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Editorial: Continuing engineering education for a sustainable future

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Editorial on the Research Topic
Continuing engineering education for a sustainable future

Introduction

Continuing Engineering Education (CEE) plays a critical role in equipping engineers and professionals with the knowledge, skills, and abilities (KSAs) required to navigate an increasingly complex technological, social, and environmental landscape. As we transition into Industry 5.0, the need for lifelong learning becomes more pressing, requiring the integration of advanced digital technologies and a renewed commitment to sustainability, equity, and social responsibility. CEE extends beyond technical reskilling to encompass the cultivation of transversal competencies, ethical reasoning, global collaboration, and personal well-being. Meeting these evolving needs requires deeper cooperation among universities, training providers, and industry, ensuring that engineering professionals remain ready to meet the challenges of a sustainable future.

This editorial stems from the international dialogue held during the IACEE 2024 World Conference in Comillas, Spain, where stakeholders from academia, industry, and policy gathered to explore "*Continuing Engineering Education for a Sustainable Future.*" The forum focused on aligning CEE with broader agendas—technological innovation, sustainability, and inclusion. Key themes discussed included education tailored to a technology-driven labor market; flexible reskilling and upskilling pathways; advancing Diversity, Equity, and Inclusion (DEI); future skills for Industry 5.0; quality assurance in professional training; competency-based approaches in CEE; and strengthening academic-industry collaboration. These topics shaped both the structure and spirit of this Research Topic, which now brings together 19 peer-reviewed articles that reflect global efforts to reimagine CEE as a key driver of sustainable, inclusive, and future-ready societies (see Figure 1).

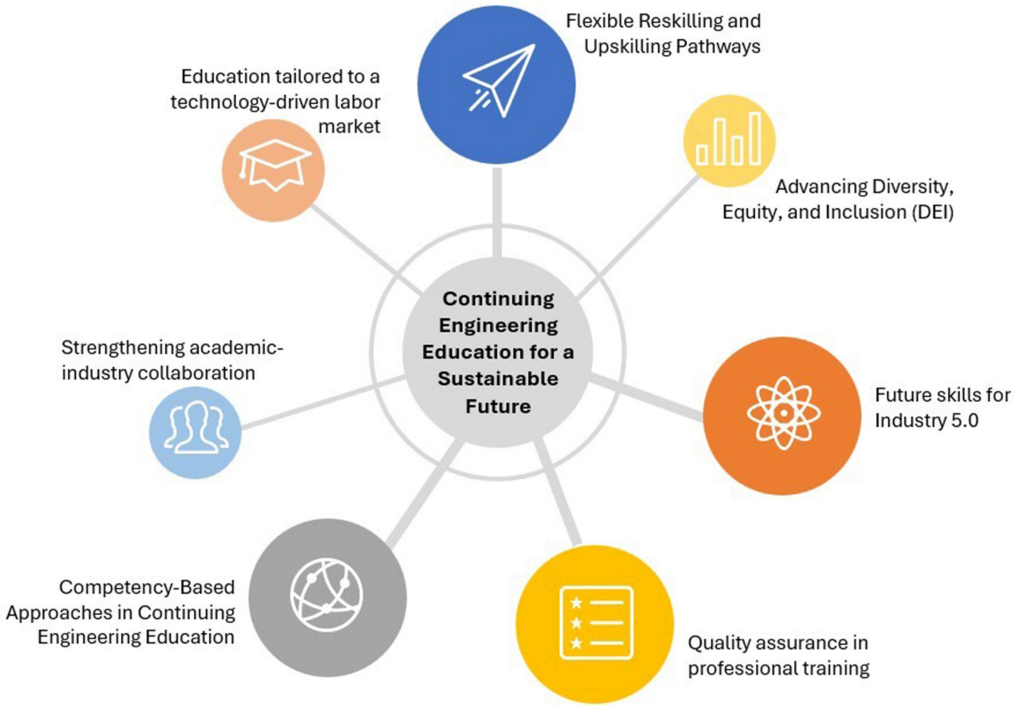

FIGURE 1
Key themes on the research topic.

Education tailored to a technology-driven labor market

Valverde-Rebaza, Rodrigues et al. presented a new hierarchical taxonomy for IT job classifications to address the lack of granularity in global standards, such as ISCO-08. The Bee-inspired Employment and Expertise Taxonomy (BEET) was built through clustering analysis of job postings and expert collaboration. This framework supports improved workforce forecasting and informs curriculum design for Industry 5.0-aligned education. By aligning labor market demands with skill-based education, BEET offers a practical tool for institutions to prepare learners for an evolving digital economy.

