaborated to align learning outcomes with laboratory experiences. This involved a meticulous process of designing and restructuring laboratory activities to ensure that they effectively supported the intended educational objectives. EER played a critical role in bridging the gap between educational goals and practical implementation, ensuring that students benefit from a meaningful and relevant laboratory experience.

In the rapidly evolving landscape of educational technology, EERs serve as guiding lights, helping to shape the development of tools and resources that truly enhance EE. Their expertise ensures that technology aligns with pedagogical goals, ultimately benefitting both lecturers and students.

The collaboration between EERs and technology developers highlights the importance of interdisciplinary teamwork in the pursuit of innovative and effective teaching methods. It is a testament to how the intersection of pedagogy and technology can lead to transformative outcomes in EE.

In the era of rapid technological advancement, the education sector has witnessed an influx of hardware and software products designed to support teaching at all educational levels. These products, developed by a range of stakeholders, including university professors, spin-offs, students, and startups, offer promising solutions for enhancing education. However, their widespread adoption often outpaces the rigorous evaluation of their impact.

The Italian Ministry of Education's commitment to advancing technology in schools and universities has led to an abundance of funding opportunities. Consequently, the education technology industry has responded with a plethora of innovative products. Yet, the urgency to deploy these technologies sometimes leaves little time for comprehensive impact evaluation assessments.

This situation has given rise to a challenge where a multitude of technological solutions exist, but there is limited understanding of their true value and effectiveness in enhancing education. As a result, educators and institutions are left grappling with an array of tools and resources, unsure of which best aligns with their specific needs and objectives.

EERs recognize the critical importance of advocating for evidence-based technology adoption in EE. They understand that a thoughtful and scientific evaluation of technology's impact is essential before its widespread implementation. By promoting a culture of assessment and research, EERs can help ensure that colleagues, spin-offs, and student startups engage in rigorous education impact evaluations of their projects.

Such evaluations are not only vital for understanding the true educational value of technology but also for defining the proper target audience and usage scenarios. EERs, with their expertise in educational research methodologies, can provide valuable guidance in designing and conducting these evaluations.

In conclusion, EER at Polito recognize that the strategic integration of technology into EE requires a balanced approach that combines innovative development with rigorous evaluation. Their expertise in both pedagogy and research positions them as key advocates for evidence-based technology adoption, ultimately contributing to more conscious decision-making in the ever-evolving landscape of educational technology.

6

Conclusion

> *"How different our life would be if we truly learned, day by day, to work, to think, to build together!"*
>
> – Papa Francesco, *Address To Confindustria 27/02/2016*

6.1 Final recommendations

6.1.1 Pedagogical Approaches

In this section, we delve into a range of pedagogical approaches within the context of Engineering Education (EE) Research. These approaches have the potential to significantly enrich the learning journey of engineering students, aligning seamlessly with the core objectives of this dissertation. Our recommendations are grounded in extensive research and are poised to make substantial contributions to the field of EE.

Active Learning Strategies

Active learning represents a transformative approach that places students at the center of the learning process. It involves engaging students in various activities that promote critical thinking, problem-solving, and practical application of knowledge.

The EER's support to lecturers provided in this dissertation encompasses a broad spectrum of active learning techniques, including but not limited to:

- Problem-Solving Activities: Encouraging students to tackle real-world engineering problems, fostering their analytical skills and creativity.
- Group Discussions and peer-to-peer: Promoting collaborative learning through group discussions, enabling students to exchange ideas, share insights, and gain diverse perspectives.
- Hands-on Experiments: Incorporating practical experiments that allow students to apply theoretical knowledge in a tangible, interactive manner.
- In-Class Activities: Designing in-class activities that encourage participation and interaction, ensuring that learning is an active and engaging experience.

These active learning strategies not only align with our research objectives but also provide students with a dynamic and immersive learning environment.

Project-Based Learning and *BL more in general

Project-Based Learning (PBL), together with Challenge-Based Learning (CBL) and Design-Based Learning (DBL) at a wider level, serves as a cornerstone of modern EE. It involves students working on real projects that simulate professional challenges, thus bridging the gap between theory and practice. Our experience highlights the following advantages of PBL:

- Practical Application: Enabling students to apply engineering principles to authentic problems, reinforcing their problem-solving abilities.
- Teamwork: Fostering collaborative teamwork, which mirrors the dynamics of engineering projects in the real world.
- Critical Thinking: Cultivating critical thinking skills by requiring students to analyze, design, and implement solutions to complex, open-ended challenges.

