Enhancing Engineering Education through Laboratory Test Benches: A Pedagogical Framework for Global Knowledge Exchange

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ABSTRACT

Advances in renewable energy integration, smart grids, and power electronics have led to the development of sophisticated laboratory platforms, including grid emulators, microgrid test benches and digital twin models. Originally conceived for research purposes, these platforms also offer powerful tools for engineering education. This paper explores how research-grade test benches developed in our laboratory can be systematically integrated into engineering curricula to bridge the gap between theory, simulation, and experimental practice. By mapping each platform to specific curricular modules, such as power systems, renewable energy integration, control engineering, and optimization, we demonstrate their capacity to foster experiential learning and strengthen competencies in modeling, system analysis, and real-time implementation. Case examples illustrate how students can engage in project-based learning by designing controllers, analyzing grid fault responses, or optimizing microgrid performance using digital twin frameworks. Beyond enhancing local curricula, these platforms enable global knowledge exchange through open-source models, remote laboratory access, and international collaborative initiatives. This work contributes to educational research by showing how cutting-edge laboratory infrastructures can enrich pedagogy, cultivate practical engineering skills, and promote collaborative learning across borders.

Keywords: Smart Grid Education, Laboratory-Based Learning, Renewable Energy Laboratory, Engineering Education, International Collaborative Learning

INTRODUCTION

The transition towards sustainable energy systems is reshaping both the research and educational landscape. Universities and engineering schools are increasingly expected to prepare students with not only theoretical knowledge but also practical competencies in renewable energy integration, microgrid operation, and digital energy management [1]2]. Traditional lecture-based approaches, while foundational, often fail to capture the interdisciplinary and system-level challenges of modern power systems. As a result, experiential and project-based learning has gained prominence, in line with broader STEM education trends emphasizing active learning, competency-based training, and industry-aligned curricula [3][4]. Within engineering education research, frameworks such as CDIO (Conceive–Design–Implement–Operate) and experiential learning theory have highlighted the importance of authentic, hands-on activities that foster not only technical proficiency but also problem-solving, teamwork, and innovation [5].

To support this paradigm shift, many research institutions have developed advanced experimental platforms. Examples include grid emulators, which replicate real grid conditions for testing distributed generation;

microgrid platforms, enabling studies on hybrid renewable energy systems; impedance emulators, allowing hardware-in-the-loop testing of dynamic power interactions; and digital twin models, which bridge physical infrastructures with real-time virtual representations. These infrastructures have proven their value in high-level research, particularly for investigating control strategies, validating models, and testing innovative solutions under realistic conditions [6] [7] [8]. At the same time, initiatives such as remote laboratories and open-source platforms have demonstrated that advanced infrastructures can be shared globally, enabling students across institutions and countries to access scarce resources, collaborate on joint projects, and participate in cross-border engineering challenges [9].

However, the integration of such infrastructures into teaching and training activities remains limited. In many cases, the facilities are primarily designed for research objectives, making them complex, costly, and inaccessible for routine student use. Moreover, while simulation tools are widely available in curricula, they often lack the realism and constraints that experimental platforms provide. Consequently, there exists a gap between research-grade infrastructures and their adaptation for pedagogy, which limits opportunities for students to engage with authentic, hands-on experiences that mirror real-world challenges.

This paper addresses this gap by examining how advanced laboratory infrastructures can be repurposed and adapted for educational contexts [10][11]. Specifically, it focuses on the pedagogical potential of grid and impedance emulators, microgrid platforms, and digital twin environments. The aim is twofold: first, to demonstrate how these platforms can enhance student learning by bridging theory and practice through experiential activities; and second, to highlight their role in fostering global collaboration via open-source resources, remote access, and international knowledge exchange. By aligning research infrastructures with educational goals, this work seeks to contribute to the development of a new generation of engineers who are both technically proficient and globally connected. This paper therefore investigates the potential of leveraging research test benches and laboratory platforms for engineering education. Specifically, it examines how these infrastructures can be adapted for teaching, the pedagogical benefits they provide, and their role in promoting global knowledge exchange.