Flexible reskilling and upskilling pathways

The original research study by Azofeifa et al. explored how integrating Industry 4.0 technologies and Education 4.0 principles can foster future skills through continuing engineering education. The authors analyze a redesigned course for practicing engineering, incorporating collaborative problem-solving and digital tools. Results show enhanced learner engagement and the development of transversal competencies such as adaptability, systems thinking, and innovation. The findings emphasize the value of immersive learning environments and lifelong upskilling strategies to prepare professionals for the evolving demands of Industry 5.0.

Caratozzolo et al. presented a novel taxonomy for Continuing Engineering Education that aligns with UNESCO's ISCED classification, aiming to clarify terminology and facilitate international comparisons. This structure categorizes CEE initiatives based on target audience, program purpose, and delivery mode. By promoting consistency in how programs are described and analyzed, the new taxonomy provides a valuable tool for researchers, policymakers, and institutions seeking to benchmark and improve lifelong learning offerings for engineers in a global context.

Smith et al.'s study investigated the role of Scotland's SCQF framework in supporting flexible lifelong learning pathways for engineers. By recognizing informal and non-formal learning, the SCQF enables learners to upskill and reskill more fluidly in response to evolving workforce demands. The authors illustrate how national qualification systems can empower individuals and institutions to adapt to economic and technological changes, contributing to more inclusive and responsive models of continuing engineering education.

Advancing diversity, equity, and inclusion (DEI)

Drawing on the Academic Women in STEM Mentoring Program (A-WSTEM), García-Silva et al. examine how structured mentoring supports women's professional growth and retention in academia. Based on surveys and interviews, the findings highlight the importance of relational support, role modeling, and access to informal networks in fostering confidence and leadership. The research contributes to broader gender equity efforts by positioning mentoring as a strategic intervention in upskilling and promoting the career development of women in engineering education.

Future skills for Industry 5.0

Focusing on digital design education, Cal Y. Mayor-Peña et al. proposed a gamified learning framework aligned with Education 4.0 principles. The authors design and evaluate a virtual platform that uses game elements to boost motivation, interaction, and knowledge retention among engineering students. The results indicate improved engagement and skill acquisition, suggesting that gamification can be a powerful pedagogical tool for developing digital and creative competencies essential for Industry 5.0. The research also underscores the importance of learner-centered innovation in continuing education.

Escobar-Castillejos et al. evaluated a custom-built digital platform to support methods engineering education for industrial engineering students. Using usability testing and educational impact assessments, the authors demonstrate that the platform enhances student interaction, task analysis, and decision-making skills. The research suggests that digital tools can significantly improve learners' comprehension of complex workflows and their readiness for smart manufacturing environments. It underscores the role of adaptive learning environments in preparing engineering professionals for Industry 5.0's collaborative and data-rich settings.

The study by Ramírez-Cedillo et al. presented "Student 5.0," an immersive, interdisciplinary course on automation and manufacturing systems designed for the Industry 5.0 era. The course fosters cross-functional collaboration and digital fluency through project-based learning and technology integration. Learners navigate realistic industrial challenges using simulation tools, IoT systems, and agile methodologies. The experience cultivates systems thinking, problem-solving, and innovation—key future skills for sustainable industry. The study highlights the need for flexible, hands-on learning models in continuing engineering education.

Valverde-Rebaza, González et al. investigated the use of generative AI tools, particularly large language models like ChatGPT, and visualization platforms to support data analytics learning in engineering. Through an instructional redesign and testing phase, the study demonstrates how these tools can scaffold conceptual understanding, automate data interpretation, and foster independent learning. The findings emphasize the potential of AI to personalize continuing education and bridge skills gaps in data-driven disciplines, a critical need for engineers operating in Industry 5.0 contexts.

Quality assurance in professional training

The case study conducted by DelaTorre-Diaz et al. examined the effects of curriculum standardization in a data analysis course for undergraduate engineering students. By implementing a unified structure across multiple campuses, the authors evaluate gains in tool proficiency, conceptual consistency, and academic outcomes. The findings suggest that standardization enhances both instructional efficiency and student learning. The article highlights how cohesive curricular frameworks can support quality assurance in CEE by ensuring that foundational competencies are uniformly delivered in rapidly evolving technical domains.

Elizondo-García et al. investigated how ChatGPT influences learning in mathematics and biology courses that use a challenge-based learning (CBL) model. Through classroom observations and student feedback, the study examines whether AI tools enhance or obscure individual problem-solving processes. Results indicate nuanced outcomes: while ChatGPT can scaffold learning and support engagement, its overuse may hinder authentic understanding. The research raises critical questions about integrating generative AI into quality-focused instructional design, highlighting the need for ethical guidance in CEE.

