

BALANCING TEACHING AND RESEARCH: INTEGRATION OF SCIENTIFIC PROJECT OUTCOMES INTO UNIVERSITY CURRICULA

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Abstract

Balancing teaching and research is a growing challenge in engineering education, particularly in the context of rapid technological development and the increasing importance of applied skills. This paper examines how research activities conducted by university teachers can be effectively integrated into undergraduate teaching without compromising curriculum structure. The study adopts a qualitative approach based on the analysis of teaching practices, student outputs, and informal feedback within electrical engineering programs. The findings indicate that the most effective forms of student engagement are those embedded within existing course structures, particularly seminar assignments, final-year projects, and field-based learning activities. These approaches enable students to work on real-world problems while developing practical and interdisciplinary competencies. The results also highlight mutual benefits: students gain improved employability and exposure to modern technologies, while teachers enhance the relevance of their teaching and extend student work into research outputs. The insights obtained in this study provide a basis for the systematic integration of research and teaching in future curricula and will be further applied within the ongoing ELENDRON project, which focuses on AI-supported monitoring of power infrastructure.

Keywords: Pedagogical innovation, AI in education, student competencies, sustainable technology, Industry 4.0.

1. Introduction

The role of university teachers has significantly evolved in recent years, extending beyond traditional teaching responsibilities to include active participation in scientific research and continuous adaptation to rapid technological advancements. In engineering education in particular, this dual role creates both challenges and opportunities, especially in the context of integrating emerging technologies such as artificial intelligence (AI) into the learning process.

One of the key challenges is how to effectively connect research activities with teaching practice in a way that enhances student learning without compromising curriculum structure or educational quality. While research-based and project-based learning approaches are widely recognized, their practical implementation often depends on individual initiatives and is not always systematically embedded in study programs.

Recent developments associated with Education 4.0 and Industry 4.0 have emphasized the need for higher education institutions to redesign learning environments and develop both technical and transversal competencies, including critical thinking, adaptability, collaboration, and data-driven decision-making. Emerging technologies such as AI, IoT, simulation platforms, and adaptive learning systems are increasingly recognized as important enablers of personalized and practice-oriented learning experiences in engineering education. [Pinto et al., 2024; Khupe et al., 2026; Azofeifa et al., 2024]

However, several studies indicate that the pedagogical integration of these technologies remains fragmented and often limited to supportive or instrumental applications rather than being systematically embedded into teaching and learning processes. Similar observations have been reported in both engineering and translation education, where digital tools are frequently used as auxiliary resources instead of being integrated into authentic learning activities and professional problem-solving contexts. [Fernández Cerero et al., 2026; García-Santiago & Díaz-Millón, 2024] Although previous studies show that AI-supported and simulation-based learning approaches can improve practical skills, systems thinking, and Industry 4.0 competencies, there is still limited evidence regarding sustainable models that effectively

connect technological innovation, research activities, and measurable educational outcomes within university teaching practice. [Pacheco-Velazquez et al., 2024; Gabrovšek & Rihtaršič, 2025]

In practice, students are often exposed to theoretical concepts with limited connection to real-world applications, while research activities remain insufficiently integrated into teaching. This gap highlights the need for structured approaches that enable meaningful student participation in ongoing research, particularly in technical fields where hands-on experience and interdisciplinary skills are essential.

The aim of this paper is to identify effective models of student involvement in research-oriented activities and to evaluate their benefits for both students and teachers. In particular, the paper seeks to answer the following research questions:

- RQ1: What are the most effective ways of involving students in research projects conducted by university teachers?
- RQ2: What are the key benefits of such involvement for students and for teachers?

The remainder of the paper is structured as follows. Following this introductory and theoretical background section, the next sections present the methodology and an analysis of current teaching practices. The results are then discussed with a particular focus on transferable insights and future implementation within new curricula, followed by concluding remarks.

2. Methodology

This study adopts a qualitative research approach based on the analysis of existing teaching practices and experiences in integrating research activities into undergraduate electrical engineering education. It does not rely on large-scale quantitative data or formal surveys; instead, it focuses on an in-depth analysis of practical experiences within a specific educational context. While this limits the generalizability of the findings, it allows for the identification of context-sensitive practices and the formulation of transferable recommendations.

The analysis draws on multiple sources: (i) teaching experience across several courses, (ii) student outputs, including bachelor theses and term papers, and (iii) informal student feedback, particularly following field-based activities.

Based on the experiences analyzed, a framework is proposed for a more systematic integration of research activities into future curricula, including planned implementation within an ongoing research project (ELENDRON). This advanced component is intended to bridge existing practices with structured, scalable models of inquiry-based teaching.

3. Analysis of current practices in research - teaching integration

This section presents an analysis of current practices in integrating research activities into teaching, focusing on forms of student engagement and their outcomes.

3.1. Teaching context and forms of student engagement

The integration of research activities into teaching is analyzed in the context of the undergraduate professional study of electrical engineering at the University North (Varaždin, Croatia). Student engagement is carried out through several complementary forms. The most common approach involves seminar assignments within elective courses, where students investigate specific technical problems related to current research topics. In addition, students are encouraged to produce final-year undergraduate theses aligned with real-world applications and new technologies.