The paper is organized as follows. Section 2 presents the developed laboratory platforms, including the grid emulator, microgrid platform, and digital twin environment. Section 3 discusses their pedagogical integration, teaching methodologies, and example assignments. Section 4 highlights educational outcomes and assessment strategies, while Section 5 addresses global knowledge exchange through remote access and international collaboration

OVERVIEW OF DEVELOPED TEST BENCHES AND PLATFORMS

In our laboratory, several experimental test benches have been designed and implemented to support both advanced research and student training in power and energy engineering. These platforms combine hardware, real-time control, and digital monitoring, providing an environment where theoretical concepts can be directly linked to practical applications. Their modular architecture makes them adaptable for diverse teaching activities, from basic demonstrations to advanced project-based learning. In this section, we will present three illustrative examples. It is worth noting, however, that our laboratory has also investigated other platforms, such as a DFIG-based test bench [12] [13] and an electric vehicle power system using an OPAL-RT real-time simulator [14] [15] [16] [17].

1. Grid Emulator

The grid emulator reproduces different voltage, frequency, and fault conditions of real distribution networks. It enables students to study grid-connected renewable energy systems, analyze voltage stability, and evaluate the impact of disturbances. By exposing learners to realistic scenarios, the emulator bridges the gap between classroom simulations and real-world grid dynamics.

The experimental setup presented in Figure 1 is composed of a power stage and a control stage. The power stage consists of a 4 kVA isolation transformer, a 4 kVA autotransformer for reduced-voltage testing, an L filter (20 mH, 3 Ω), two Semikron Semi-Teach converters (AC/DC and DC/AC), an LCL low-pass filter, and a

4 kW variable resistive load adjustable in 5% increments. The LCL filter includes converter-side inductors (4 mH, 20 A), grid-side inductors (2 mH, 20 A), and capacitors (30 μF, 400 V). The control stage incorporates current and voltage measurement boards, along with two interface boards that connect the STM32F4 digital target to the IGBT drivers, providing appropriate voltage level adaptation for the control signals [18][19][20].

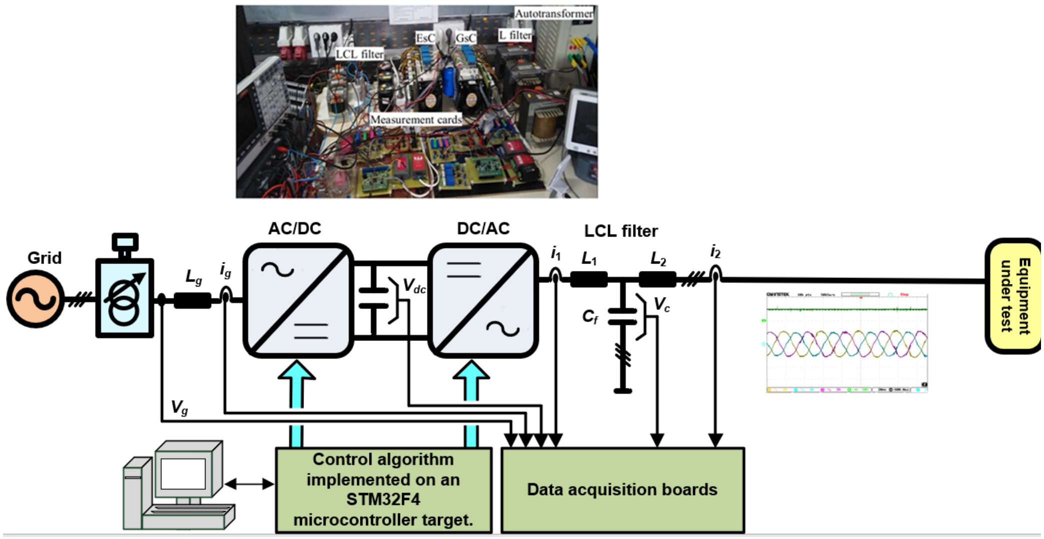

Figure 1. Architecture of the Grid Emulator for Educational Use

2. Microgrid Test Platform

The microgrid test platform integrates renewable generation units, energy storage systems, and controllable loads, enabling flexible operation in both grid-connected and islanded configurations. It provides a practical environment for studying energy management strategies, demand response, and the coordinated operation of hybrid storage systems [21][22].