Mirón-Mérida and García-García analyzed how ChatGPT impacts the development of Spanish-language writing skills among engineering students. The authors assess improvements in argumentation, structure, and linguistic accuracy through controlled experimentation. The results suggest that while AI can support basic writing processes, it may also limit deeper reflection and critical thinking if over-relied upon. The study offers valuable insights into the appropriate role of AI in enhancing quality communication competencies, a crucial yet often overlooked component of engineering education.

The original research by Nava-Manzo et al. focused on the relationship between continuing education engagement and the psychological well-being of engineering faculty. Using survey data, the authors examine how professional development activities affect emotional exhaustion, self-efficacy, and institutional commitment indicators. The findings show that structured learning opportunities can serve as protective factors for faculty mental health. By linking professionalization with wellness, the study expands the scope of quality assurance in CEE to include support for the human dimension of teaching.

Competency-based approaches in continuing engineering education

The article by Camacho-Zuñiga et al. examines a case study from a Mexican private university that has restructured its educational model around lifelong and continuous learning principles. Through curricular integration, industry collaboration, and flexible credentialing, the model supports students in developing transversal competencies needed for ongoing professional growth. The study highlights how institutional design can promote a mindset of learning beyond graduation—an increasingly critical aspect of continuing engineering education in dynamic, innovation-driven environments.

Chans et al. explored how international mobility programs influence the development of transversal competencies in engineering students. Based on qualitative interviews, the study shows that experiences abroad enhance students' adaptability, cross-cultural communication, and global collaboration skills. These competencies are essential for engineering professionals operating in a globally connected and interdisciplinary workforce. The article supports the integration of international experience into competency-based education frameworks for lifelong learning and Industry 5.0 readiness.

Pelaez-Sanchez et al. worked on designing and validating instruments to assess digital competencies in higher education. Drawing on Industry 5.0 frameworks, the authors construct a multidimensional toolset to measure skills, such as digital literacy, data fluency, and digital ethics. The validated instruments offer actionable insights for educators seeking to align instructional design with evolving technological needs. The study contributes to quality

assurance in CEE by providing robust evaluation methods for one of the most critical competencies of the digital era.

This article by Valdes-Ramirez et al. presented a large-scale, data-driven analysis of sustainability competencies among STEM students at a leading Mexican university. The authors employ quantitative survey techniques to evaluate how curricular and extracurricular activities influence systems thinking, ethical awareness, and environmental responsibility. The findings suggest that intentional integration of sustainability themes enhances key graduate attributes aligned with Industry 5.0 goals. The study presents a model for assessing and strengthening sustainability education within engineering curricula and continuing education programs.

Strengthening academic-industry collaboration

Vasquez-Lopez et al. explored the implementation of challenge-based learning (CBL) in engineering education through structured academic–industry collaboration. Based on a multi–semester case study, the authors presented a framework for company selection, challenge formulation, team formation, and evaluation. Findings emphasize the importance of aligning educational goals with industry needs while ensuring student ownership of problem-solving. The study offers practical insights into how structured engagement with industry partners can enhance experiential learning and long-term workforce relevance in continuing engineering education.

Focusing on gender equity in the automotive sector, Zavala-Parrales et al. reviewed and analyzed educational strategies to increase women's participation and leadership in engineering roles. The authors examined case studies of vocational training, mentorship programs, and leadership development initiatives, highlighting their impact on recruitment, retention, and advancement. The article positions gender-inclusive education as essential to sustainable innovation and industry competitiveness. It underscores how strategic partnerships between academia and industry can advance both equity and skills development in continuing education.

Remarks

Together, these 19 contributions reveal a rich tapestry of innovation in engineering education. They show that CEE must evolve beyond technical upskilling to address broader imperatives—including sustainability, equity, inclusion, and mental well-being. The articles reflect a shared commitment to reforming educational models, embedding sustainability, ensuring equity, and embracing new technologies—not as end goals, but as tools to empower learners and reshape professional futures. As we look ahead, the insights from this Research Topic provide a roadmap for CEE programs worldwide. Institutions must build adaptable, inclusive, and high-impact learning ecosystems, which means forming deeper industry alliances, adopting flexible credentials, promoting diversity, equity, and inclusion, incorporating ethical considerations, and supporting the mental health of both learners and educators. Above all, it means reaffirming the value of engineering education not just as an economic lever, but as a cornerstone of sustainable global development.

Author contributions

PC: Conceptualization, Funding acquisition, Supervision, Writing – original draft, Writing – review & editing. GC: Conceptualization, Supervision, Writing – original draft, Writing – review & editing. AD: Conceptualization, Supervision, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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