Be an Engineer? I'm game!
Empower education to foster engineering
Long Abstract

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Video abstract https://youtu.be/NtbCDTObYm4?si=ILzrNltArGhRhN76

The landscape of Engineering Education (EE) research is undergoing a profound transformation to meet the evolving demands of the 21st century. This dissertation meticulously explores the intricate interplay between pedagogy and engineering within Politecnico di Torino, a renowned Italian technical university. Its primary objective is to elucidate the pivotal role played by an Engineering Education Researcher (EER) and its consequential impact on both students' understanding and lecturers' roles.

1. Main Research Question and Objectives

The central inquiry guiding this research revolves around the role of an EER within an Italian technical university like Politecnico di Torino and its influence on students' understanding and lecturers' roles. This overarching question is pursued through two primary objectives.

1. The research comprehensively explores the multifaceted role of an EER within the unique academic context of Politecnico di Torino, delving into the various dimensions and responsibilities defining the EER's role in this esteemed institution.
2. The study aims to provide a compelling narrative of the tangible benefits that an EER brings to the educational ecosystem at Politecnico di Torino. It illustrates how EER work enhances students' comprehension of engineering concepts and refines lecturers' teaching practices.

Beyond the institutional confines of Politecnico di Torino, this research holds profound implications for the broader field of EE and the educational landscape in Italy. It contributes to the continuous improvement of EE by adapting existing literature to the specific Italian context. Moreover, it underscores the vital role that research plays in shaping pedagogical practices, supporting lecturers in ongoing professional development, and fostering a culture of continuous improvement in teaching.

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 Methodology adopted for each project

2. Methodology

This research employs a comprehensive methodology to systematically collect and analyze data from diverse Electrical Engineering (EE) research projects at Politecnico di Torino. The mixed investigation approach incorporates both quantitative and qualitative data, ensuring a holistic representation of EE research activities. The foundation lies in the systematic collection of data from various projects, covering a wide spectrum of activities within EE. Qualitative data analysis techniques, including thematic and content analysis, are central to deriving contextually rich conclusions about the impact of EE research. The analysis delves into underlying factors and experiences, providing a nuanced understanding of EE research initiatives. The methodology not only assesses the current EE research landscape but also offers insights for future enhancements. Additionally, individual projects follow tailored methodologies, such as Randomized Control Trial (RCT) for some and semi-epistemological interviews for others, enhancing the research's depth (see Table 1). The implementation involves a carefully planned timeline, graphically represented in Figure 1, illustrating the parallel development and interconnected nature of various projects run by the Engineering Education Research (EER) group at Politecnico di Torino. This approach provides a roadmap for readers to understand the temporal evolution of each subproject and its discussion in specific subsections of the dissertation.