As illustrated in Figure 2, the platform is primarily based on photovoltaic (PV) systems and incorporates a battery energy storage system (BESS). The BESS represents an optimal solution for compensating power deficits during autonomous operation and for supporting transient load profiles, owing to its high energy density and adequate power capability.

The experimental setup installed in the laboratory consists of PV panels with a total capacity of 3.12 kWp and battery storage rated at 200 Ah. The platform also includes emulated loads, comprising both a variable resistive load and a variable inductive load, each rated at a maximum power of 4 kVA [23].

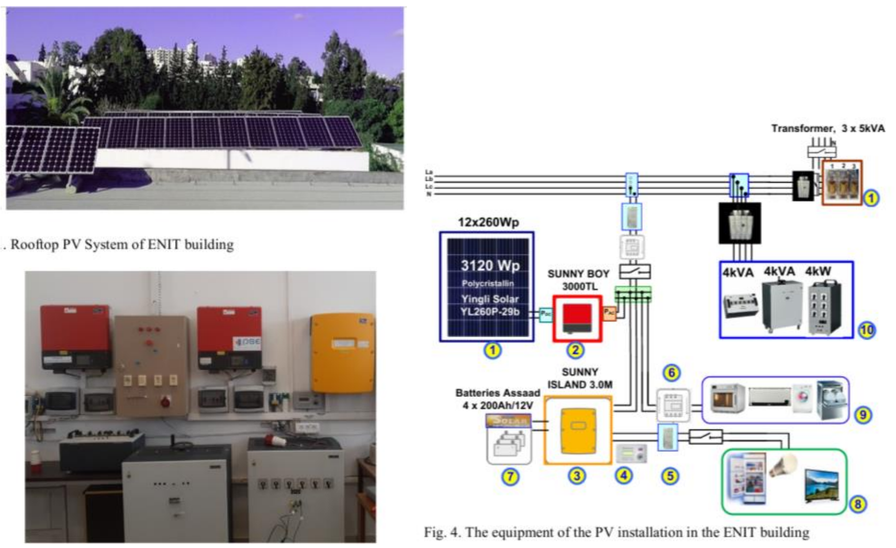

Figure 2. Microgrid Test Platform with Renewable and Storage Units

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3. Digital Twin Environment

The digital twin environment integrates real-time data acquisition from physical test benches with a virtual simulation layer, creating a cyber-physical framework for advanced experimentation. It allows students to interact simultaneously with physical and digital systems, thereby deepening their understanding of smart grids, energy management, and cyber-physical infrastructures. Remote access features further support international collaboration and shared learning experiences.

In this study, a digital twin of the commercial microgrid platform is employed to provide a reliable framework for validating proposed algorithms and comparing simulated outputs with experimental results. This dual validation process ensures the accuracy of simulation studies while reducing the risks and costs associated with deploying new algorithms directly on the physical system. Unlike traditional test systems that rely solely on physical components, the digital twin serves as a virtual counterpart, enabling flexible, risk-free testing, scenario analysis, and performance optimization [24][25][26][27].

As illustrated in Figure 3, the digital twin structure operates by continuously collecting and storing asset data, which is then analyzed to optimize the energy management system (EMS) algorithms until predefined accuracy metrics are achieved. The dataset includes historical records obtained under various operating conditions and meteorological scenarios, covering a wide spectrum of load profiles. Current measurements are acquired via dedicated sensors, transferred through a data acquisition system, and processed in LabVIEW for real-time monitoring and interface with the virtual environment.