Final year students attend several courses taught by authors, including Electronic Circuits, Digital Electronics, Automation of Machines and Devices, PLC Control Systems, and Electromotive Drives. Of particular importance is the elective course Power Electronics Devices, which focuses on the application of power electronics in systems based on renewable energy sources (RES). This course is chosen by the majority of students and currently serves as the primary entry point for integrating research-related topics into teaching. The elective format allows greater flexibility in adapting content to student interests and research-related activities.

Another key element of this approach is the possibility of organizing field learning activities, such as visits to industrial plants and renewable energy plants. These visits provide students with direct insight into real operating systems, including critical monitoring and maintenance points. In particular, the demonstration of real-time monitoring and remote control via mobile devices introduces students to the concepts of digital management and the role of data-driven decision-making, which aligns with modern AI-based approaches to energy system management. Such experiences bridge the gap between theoretical knowledge and practical application, while at the same time serving as a strong motivational factor for further student engagement.

Figure 1. Student visit to photovoltaic power plants. Left: photovoltaic panels mounted on a solar tracking system that follows the sun to increase energy production. Right: students and the teacher observing real-time monitoring and control of the power plant via a mobile interface, demonstrating remote management and data-driven operation.



After these field visits, a noticeable increase in student interest in renewable energy topics, especially related to solar energy systems, was observed. This often results in the selection of related topics for seminar papers and final undergraduate theses.

3.2. Student outputs and measurable outcomes

The effectiveness of the described approach is reflected in the analysis of student results and subsequent research activities. A significant number of final theses were developed based on practical experiences gained through field visits and laboratory work. An analysis of 218 defended theses over the past ten years shows that 28 were related to renewable energy, including 18 specifically focused on solar systems.

One example is a student project focused on developing a functional model of a photovoltaic system with a solar energy tracking mechanism (Solar Power Plant with Solar Tracker), directly inspired by a field visit to a solar power plant [Juričan, 2018]. In another case, the installation of a small off-grid photovoltaic system at a university enabled two students to conduct equipment testing, resulting in two separate final year theses [Kornet, 2017; Pozder, 2018]. These works were later partly used as a basis for further research, leading to several conference publications co-authored by faculty members [Havaš et al., 2023; Horvat et al., 2023; Srpak et al., 2017].

Furthermore, in several cases, high-quality student works related to solar energy systems, including grid impact analyses at the connection point [Pajan, 2015] and practical applications of photovoltaic systems in real buildings [Stijačić, 2014], were extended by collaboration with faculty members, resulting in co-authored scientific publications [Srpak et al., 2014; Srpak & Pajan, 2016]. This shows that student engagement in research-oriented activities can contribute not only to their learning outcomes, but also to the research productivity of academic staff.

4. Discussion

The analysis confirms that research-based and project-based learning can be effectively integrated into undergraduate engineering education through flexible mechanisms. Activities such as fieldwork and project assignments act as strong motivational drivers, particularly in technical disciplines. In response to RQ1, the most effective forms of engagement are those embedded in existing course structures, especially term papers and final theses aligned with ongoing research.

In relation to RQ2, the results highlight clear benefits for both students and faculty. Students acquire practical and interdisciplinary competencies, including exposure to modern technologies, real-world system operation, and data-driven decision-making. This improves labor market readiness and aligns student competencies with Industry 4.0 requirements. At the same time, teachers benefit from the increased relevance of teaching and the potential to extend student work to research outputs, including co-authored publications.

However, the findings also point to several challenges. Student engagement in research activities is often informal and dependent on individual motivation and prior knowledge. In addition, the lack of systematic monitoring of learning outcomes makes it difficult to quantitatively assess the impact of these approaches. This suggests the need for more structured frameworks that would enable consistent implementation and evaluation.

Based on the practices observed, several recommendations can be identified. These include aligning student assignments with real-world research problems, introducing fieldwork as a standard component of courses where possible, and allowing flexibility in curriculum design to accommodate new technologies. Furthermore, the selection of students for more advanced engagement should take into account prior competencies, particularly in areas such as data analysis and the application of artificial intelligence.

These insights provide the basis for the future development of a more systematic model for integrating research and teaching. This model will be implemented and further evaluated within the ongoing ELENDRON project, which focuses on the application of artificial intelligence and unmanned aerial vehicles (UAVs) for monitoring and maintaining Croatia's electrical infrastructure. As the project is currently in its early implementation phase, it provides an opportunity to further evaluate and extend the approaches presented in this study.

5. Conclusion

This paper examined the integration of research activities into undergraduate electrical engineering education, focusing on practical teaching approaches and student engagement in real-world contexts.

The findings show that effective student involvement can be achieved through existing course structures, particularly via seminar assignments, final-year projects, and field-based learning. These approaches support the development of practical and interdisciplinary competencies while simultaneously increasing student motivation and participation in applied learning activities. At the same time, they create opportunities for extending student work into research outputs, contributing to academic productivity.

Although based on a qualitative and context-specific analysis, the results highlight a practical and transferable approach to research-teaching integration that does not require major curricular changes.

Future work will focus on developing a structured framework for monitoring learning outcomes and evaluating the long-term impact of this approach, particularly within ongoing research projects.

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