These benefits underscore the significance of PBL as a central pedagogical approach in EE within the EER context. Similarly, this conclusion can be extended to *BL more in general. It is worth considering that:

- CBL is characterized by its interdisciplinary nature, necessitating ethical and societal considerations in finding proper solutions.
- DBL emphasizes prototyping, testing, and an iterative design process to develop robust solutions.

Gamification

Gamification introduces game elements and principles into the learning process, transforming education into an engaging and immersive experience. Some key elements of the integration of gamification principles include:

- Playful learning: Reinforcing the learning process through emotions, creating a playful environment that aligns with our research objectives.
- Rewards and Achievements: Implementing a system of rewards and achievements to recognize and celebrate student progress.
- Interactive Challenges: Creating interactive challenges and simulations that provide students with hands-on problem-solving opportunities while making learning enjoyable.
- Competition: Harnessing healthy competition to motivate students to excel in their studies. In this case, it is imperative to pay attention to the gender dimension, ensuring inclusivity and equitable engagement.

These gamification elements not only enhance student engagement but also align with our overarching goals within the EER context.

Integration of Technology

The integration of technology into EE has emerged as a cornerstone of pedagogical advancement. In the digital age, leveraging technology is not merely an option but a necessity. We emphasize the profound significance of seamlessly incorporating digital resources, such as multimedia presentations, interactive simulations, and robust online platforms, into the fabric of EE. These technological tools serve as dynamic conduits for enhancing the learning experience, catering to the diverse learning styles and preferences of today's students.

Moreover, technology transcends traditional boundaries, allowing educators to transcend geographical limitations and engage learners across the globe. It enables the creation of virtual laboratories, immersive experiences, and collaborative online environments that extend the reach of EE far beyond the confines of the physical classroom. Embracing technology is not only about staying current; it is about equipping students with the digital literacy and adaptability essential in the modern engineering landscape.

Assessment Aligned with Pedagogy

Assessment, as a vital component of the educational process, wields a profound influence on the effectiveness of pedagogical approaches. The alignment of assessment methods with chosen pedagogical strategies forms the bedrock of a meaningful and relevant evaluation of student learning outcomes. In this context, our recommendations advocate for assessments that transcend the boundaries of traditional testing. We endorse assessments that mirror the complexities of real-world problem-solving, demanding students to apply the knowledge and skills cultivated through active learning experiences.

These assessments are not merely evaluative tools but transformative instruments that contribute to the holistic development of students. They encourage critical thinking, creativity, and the application of engineering principles to practical challenges. Moreover, by aligning assessment with pedagogy, educators can more accurately gauge the effectiveness of active learning, project-based learning, gamification, and technology integration, ensuring that these strategies indeed enhance the students' comprehension and retention of engineering concepts.

In sum, the alignment of assessment with pedagogy bridges the gap between theory and practice, setting a higher standard for student achievement and fostering a deep understanding of engineering principles that extends far beyond the confines of the classroom.

Incorporating these pedagogical approaches into EE promises to transform the learning experience, better preparing students for the challenges they will encounter in their engineering careers. Each approach offers unique benefits, and their strategic integration can create a holistic and dynamic educational environment that empowers students to excel and innovate in the field of engineering.

6.1.2 Engineering as a Holistic Educational Approach

In this subsection, we advocate for a transformative shift in the perception of EE. Engineering should not be viewed solely as a specialized field but as an ongoing, multidisciplinary educational journey that commences at an early age. This paradigm redefines engineering as a dynamic and integrated subject that progressively cultivates both mindset and skill set over time. Our recommendations within this context aim to address the challenges posed by prerequisite mismatches among students and enhance their foundational STEM abilities, with a particular focus on spatial thinking.

Early Introduction to Engineering Concepts

We strongly advocate for the early introduction of fundamental engineering prerequisite concepts and problem-solving skills in primary and secondary education. By weaving these principles into the broader curriculum, we nurture curiosity and critical thinking from a young age. This approach not only demystifies engineering but also instills an appreciation for its relevance in everyday life.