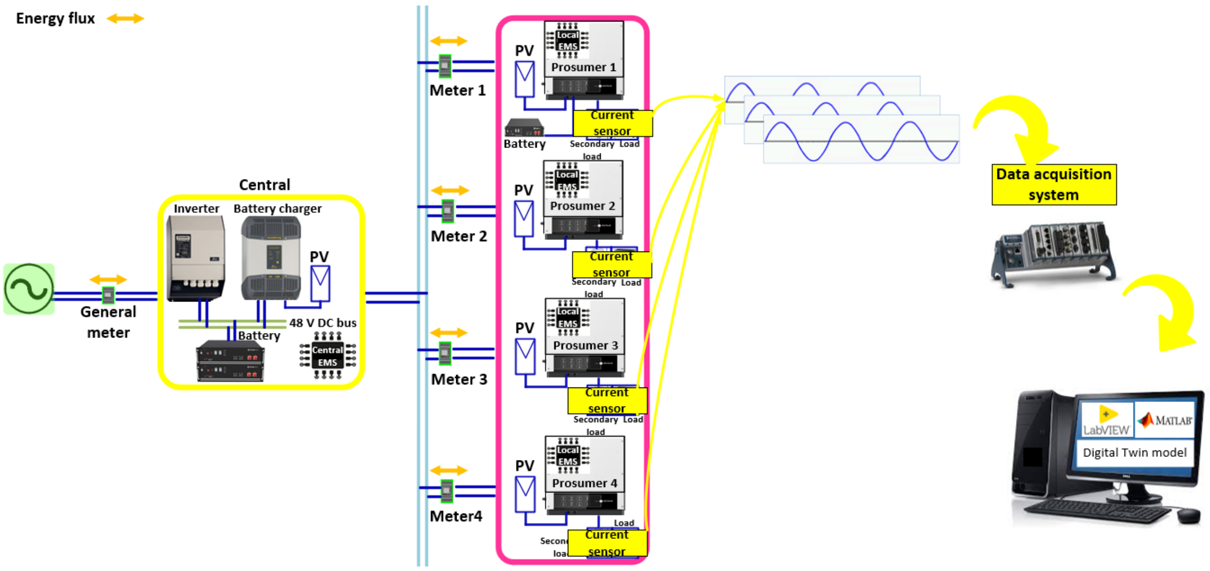

Figure 3. Digital Twin Environment Connecting Physical and Virtual Layers

PEDAGOGICAL INTEGRATION

The integration of advanced laboratory platforms into engineering curricula provides a unique opportunity to enhance student learning by linking theoretical knowledge with hands-on experience. By mapping the developed test benches to specific modules within power and energy programs, educators can design structured learning pathways that promote active engagement, critical thinking, and problem-solving skills

1 Mapping Platforms to Curriculum Modules

Each laboratory platform offers opportunities to address key topics in engineering education:

- Grid Emulator including power electronics, power systems, and grid integration: Enables students to investigate voltage and frequency regulation, analyze the effects of disturbances, and implement converter control algorithms on digital hardware. It also supports the study of power quality issues and the validation of simulation models through hardware experiments.

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- Microgrid test platform incorporating smart grid concepts, energy management, and hybrid storage systems: Provides students with a comprehensive environment to study renewable integration, storage coordination, and energy management strategies. Learners can analyze grid-connected vs. islanded operation, evaluate demand response techniques, and assess the performance of PV generation combined with battery storage systems under real load conditions.
- Digital Twin environment encompassing modeling, simulation, and cyber-physical systems: Offers students a platform to validate algorithms, compare simulated and experimental results, and conduct scenario-based studies in a risk-free environment. It enhances understanding of data-driven optimization, predictive control, and real-time monitoring, while also supporting remote collaboration and international knowledge exchange.

By aligning platforms with curriculum modules, students are exposed to practical applications of abstract concepts, reinforcing their theoretical knowledge while developing the technical competencies required in modern energy engineering.

2 Teaching Methodologies

The platforms support a variety of active learning approaches:

2.1 Project-Based Learning (PBL):

- Grid Emulator: Students design and test control strategies for converters under disturbed grid conditions.
- Microgrid Platform: Teams develop energy management policies for hybrid PV–battery systems in both grid-connected and islanded modes.
- Digital Twin: Learners validate predictive algorithms and evaluate their robustness under varying load and weather profiles.