3. Nurturing STEM Pathways: Fostering Learning and Diversity

3.1. Preparatory Study in Short

The preparatory study for EE emerges as a crucial phase in shaping the competencies and capabilities of potential engineering students. It involves a comprehensive evaluation process
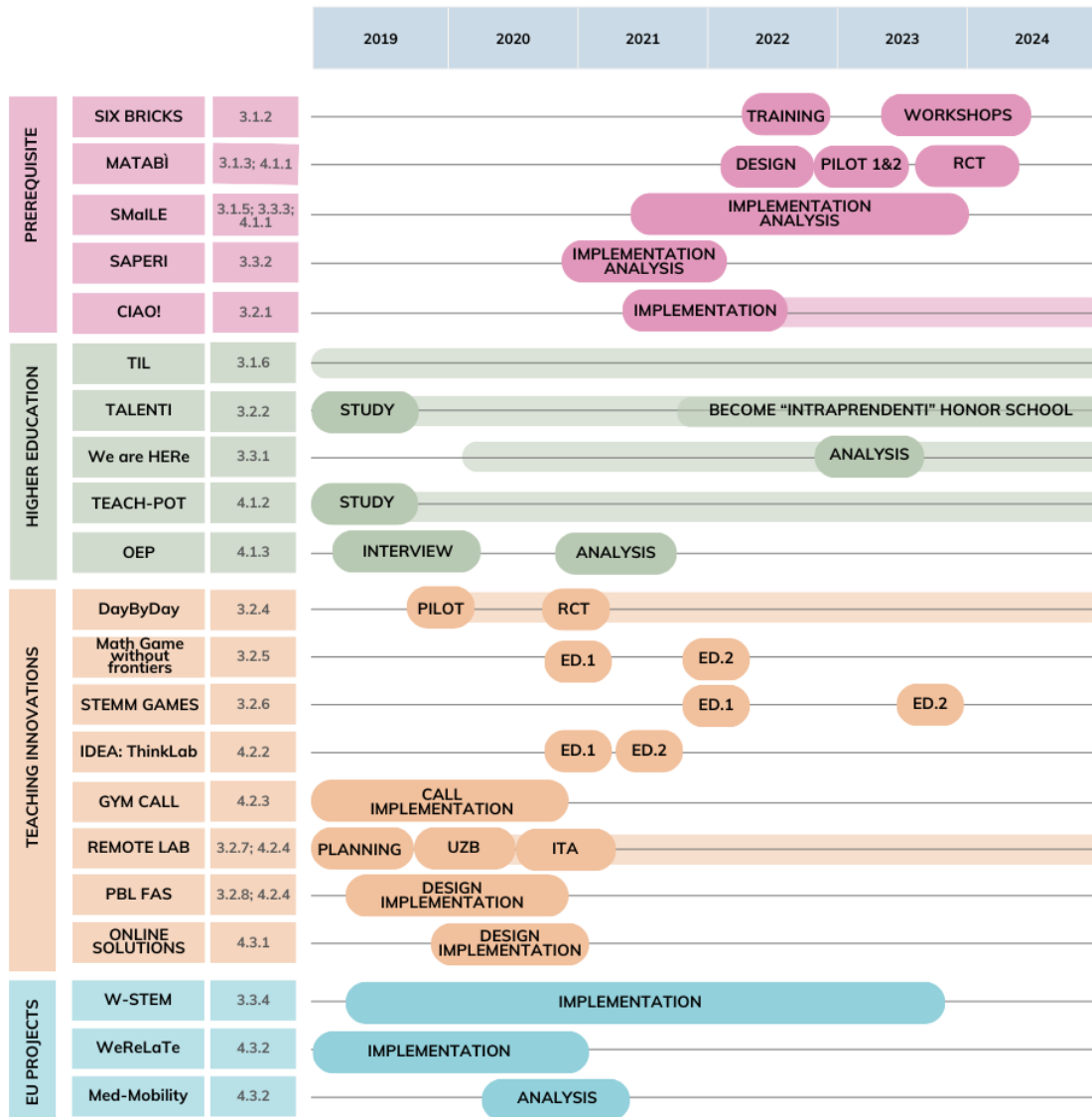
Fig. 1 Projects' timeline

considering both formal and informal learning modalities to identify and prepare students adequately for the challenges of an engineering curriculum.

Addressing spatial ability, a critical component in engineering disciplines, the study integrates innovative training methods to enhance students' spatial reasoning abilities, ensuring their preparedness for the spatial demands inherent in engineering tasks.

Acknowledging knowledge mistakes among incoming students, the study conducts an in-depth analysis of common misconceptions and knowledge gaps, informing the development of targeted interventions. This proactive approach ensures that students enter the engineering curriculum with a solid foundation, mitigating potential challenges in their academic journey.

The integration of assessment tools like the Test in Laib (TIL) serves as a testament to the commitment of educational institutions to enhancing the quality and attractiveness of incoming engineering students. Such tools effectively predict subsequent academic performance, aiding in selecting students likely to excel in their university journey.

Selective measures, including numerus clausus and rigorous evaluation processes like the TIL, contribute to the overall advancement and reputation of engineering education while addressing industry demands for highly skilled and employable graduates. This comprehensive approach to preparatory study ensures that students possess not only the requisite academic background but also the spatial abilities crucial for success in engineering disciplines.

3.2. Higher Education in Short

The transformative journey towards innovative engineering education at Politecnico di Torino is characterized by initiatives optimizing the study experience for students. The "CIAO! (Corso Interattivo di Accompagnamento Online)" addresses mathematical skills mismatch, "Progetto Talenti" supports talented students through reverse inclusion, and the "DayByDay project" empowers students with self-directed learning opportunities.

Game-based learning initiatives like "Math game without frontiers" and "STEMM game" harness the power of play to enhance technical and soft skills. Additionally, the "REAL (Remote Experimentation for Automation Learning)" project offers a shared remote laboratory, fostering accessibility and flexibility.

The integration of Problem-Based Learning (PBL) principles into an architecture course exemplifies the commitment to active learning and real-world application, bridging the gap between architecture and engineering education.

3.3. Gender Perspective in Engineering in Short

The third macro theme delves into key projects addressing the gender gap within STEM fields. Initiatives like the "We Are HERe" project focus on targeted recruitment and retention strategies, while the SAperI project aims to enhance women's spatial abilities through innovative training methods.

Exploring the relationship between gender, self-efficacy, and academic performance reveals gender-specific patterns, emphasizing the need for targeted interventions to boost female students' self-confidence.

Projects such as ATTRACT, INGDIVS, and the Anna tool showcase a global paradigm for matching profiles, contributing to gender equality in engineering education and encouraging exploration and decision-making.

4. Enhancing Engineering Education from the Lecturer's Perspective

4.1. 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 empowers university lecturers with methodological training, the integration of teaching technologies, and incorporating methodological experiences.