Building Blocks of Engineering Mindset

Central to our vision is the concept of "building step by step" the engineering mindset. We emphasize the importance of commencing with foundational knowledge and progressively advancing to more complex topics. This sequential approach to education ensures that each level of learning contributes organically to the development of engineering skills. It fosters a sense of continuity, wherein students perceive engineering as a continuous and accessible journey rather than an insurmountable specialization.

Interdisciplinary Collaboration

Recognizing the interconnectedness of knowledge, we underscore the paramount importance of fostering networks among educators and teachers across different educational years. This interdisciplinary collaboration serves as a cornerstone for enriching the educational experience by facilitating the exchange of insights, teaching methods, and resources. A notable example of this collaborative approach involves addressing the foundation of STEM education in primary schools.

Currently, primary school teachers often possess strong educational and pedagogical foundations but may have limited exposure to STEM education. To address this, we advocate for the integration of proper STEM education training during their university studies. This holistic approach ensures that future educators are equipped with not only pedagogical expertise but also a robust understanding of STEM principles. By bridging the gaps between different levels of education and nurturing a generation of educators with multidisciplinary competencies, we pave the way for students to tackle complex, interdisciplinary challenges with confidence and competence.

Reducing Prerequisite Mismatches

One of our primary goals is to address the prevalent issue of prerequisite mismatches among students. We advocate for the implementation of a structured educational framework that provides clarity and guidance. This framework should offer clear pathways, enabling students to progressively acquire the knowledge and skills necessary for success in STEM. By reducing gaps in their understanding and competence, we create a more inclusive and equitable educational environment.

Enhancing Spatial Abilities

Recognizing the critical role of spatial ability in engineering and STEM fields, we emphasize its significance. Our recommendations extend to specific educational interventions and activities designed to enhance students' spatial thinking abilities. By focusing on this foundational skill, we not only improve students' aptitude for engineering but also contribute to their overall cognitive development.

This holistic approach to EE reimagines the educational journey, emphasizing continuity, inclusivity, and collaboration. By implementing these recommendations, we aim to transform EE into a dynamic and accessible field that empowers students from diverse backgrounds to excel in the ever-evolving landscape of STEM disciplines.

6.1.3 Assessment and Evaluation

In this subsection, our focus is squarely on enhancing assessment methods to accurately gauge the effectiveness of teaching strategies and foster an enriched learning process for engineering students. We recognize that assessment is not merely a tool for measuring student performance but a means to guide and enhance their educational journey.

Simultaneously, we acknowledge the critical role of evaluation in the hands of educators. Effective teaching strategies and their impact on student learning must be rigorously assessed and improved upon. Lecturers play a pivotal role in course evaluation, where the ability to measure the impact of teaching strategies is fundamental.

Formative Assessment Tools

We advocate for the seamless integration of formative assessment tools throughout the learning process. These tools serve as dynamic checkpoints, enabling both educators and students to monitor progress continually. We emphasize the critical importance of continuous feedback mechanisms that empower students to track their learning journey actively. This feedback-driven approach allows students to adapt and refine their learning strategies, fostering a deeper understanding of engineering concepts.

We emphasize that assessment should serve a dual purpose – not only for student evaluation but also as a powerful tool for learning improvement. Faculty members should view assessment as an opportunity to provide constructive feedback that guides students in their learning journey. By focusing on learning improvement, we create a culture of continuous growth and development, where students are motivated to strive for excellence.

Authentic Assessment Practices

Authenticity lies at the heart of effective assessment practices. We promote the use of authentic assessments that mirror real-world engineering challenges. By encouraging faculty to design assessments that demand problem-solving, critical thinking, and the application of knowledge in practical scenarios, we ensure that assessment aligns with the complexities of the engineering profession. Authentic assessments not only evaluate students' competence but also prepare them for the challenges they will encounter in their careers.

Use of Technology in Course Evaluation

The role of technology in modern assessment methods cannot be understated. We highlight the transformative potential of technology in course evaluation practices. We suggest the incorporation of online assessment platforms, simulations, and digital tools. These technological advancements not only streamline the course evaluation process but also enable educators to create dynamic, engaging, and efficient evaluation methods. By embracing technology, we enhance the overall evaluation experience for both educators and students.

Evaluation for Improvement

We recognize that continuous improvement is integral not only for students but also for educators. In this context, we emphasize the importance of evaluation from the lecturer's perspective as a means to enhance their own teaching strategies and course design. Lecturers should view evaluation as a tool for their own growth and the refinement of their teaching practices.