2.2 Problem-Based Labs:

- Grid Emulator: Fault scenarios such as voltage sags or frequency deviations are introduced for stability analysis.
- Microgrid Platform: Students address challenges of power sharing between PV and storage units during peak loads.
- Digital Twin: Learners optimize EMS algorithms and compare outcomes with physical test bench data.

2.3 Virtual and Remote Labs:

The digital twin environment extends accessibility by allowing students worldwide to interact with real systems through virtual interfaces, fostering collaborative international learning.

These methodologies encourage iterative learning through design, testing, evaluation, and optimization, while also strengthening soft skills such as teamwork, communication, and project management. 3 Example Course Assignments

3. Example Course Assignments

To illustrate practical applications, the following course assignments can be implemented using the laboratory platforms:

- Controller Implementation (Grid Emulator): Students design and implement a grid-synchronization or MPPT controller, testing its performance under realistic voltage and frequency disturbances.
- Hybrid Energy Management (Microgrid Platform): Learners develop and evaluate strategies for optimal power sharing between PV panels and the BESS during varying demand and weather conditions.
- Predictive Algorithm Validation (Digital Twin): Students design EMS algorithms using historical datasets and validate them by comparing simulation results with real test bench measurements.

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- Remote Collaborative Projects (Digital Twin + Microgrid Platform): Teams from different institutions collaborate remotely to analyze data, simulate operating strategies, and propose optimizations for shared microgrid scenarios.

Through these activities, students gain hands-on experience, integrate multidisciplinary knowledge, and develop competencies aligned with modern engineering practice and global industry expectations.

To synthesize the pedagogical potential of the developed platforms, Table 1 summarizes the key learning actions that each platform enables, along with the corresponding competencies that students are expected to acquire.

Table 1. Comparative Pedagogical Mapping of Platforms

Platform	Pedagogical Actions	Targeted Competencies
Grid Emulator	- Study voltage/frequency regulation under grid disturbances - Implement and test converter controllers (STM32F4) - Analyze fault scenarios (voltage sag, short-circuit) - Evaluate power quality and filtering (L, LCL) - Compare simulation vs. hardware results	- Mastery of power electronics and control - Understanding of grid integration challenges - Fault analysis and protection strategies - Experimental validation of theoretical models - Critical thinking and problem-solving under real conditions
Microgrid Test Platform	- Configure grid-connected and islanded operating modes - Analyze energy management strategies and demand response - Study hybrid PV/battery operation under variable load - Evaluate renewable integration and storage coordination - Test impact of load types (resistive/inductive) on stability	- Competence in smart grid and microgrid operation - Skills in energy management and optimization - Knowledge of storage system dynamics (BESS) - Ability to integrate renewable resources in hybrid systems - Practical experience with real-world load interactions
Digital Twin Environment	- Validate algorithms by comparing simulated and experimental results - Conduct scenario-based studies in a risk-free virtual environment - Perform real-time monitoring and EMS optimization - Analyze historical datasets under diverse operating conditions - Engage in remote collaborative experiments	- Understanding of cyber-physical systems and digital twins - Data analytics and predictive control skills - Ability to evaluate and optimize EMS algorithms Competence in virtual experimentation and risk-free validation - Experience in remote collaboration and global knowledge exchange

EDUCATIONAL OUTCOMES & ASSESSMENT

While the previous section described the integration of research-grade platforms into teaching practice, this section highlights the **learning outcomes** achieved and the **methods used to assess their impact**. The emphasis is placed not only on the technical knowledge gained but also on the broader professional skills that are essential for modern engineering careers.

1 Skills Developed

The use of test benches and digital twin platforms supports the acquisition of both technical competencies and

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transversal skills:

- Modeling and Simulation: Students learn to convert theoretical models into computational representations, simulate operating scenarios, and anticipate system responses before real-world implementation.
- Experimental Validation: Learners gain practical experience with hardware-in-the-loop setups, grid emulators, and microgrid platforms, validating theoretical models against measured data and identifying their limitations.
- System-Level Analysis: By working with integrated platforms combining renewable sources, storage, and controllable loads, students acquire the ability to analyze performance, stability, and energy flows under various operating conditions.
- Teamwork and Project Management: Collaborative projects foster communication, coordination, and problem-solving skills, preparing students to operate in multidisciplinary engineering environments