POT immerses educators in diverse teaching methodologies, enabling them to harmonize instructional goals with students' learning needs. The Teach2Teach program exemplifies a comprehensive training initiative, offering workshops that enhance pedagogical techniques and technology integration.

Open Educational Practices (OEP) have emerged as a transformative force, leveraging open principles and digital technologies to enhance education's creation, sharing, and use. A study at Politecnico di Torino explores educators' fluency in working with open approaches across dimensions like design, content, pedagogy, and assessment.

4.2. 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. Initiatives like the ThinkLab: IDEA Workshop, the TEACH-GYM framework, and the integration of Problem-Based Learning (PBL) principles into the Structural Analysis course exemplify this paradigm shift.

The initiatives collectively represent a shift in engineering education, an era defined by collaboration, technology integration, and student-centered approaches. Through the convergence of pedagogy and innovation, engineering education paves the way for a future of continuous growth and excellence.

4.3. Global Perspective in Engineering Education in Short

This dissertation delves into the global perspective in engineering education, emphasizing adaptability and collaboration. Examining responses to educational challenges during the COVID-19 pandemic, the TEACH-GYM initiative showcases the transformative potential of multidisciplinary integration, ensuring continuity and inclusivity in education. The collaboration between Politecnico di Torino and the Turin Polytechnic University in Tashkent highlights the importance of proactive digital engagement and pedagogical adaptability.

International mobility, training, and networking emerge as pivotal elements. Initiatives like Erasmus and the Cost Action framework embody the EU's commitment to global collaboration. TTPU's participation in projects like TEACH-GYM and WeReLaTe exemplifies

cross-disciplinary collaboration's transformative power. The W-STEM project addresses gender disparities, adding a crucial dimension. Additionally, the study by UNIMED and UfM explores internationalization dynamics within the Euro-Mediterranean region.

In essence, this dissertation provides a concise exploration of global perspectives in engineering education, emphasizing adaptability, collaboration, and transformative initiatives that shape an inclusive and interconnected future.

5. Discussion

The discussion section critically engages with key themes, unveiling insights to foster engineering excellence and empower educators. It explores the pivotal role of spatial ability in engineering education, advocating for its incorporation into curricula to enhance students' problem-solving skills. Addressing gaps in prerequisite knowledge emerges as a crucial aspect, emphasizing the need for tailored preparatory study methods. The scientific study method in engineering studies is dissected, highlighting its significance in shaping effective learning experiences. In the realm of empowering educators, the discussion delves into the duality of teaching and research, showcasing the interconnected nature of these roles. It further examines diverse course approaches and methodologies, emphasizing the transformative potential of problem-based learning and real-world applications. Impact evaluation becomes a focal point, navigating the complex terrain of teaching research, emphasizing its role in continuous improvement. Global perspectives in engineering education are explored, underlining the importance of cross-cultural collaboration and innovative initiatives. Lastly, the transformative role of technology takes center stage, evaluating its impact, supporting teaching, and acknowledging the strategic role of technology developers in shaping the future of engineering education.

6. Conclusion

This dissertation delves into EE research at Politecnico di Torino, uncovering key insights and proposing practical initiatives for advancing engineering education.

6.1. Insights

The study highlights:

- Engineering as a holistic journey: addressing prerequisite challenges and fostering interdisciplinary collaboration.

- Effective pedagogical approaches: active learning, project-based learning, gamification, and technology integration.

- Transformative assessment and evaluation practices.

- Dynamic faculty development recommendations.

Methodologically, the mixed-methods approach successfully achieved research objectives, providing nuanced insights into lecturer collaboration, prerequisite challenges, and the impact of EER.

6.2. Practical Contributions

The dissertation lays the groundwork for tangible interventions:

- Policy advocacy for formal EER recognition.

- Development of the Teach2TEACH training course.

- Prerequisite study for development of an impact evaluation support system.

Crucially, the study calls for national and international collaboration, cultural shifts in recognizing teaching excellence, student involvement in EER, and expanded research into ethical and societal aspects.

6.3. Limitations

Transparently acknowledging limitations, including sample size constraints and contextual specificity, sets the stage for future research improvements.

6.4. Future Directions

Crucial directions for further exploration and development include:

- Implementing the Teach2TEACH training course.

- Establishing an impact evaluation support system.

- Advocating for formal EER recognition.

- Developing Indicators for a Holistic Approach in EE.

- Expanding collaboration nationally and internationally.

- Longitudinal studies for tracking long-term effects.

- Creating mentoring programs within Politecnico di Torino.

- Actively involving students in EER initiatives.

- Expanding research into ethical and societal aspects.

In summary, this dissertation offers evidence-based insights and practical recommendations 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!"