This evaluation-for-improvement approach encourages lecturers to:

- Reflect on the effectiveness of their teaching methods.
- Solicit feedback from students to gain insights into the learning experience.
- Identify areas for enhancement in course design and delivery.
- Embrace professional development opportunities to stay current with innovative pedagogical approaches.

By adopting a proactive approach to self-evaluation, educators can continually enhance their teaching, creating a dynamic and effective learning environment for engineering students.

Through these recommendations, we envision an assessment and evaluation framework that not only measures student performance but also actively contributes to their growth and mastery of engineering concepts. Our approach fosters a learning environment where assessment and evaluation are catalysts for continuous improvement and excellence.

6.1.4 Faculty Development

In this subsection, we underscore the critical role of professional development for engineering educators. We emphasize that ongoing growth and expertise among educators are essential for delivering high-quality instruction. These recommendations aim to support faculty in implementing modern teaching techniques, staying updated with industry trends, and gaining insights from neuroeducation to enhance their teaching effectiveness.

Lifelong Learning for Educators

We advocate for the concept of lifelong learning for educators, starting from their university studies and continuing throughout their careers. The pursuit of knowledge should not be limited to formal education but should extend into professional practice. Lifelong learning enables educators to adapt to evolving pedagogical approaches, technologies, and educational theories. It emphasizes the value of continuous education and skill development, even when immediate career rewards may not be apparent.

Modern Teaching Techniques

To create engaging learning experiences, we recommend that faculty explore and incorporate modern teaching techniques into their pedagogy. The adoption of active learning strategies, flipped classrooms, and technology-enhanced instruction can invigorate the classroom environment. These techniques not only enhance student engagement but also foster deeper understanding and retention of engineering concepts.

Staying Informed About Industry Trends

Highlighting the importance of faculty members staying informed about industry trends, technological advancements, and emerging engineering practices is essential. To maintain relevancy in their teaching, educators should actively engage with industry partners, attend conferences, and participate in relevant professional associations. By fostering these connections, faculty can bring real-world relevance to their instruction and provide students with insights into the latest developments in engineering.

Neuroeducational Insight

Neuroeducational insights offer a valuable perspective on optimizing teaching methods. Faculty members are encouraged to explore research on cognitive neuroscience and its applications in education. Understanding the cognitive processes of learning and memory can inform instructional strategies that align with how students best acquire and retain knowledge. Providing resources and training opportunities for educators in this area can empower them to create more effective learning experiences.

Faculty Training Programs

To support faculty in their journey of continuous improvement, we advocate for the establishment of faculty training programs specifically designed to enhance teaching skills. Academic institutions should invest in faculty development initiatives that offer workshops, seminars, and peer mentoring opportunities focused on pedagogical advancements. These programs provide educators with the tools and knowledge needed to excel in the classroom.

Recognition of Teaching Excellence

We emphasize the need for academic institutions to recognize and reward teaching excellence. A culture within universities that values and acknowledges educators' efforts in enhancing the quality of EE is crucial. Creating teaching awards and honors can celebrate outstanding contributions to student learning and inspire educators to strive for teaching excellence. Recognizing and promoting effective teaching practices is essential to fostering a vibrant and innovative EE community.

6.2 Dissertation highlights

6.2.1 Research Objectives and Methodology

EE Research stands at the intersection of pedagogy and engineering, forging a dynamic space where theory and practice converge. It plays a pivotal role in nurturing individuals who can navigate the complexities of modern engineering while addressing ethical and societal aspects. This interdisciplinary field fosters awareness, ethical reasoning, and effective communication, recognizing engineers as societal stewards.

However, within the Italian educational landscape, there's a notable gap in dedicated EE research, particularly in the context of Politecnico di Torino (Polito), an esteemed Italian technical university. While STEM education is growing, EE often remains overlooked. This gap is underscored by Italy's rich engineering heritage, which further highlights the need for dedicated research in this area.

The role of an EER within Polito, and by extension, within an Italian technical university, is multifaceted and pivotal. EERs serve as catalysts for transformation, bridging the gap between theory and practice in EE. Their work positively impacts students' understanding of engineering concepts and lecturers' roles by providing evidence-based methods, enriching student experiences, and shaping capable engineering professionals equipped to tackle modern challenges.

The primary objectives of this study are twofold:

1. **Examine the Role**: Investigate and elucidate the multifaceted role of an EER within the context of PoliTo, shedding light on the diverse ways in which they contribute to the university's educational landscape.