2 Evidence of Learning Impact

The impact of platform-based learning can be assessed through multiple complementary approaches:

- Surveys and Feedback: Students consistently report higher motivation, stronger engagement, and increased confidence in applying theoretical concepts when using advanced laboratory platforms
- Project Performance: Assessment of student projects (e.g., controller design, fault analysis, or microgrid optimization) demonstrates the transfer of modeling and simulation knowledge to practical experimental validation.
- Comparative Evaluation: Pre and post lab assessments, including concept inventories and exam performance, provide quantitative evidence of improved comprehension and knowledge retention.

3 Synthesis

As shown in Table 2, research-grade platforms provide higher complexity, integrated system-level exposure, and enhanced student engagement, reinforcing both technical skills and professional competencies. This comparison underscores how these platforms bridge the gap between theoretical instruction and real-world engineering challenges, offering students a more authentic and impactful learning experience.

Table 2. Comparison of Conventional and Research Grade Platforms

Aspect	**Traditional Lab**	**Research Grade Test Bench**
Complexity	Low to moderate	High; mirrors real-world systems
Scope	Isolated experiments	Integrated, multi-component platforms
Learning Focus	Step-by-step procedures	Problem-solving, system optimization, critical analysis
Student Engagement	Moderate	High, through project-based and hands-on challenges
Remote/Collaborative Access	Limited	Enabled via digital twins and virtual labs

PROMOTING GLOBAL KNOWLEDGE EXCHANGE

Beyond local educational benefits, the laboratory platforms developed in our research group offer significant potential for international collaboration and knowledge dissemination. By leveraging open-source tools, digital twins, and remote-access capabilities, these infrastructures can support a broader community of learners and educators worldwide.

1. Remote Access and Open-Source Experimental Frameworks

The digital twin environment and software interfaces of our test benches enable remote operation and experimentation, allowing students and researchers from different institutions to interact with physical systems virtually. Open-access models, simulation scripts, and experimental protocols promote reproducibility, transparency, and adaptability. This approach extends the reach of advanced laboratory setups to institutions

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with limited resources, enabling learners to implement controllers, analyze microgrid stability, and explore fault conditions remotely across the grid, impedance, and microgrid platforms.

2. International Collaboration and Joint Teaching Modules

Integrating research grade platforms into collaborative, remote learning environments enables joint teaching initiatives across universities. International student teams can conduct experiments on shared test benches through virtual interfaces, exchange data, and collaboratively solve complex energy management problems. Such activities foster cross-cultural learning, teamwork, and exposure to diverse engineering practices, while promoting standardized approaches in engineering education. These collaborative experiences are particularly relevant in the context of global energy challenges, where engineers must understand and address problems that transcend national boundaries.

3. Contribution to Global Educational Initiatives

By sharing laboratory designs, experimental protocols, and digital twin frameworks, our platforms contribute to international educational efforts in engineering, including:

- UNESCO and global STEM initiatives: Supporting equitable access to practical learning tools in developing countries.
- IEEE Power & Energy Society (PES) Education Activities: Offering standardized methodologies for teaching renewable energy, microgrids, and control systems.
- Global Engineering Deans Council (GEDC) and WEEF collaborations: Facilitating joint curricula development and knowledge exchange among higher education institutions.

Collectively, the grid emulator, microgrid platform and digital twin environment form a cohesive suite of tools that support both local learning and global collaboration, enabling the exchange of knowledge, skills, and best practices across institutions and borders. These platforms not only advance pedagogy but also prepare students to tackle the challenges of modern, interconnected energy systems on a global scale.

CONCLUSION

This paper has demonstrated how research-grade laboratory platforms, initially developed for advanced studies in renewable energy systems, microgrids, and power electronics, can be effectively repurposed to enhance engineering education. By integrating grid emulators, microgrid platforms and digital twin environments into curricula, students gain hands-on experience that bridges theoretical knowledge with practical application. This approach fosters competencies in modeling, simulation, experimental validation, system-level analysis, and teamwork, equipping learners to tackle the complex challenges of modern energy systems.

Moreover, the incorporation of remote access and digital twin capabilities enables global knowledge exchange. Students and educators can collaborate across institutions, access high-fidelity experimental setups virtually, and share open-source models, promoting international best practices in engineering pedagogy. These initiatives contribute to broader global efforts, including UNESCO STEM education programs and IEEE PES educational activities, which aim to democratize access to high-quality learning resources and strengthen cross-border collaboration.

Looking forward, several avenues can further enhance both research and educational outcomes:

- Expand Remote and Virtual Laboratories: Increase the number of experiments accessible online with immersive, real-time features.
- Integrate Industry 4.0 and Smart Grid Education: Leverage IoT, cloud monitoring, and advanced analytics for hands-on training on emerging digital energy technologies.
- Promote Collaborative International Projects: Develop joint courses, competitions, and research projects to engage students in global energy challenges.
- Strengthen Assessment and Pedagogical Research: Systematically evaluate student outcomes, engagement, and knowledge retention to refine curriculum design and teaching strategies.

By combining research excellence with educational innovation, these platforms offer a model for transforming engineering education, linking theory, experimentation, and global collaboration, and equipping the next generation of engineers with the interdisciplinary skills required to address pressing energy challenges.

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REFERENCES

1. Larrondo-Petrie, M. M., Zapata-Rivera, L. F., Aranzazu-Suescun, C., Sanchez-Viloria, J. A., Molina-Peña, A. E., & Santana-Santana, K. S. (2021, November). Addressing the need for online engineering labs for developing countries. In *2021 World Engineering Education Forum/Global Engineering Deans Council (WEEF/GEDC)* (pp. 387-396). IEEE.
2. May, D., Alves, G. R., Kist, A. A., & Zvacek, S. M. (2023). Online laboratories in engineering education research and practice. In *International handbook of engineering education research* (pp. 525-552). Routledge.
3. Li, Y., Wang, K., Xiao, Y., & Froyd, J. E. (2020). Research and trends in STEM education: A systematic review of journal publications. *International journal of STEM education*, *7*(1), 11.
4. Terzieva, V., Paunova-Hubenova, E., & Slavcheva, S. (2024). Trends, challenges, opportunities, and innovations in STEM education. *IFAC-PapersOnLine*, *58*(3), 106-111.
5. Anitha, D., Jeyamala, C., & Thiruvengadam, S. J. (2025). Impact Analysis of Conceive-Design-Implement-Operate (CDIO) Educational Framework–a Longitudinal Study. *Journal of Engineering Education Transformations*, 540-547.
6. Frady, K. (2023). Use of virtual labs to support demand-oriented engineering pedagogy in engineering technology and vocational education training programmes: A systematic review of the literature. *European Journal of Engineering Education*, *48*(5), 822-841.
7. Van den Beemt, A., Groothuijsen, S., Ozkan, L., & Hendrix, W. (2023). Remote labs in higher engineering education: engaging students with active learning pedagogy. *Journal of Computing in Higher Education*, *35*(2), 320-340.
8. Kamp, A. (2023). *Engineering Education in the Rapidly Changing World: Rethinking the Vision for Higher Engineering Education*|. TU Delft OPEN Publishing.
9. Van den Beemt, A., Groothuijsen, S., Ozkan, L., & Hendrix, W. (2023). Remote labs in higher engineering education: engaging students with active learning pedagogy. *Journal of Computing in Higher Education*, *35*(2), 320-340.
10. Skander-Mustapha, S., Ghorbal, M. J. B., Said-Romdhane, M. B., Miladi, M., & Slama-Belkhodja, I. (2018). Grid emulator for small scale distributed energy generation laboratory. Sustainable cities and society, 43, 325-338.
11. Said-Romdhane, M. B., Skander-Mustapha, S., & Slama-Belkhodja, I. (2020). Robust dynamic grid emulator control. Computers & Electrical Engineering, 85, 106663.
12. Ngom, I., Mboup, A. B., Thiaw, L., Skander-Mustapha, S., & Belkhodja, I. S. (2018, March). An improved control for DC-link fluctuation during voltage dip based on DFIG. In *2018 9th International Renewable Energy Congress (IREC)* (pp. 1-6). IEEE.
13. Ghodbane-Cherif, M., Skander-Mustapha, S., & Slama-Belkhodja, I. (2019). An improved predictive control for parallel grid-connected doubly fed induction generator-based wind systems under unbalanced grid conditions. *Wind Engineering*, *43*(4), 377-391.
14. Sayah, A., Saïd-Romdhane, M. B., & Skander-Mustapha, S. (2024). Advanced energy management system with road gradient consideration for fuel cell hybrid electric vehicles. *Results in Engineering*, *23*, 102721.
15. Said-Romdhane, M. B., Skander-Mustapha, S., & Slama-Belkhodja, I. (2021, December). Analysis study of city obstacles shading impact on solar PV vehicle. In *2021 4th International Symposium on Advanced Electrical and Communication Technologies (ISAECT)* (pp. 01-06). IEEE.