2. **Demonstrate Impact**: Showcase and provide empirical evidence of the positive influence and contributions that an EER can make in enhancing students' understanding of engineering concepts and improving lecturers' teaching practices.

To achieve these objectives, a rigorous and systematic mixed-methods investigation is employed. The foundation of this research lies in the systematic collection of data from a diverse array of projects and initiatives carried out within the domain of EER at Polito. These initiatives represent the practical manifestations of EER, encompassing innovative teaching methods, the development of educational technology, and more.

Qualitative data analysis techniques, including thematic analysis and content analysis, are diligently applied to the collected data. This rigorous process involves a comprehensive examination of both quantitative and qualitative data from each subproject. The aim is to derive meaningful and contextually rich conclusions regarding the impact of EER activities.

Through this analysis, recurring patterns, emergent themes, and nuanced narratives from both students and lecturers are uncovered. This approach delves beyond surface-level observations, providing deep insights into the underlying factors, perspectives, and experiences that shape the influence of EER on education and pedagogy.

By adopting this mixed-methods approach, this research aims to provide a comprehensive understanding of the multifaceted influence of EER within Polito. It not only assesses the current landscape but also offers valuable insights into the potential for future enhancements in EE.

The research process adheres to rigorous standards of validity and reliability, ensuring that the findings accurately represent the impact of EER activities within Polito and the broader context of Italian technical universities.

6.2.2 Major Findings

Since the inception of this research journey in 2017 as an EER within Polito, a series of projects and course revisions have been undertaken. Over these years, active interactions with 47 lecturers spanning across 10 departments and various career stages have taken place. The study highlights the willingness and interest of lecturers to collaborate with an EER, recognizing the crucial role of an education expert in supporting their teaching efforts and fostering improvements.

This finding is particularly significant because it underscores a clear need for educational support and enhancement within the institution. However, despite this evident need, EER is not officially recognized as an established research field in Italy. Career progression in Italy relies on scientific sectors (SSD), and EE is absent from any SSD classification. Consequently, there is no formal acknowledgment or designation for EER within the Italian academic framework.

The major findings of this study can be categorized into three key perspectives:

- **Students' Perspective**: The study reveals several crucial insights from the students' viewpoint. Notably, it highlights the challenge of prerequisite mismatches, both in terms of knowledge, primarily in mathematical concepts, and skills, with a particular emphasis on spatial ability. Additionally, it underscores the necessity for a robust scientific study methodology in EE. Furthermore, addressing the gender gap in engineering is a pertinent issue. While role models play a significant role, the change starts with self-perception regarding engineering prerequisites.
- **Lecturers' Perspective**: The research confirms that, within the Italian academic context, education is often considered a mandatory but peripheral aspect of a lecturer's role, with minimal impact on their career progression. However, it also reveals that lecturers are generally willing to improve their teaching practices, especially when supported in reducing the effort required while increasing the impact of their courses. Therefore, key elements for lecturers include cross-fertilization among peers to avoid isolation in investing time and effort in teaching, both nationally and internationally, where EER is more integrated.
- **Technological Role**: The role of technology emerges as crucial in facilitating the educational journey for both students and lecturers. However, it's essential to ensure that technology is properly integrated into the learning process, and its impact is rigorously evaluated.

These findings represent a significant step in recognizing the value of EER within Polito and the broader Italian educational landscape. They shed light on the challenges and opportunities in EE, paving the way for future endeavors in enhancing the quality of education and teaching practices within technical universities.

6.2.3 Contributions to the Field and Relevance to Existing Literature

This section discusses the substantial contributions made by this research to the body of knowledge in EE, emphasizes the practical implications of its findings, contextualizes the dissertation within existing literature and research in the field, and identifies areas of alignment or divergence from previous studies.

The findings of this research significantly contribute to the field of EE. They shed light on the challenges faced by students and lecturers within the Italian technical university context. Importantly, the study highlights the critical role of EER in addressing these challenges and fostering improvements. The identification of prerequisite mismatches, both in knowledge and skills, as well as the emphasis on the importance of a robust scientific study methodology, adds depth to the existing body of knowledge in EE. Furthermore, the research underscores the need for addressing the gender gap in engineering through self-perception and role modeling, which can be applied not only in Italy but also in international contexts.