16. Said-Romdhane, M. B., Skander-Mustapha, S., & Belhassen, R. (2023). Adaptive Deadbeat Predictive Control for PMSM-based solar-powered electric vehicles with enhanced stator resistance compensation. *Science and Technology for Energy Transition*, *78*, 35.
17. Said-Romdhane, M. B., & Skander-Mustapha, S. (2024). Optimizing solar vehicle performance in urban shading conditions with enhanced control strategies. *Ain Shams Engineering Journal*, *15*(10), 102985.
18. Skander-Mustapha, S., Ghorbal, M. J. B., Miladi, M., & Slama-Belkhodja, I. (2018, March). Load analysis effect on grid fault emulator. In 2018 9th International Renewable Energy Congress (IREC) (pp. 1-6). IEEE.
19. Saïd-Romdhane, M. B., Skander-Mustapha, S., & Slama-Belkhodja, I. (2019, March). Enhanced real time impedance emulation for microgrid equipments testing and applications. In 2019 10th International Renewable Energy Congress (IREC) (pp. 1-6). IEEE.
20. Saïd-Romdhane, M. B., Skander-Mustapha, S., & Slama-Belkhodja, I. (2020). Line Impedance Emulator: Modeling, Control Design, Simulation and Experimental Validation. In Numerical Modeling and Computer Simulation. IntechOpen.
21. Skander-Mustapha, S., & Slama-Belkhodja, I. (2020, March). Energy management of rooftop PV system including battery storage: case study of ENIT building. In 2020 International Conference on Electrical and Information Technologies (ICEIT) (pp. 1-6). IEEE.
22. Dellaly, M., Moussa, S., Skander-Mustapha, S., & Slama-Belkhodja, I. (2021, May). Analysis and Assessment of a Commercial Microgrid Laboratory Platform. In International Conference of the IMACS TC1 Committee (pp. 399-409). Cham: Springer International Publishing.
23. Mdini, N., Skander-Mustapha, S., & Slama-Belkhodja, I. (2020). Design of passive power filters for battery energy storage system in grid connected and islanded modes. SN Applied Sciences, 2(5), 933.
24. Dellaly, M., Skander-Mustapha, S., & Slama-Belkhodja, I. (2024). A digital twin model-based approach to cost optimization of residential community microgrids. Global Energy Interconnection, 7(1), 82-93.
25. Dellaly, M., Skander-Mustapha, S., & Slama-Belkhodja, I. (2023). Optimization of a residential community's curtailed PV power to meet distribution grid load profile requirements. *Renewable Energy*, *218*, 119342.
26. Said-Romdhane, M. B., Skander-Mustapha, S., & Slama-Belkhodja, I. (2020, October). PV system inverter control design based on H∞ control. In 2020 11th International Renewable Energy Congress (IREC) (pp. 1-6). IEEE.
27. Takriti, M., Skander-Mustapha, S., Boussaada, Z., & Mrabet Bellaaj, N. (2025). Data-driven optimization for efficient integration of photovoltaic agents in residential microgrid systems. Euro-Mediterranean Journal for Environmental Integration, 1-13.