The practical implications of this research are manifold. For educators, the findings underscore the value of collaborating with an EER to enhance teaching practices and reduce the effort required. The recognition of lecturers' willingness to improve their teaching, particularly when supported, holds significant implications for institutions aiming to enhance the quality of education. Policymakers can draw from this research to inform decisions regarding support for EE research and the recognition of EER as a vital field within the Italian academic framework. The emphasis on technology as a facilitator in education calls for institutions and educators to invest in the effective integration and evaluation of technological tools.

This research aligns with previous studies in the field, such as the work of Valentine and Williams [321], which highlighted the publishing patterns of engineering academics and the impact on their h-index values. Similarly, this dissertation emphasizes the value of EER in guiding individual engineering educators in planning their research careers, particularly highlighting that lecturers who actively worked with EER (See Table 5.1) were often in the later stages of their careers, and their initial educational publications were relatively late compared to counterparts in other countries. These parallels emphasize the broader applicability of the findings.

While this research aligns with the recognition of the value of EER in EE, it also diverges in terms of the specific challenges and contexts identified within the Italian technical university landscape. The focus on prerequisite mismatches, gender gap, and the unique institutional context of Italy provides a distinctive perspective that complements existing literature. Additionally, the emphasis on collaborative efforts among lecturers nationally and internationally aligns with the global trend of EER collaboration while offering insights specific to Italy.

In summary, this research enriches the field of EE by contributing new knowledge, offering practical guidance for stakeholders, and aligning with broader trends in EER. It serves as a valuable resource for educators, institutions, and policymakers seeking to enhance EE and supports the recognition of EER as an essential component of educational excellence.

6.3 Limits

In this section, we acknowledge and discuss the limitations encountered during the course of this research. It is crucial to recognize these limitations to provide a balanced and transparent view of the study's scope and constraints.

Sample Size and Contextual Specificity One significant limitation of this research is the sample size. While interactions with 47 lecturers from 10 departments provide valuable insights, the sample might not fully represent the diversity of all engineering disciplines. Additionally, the findings are specific to the context of Polito and may not be directly transferable to other technical universities or international settings.

Furthermore, it's important to note that this dissertation primarily considers projects in which the EER was directly involved. Other projects related to EE, which were autonomously implemented by faculty members, are not comprehensively examined. For instance, projects like AutoCircuit by Professor Grivet, as mentioned in the discussion, fall outside the scope of this research.

Additionally, while this dissertation addresses several aspects of EE research, it does not cover all relevant fields comprehensively. Some areas, such as ethics in EE or professional practice and lifelong learning, were not directly explored, indicating potential gaps in the research scope.

Gender Gap Perspective The examination of the gender gap in engineering is an important aspect of this study. However, the research does not delve deeply into the experiences of underrepresented genders in the field. Future research could explore this aspect more comprehensively, considering the unique challenges and perspectives of women and other underrepresented groups in engineering.

Time Frame The research covers the period since 2017, providing insights into the recent development of EE Research within Polito. However, a more extended time frame could reveal longer-term trends and evolution, offering a deeper historical context for the changes observed.

Interactions with EER While the research explores interactions with lecturers who actively worked with an EER, it does not encompass the perspectives of those who did not engage with EER initiatives. Understanding the reasons behind non-engagement could provide additional insights, shedding light on potential barriers or misconceptions regarding the role of EER in teaching.

Generalizability The findings of this study are valuable within the context of Italian technical universities, but their generalizability to other educational systems may be limited. The specific characteristics of the Italian higher education system and its challenges may not align with those of other countries. Future research could explore how EER findings and recommendations apply in diverse international settings.

Technology Integration Evaluation The research highlights the importance of technology in education but does not extensively evaluate the effectiveness of specific technological tools or interventions. Further studies could delve deeper into the impact of technology on student learning outcomes, considering factors like the accessibility and usability of technology in different educational contexts.

Cross-disciplinary Variations While the study encompasses interactions with lecturers from various engineering disciplines, it does not explore potential variations in educational challenges or opportunities across different fields within engineering. Future research could investigate whether certain engineering disciplines require specialized pedagogical approaches.

Researcher Bias Despite efforts to maintain objectivity, the researcher's perspective and involvement as an EER within Polito may introduce a degree of bias in the interpretation of findings. Future research could involve multiple researchers to provide a more balanced perspective and reduce potential bias in data interpretation.

Acknowledging these limitations ensures a transparent presentation of the research's scope and constraints while providing opportunities for future studies to address these areas in more depth.

6.4 Further directions

This research journey has illuminated the path forward for EER within Polito and the broader landscape of EE. While this study has made significant strides in bridging the gap between education and engineering, there are numerous avenues for further exploration and development. The following directions represent critical areas for growth and expansion in the field of EER:

Teach2TEACH Training Course Drawing from the insights gained during this study, the development of the Teach2TEACH training course is underway. This course is designed to empower educators, ranging from master's students to seasoned professors, with the necessary skills and knowledge to excel in the realm of EE. It will serve as a comprehensive resource, fostering a community of educators committed to advancing pedagogical excellence.

Impact Evaluation Support To ensure that the innovations in EE have a meaningful impact, the establishment of a support system for impact evaluation within engineering courses is paramount. This initiative will provide the framework and tools necessary for instructors to assess the effectiveness of their teaching methods and interventions, ultimately enhancing student learning outcomes.

Policy Advocacy Recognizing the significance of EER within the Italian educational system, there is a pressing need for policy advocacy. This involves lobbying for the formal recognition of EE Research as a distinct field, with established scientific sectors (SSD). By securing its place within the system, we can institutionalize EER and facilitate its growth and integration into EE.

Developing Indicators for a Holistic Approach in EE In line with the commitment to holistic education, there is a distinct need to develop comprehensive indicators for assessing the effectiveness of holistic approaches in EE. These indicators will be designed to capture the multidimensional impact of holistic educational strategies, including their influence on students' mindset, skill set, and ethical awareness. By establishing clear metrics and assessment criteria, this initiative aims to provide educators and institutions with a systematic framework for evaluating the success and continuous improvement of holistic pedagogical practices in EE.

International Collaboration Collaboration knows no boundaries, and the field of EER can benefit immensely from international partnerships. Expanding our collaboration efforts with institutions and researchers worldwide can enrich our knowledge base and provide fresh perspectives on EE. The existing research group "TEACH - Teaching Engineering Avant-garde Challenge Host," established in 2018, can serve as a valuable platform for fostering international collaborations.

Collaboration with Other Institutions While Polito has been a focal point of this research, collaboration with other technical universities and educational institutions in Italy can further amplify the impact of EER. Sharing best practices, resources, and research findings can lead to collective advancements in EE.

Longitudinal Studies The insights gained through this research span several years, but the potential for longitudinal studies is substantial. Tracking the long-term effects of pedagogical changes and EER initiatives can provide a deeper understanding of their lasting impact on both educators and students.

Mentoring Programs Establishing mentoring programs within PoliTo can foster knowledge transfer and support newcomers to the field of EE. Pairing experienced educators with novices can accelerate the adoption of best practices and enhance teaching effectiveness.

Student Involvement Engaging students actively in EER initiatives is a valuable direction for the future. Incorporating their perspectives, involving them in research projects, and seeking their feedback on educational interventions can provide valuable insights and ensure that educational improvements align with student needs and aspirations.

Ethical and Societal Aspects Expanding research efforts into areas such as ethics and societal aspects of EE is crucial. Investigating how EER can contribute to the development of ethical engineers who are socially responsible and aware of the broader implications of their work aligns with the evolving demands of the engineering profession.

As we embark on these further directions, the goal remains clear: to continue the transformative journey of EE, shaping it into a dynamic and responsive field that equips future engineers with the skills, knowledge, and ethical awareness needed to navigate the complexities of our ever-evolving world.

In conclusion, "Be an Engineer? I'm game! Empower Education to foster engineering" is more than a title; it encapsulates a transformative journey. This dissertation has illuminated the path to empower education as the cornerstone of engineering excellence. It has revealed the critical role of Engineering Education Research in bridging the gap between theory and practice, educator and student, and academia and industry. The findings presented here demonstrate that EE is not merely a specialization but a dynamic and integrated educational journey. By nurturing curiosity, critical thinking, and ethical awareness, we forge a generation of engineers who are not just game players but game changers, ready to tackle complex challenges and shape a brighter future. As we embark on the path ahead, armed with evidence-based insights and a commitment to excellence, we strive to empower education, foster engineering, and create a world where the answer to the question, "Be an Engineer?" is met with resounding enthusiasm— "I'm game!"

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