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Future skills for Industry 4.0 integration and innovative learning for continuing engineering education

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Introduction: This research explores leveraging Industry 4.0 technologies and best practices to address the challenges faced by Continuing Engineering Education (CEE) in Higher Education, ensuring its sustainability and relevance. CEE is essential for engineers' continuous professional growth and adaptability, especially in an era marked by swift technological progress and changing job requirements. CEE must adapt to rapid technological advancements and evolving workforce demands. Nevertheless, traditional pedagogical methods often lag behind the needs of modern engineering professionals.

Methods: Through a case study, this study aims to show how skills visualization allows the creation of comparisons between professional scenarios to enhance the effectiveness and efficiency of CEE programs. To achieve this goal, we utilized a platform based on the KSA taxonomy, which enables the visualization of skills and supports creating personalized and adaptive learning.

Results: Our results demonstrate the transformative potential of integrating new technologies and learning approaches in CEE programs. By leveraging Industry 4.0 technologies, developing personalized learning experiences, and embracing Education 4.0 principles, CEE programs can empower the workforce of the future to thrive in an increasingly complex and dynamic landscape.

Discussions: This study underscores the significance of Education 4.0 principles in shaping the future of CEE programs, emphasizing the crucial role of innovative learning approaches and technological integration in empowering the future engineering workforce in the Industry 4.0 era.

KEYWORDS

Industry 4.0, higher education, lifelong learning, future skills, artificial intelligence, educational innovation

1 Introduction

Continuing Engineering Education (CEE) is crucial for the ongoing professional development and adaptability of engineers, particularly in an era characterized by rapid technological advancements and evolving job demands (Ekren and Kumar, 2020; Treviño-Elizondo and García-Reyes, 2023). Traditional pedagogical methods often struggle to keep pace with the dynamic landscape of Industry 4.0, failing to provide the agility and expertise required by modern engineering professionals (Ahsan et al., 2022; Thwe and Kálmán, 2023). This discrepancy underscores the need for a significant transformation in CEE to maintain its relevance and effectiveness.

This research addresses the challenges faced by CEE, exploring the integration of Industry 4.0 technologies and advanced Higher Education (HE) practices. By leveraging emerging technologies such as artificial intelligence (AI), a comprehensive platform was created based on Skills, Knowledge, and Abilities (KSA) taxonomy driven by Natural Language Processing (NLP). In constant transformation, this platform enables the skills visualization that could support the creation of personalized and adaptive learning experiences for engineering professionals, thereby improving the effectiveness of online courses, virtual laboratories, and industry-aligned projects. (Newton et al., 2020; Caratozzolo et al., 2023a; ShapingSkills, 2023a).

Considering the first Shaping Skills functionalities described, this study aims to show, through a case study, how skills visualization allows creating comparisons between professional scenarios to enhance the effectiveness and efficiency of CEE programs, paving the way for a paradigm shift in the delivery and consumption of engineering education (Diery et al., 2020; Caratozzolo et al., 2023a).

Central to our approach is the critical role of Education 4.0 principles, emphasizing learner-centeredness, technology integration, and lifelong learning (Caratozzolo et al., 2023a). These principles provide a holistic framework for reimagining engineering education in the digital age and align with the evolving needs of the engineering workforce (Hernández-Muñoz et al., 2019; Chakrabarti et al., 2021; Caratozzolo et al., 2023b).

At the core of our efforts is the ambition to harness the transformative power of integrating new technologies and innovative learning approaches to empower the future engineering workforce. We envision a future where engineering professionals are not only equipped with the necessary technical skills but also possess the adaptability, resilience, and creativity needed to thrive in the ever-changing landscape of Industry 4.0.

The success of this integration hinges on the collective efforts of educators, industry stakeholders, and policymakers. Embracing change, fostering collaboration, and cultivating a culture of lifelong learning are essential to harnessing the full potential of Industry 4.0 technologies and Education 4.0 principles. Through these collaborative efforts, we can chart a course toward a more vibrant, resilient, and sustainable future for Continuing Engineering Education.

2 Overview

Continuing Engineering Education serves as a critical nexus between ongoing professional development and the advancement of technology within the engineering sector. As Industry 4.0 continues to drive rapid technological change and shift workforce demands, CEE programs face the pressing challenge of maintaining relevance and effectiveness. This section explores fundamental concepts and related work, highlighting the synergies between Industry 4.0 technologies and contemporary HE practices in CEE. The aim is to enhance the efficacy and efficiency of CEE through the transformative potential of integrating cutting-edge technologies.

The principles of Education 4.0 advocate for integrating advanced technologies and adaptive learning methodologies to address the evolving landscape of engineering education (Miranda et al., 2021). Through technology-enhanced learning, transformative technologies, such as AI, VR, and NLP, are leveraged to improve educational outcomes (Chen L. et al., 2020; Krstić et al., 2022). These technologies facilitate personalized learning experiences tailored to the individual needs and preferences of engineering professionals (Zawacki-Richter et al., 2019; Chen X. et al., 2020). AI algorithms and NLP techniques enable educational platforms to dynamically adapt content delivery and assessment methods, ensuring both relevance and engagement (Chiu et al., 2023).

Furthermore, the importance of aligning engineering education with industry needs and real-world applicability is emphasized in contemporary research. By integrating industry-aligned projects and experiential learning opportunities, students can acquire practical skills and knowledge that reflect current engineering practices (Chen et al., 2021; Sukackė et al., 2022). This alignment ensures that graduates possess the competencies necessary to thrive in the dynamic engineering landscape (Ambiyar et al., 2024).

Recent studies have demonstrated the effectiveness of AI-powered platforms and online learning environments in enhancing learning outcomes and preparing engineering professionals for the challenges posed by Industry 4.0 (Araiza-Alba et al., 2021; Yousuf and Wahid, 2021). Case studies highlight the benefits of personalized and interactive learning environments, showing significant improvements in student engagement, knowledge retention, and problem-solving skills (Daniela et al., 2019; Marín et al., 2020). These initiatives underscore the transformative potential of technology-enhanced learning strategies in engineering education.

Expert consultations have provided valuable insights into the integration of technology in CEE programs, underscoring the need to align educational curricula with industry requirements and leverage advanced technologies to equip graduates for the engineering workforce (Maisiri and van Dyk, 2020; Santana and de Deus Lopes, 2020; Diogo et al., 2023). Industry experts emphasize the critical role of technology in bridging the gap between educational outcomes and industry needs (Armstrong et al., 2020).

Exploring AI within the CEE could open new perspectives on improved learning methodologies, offering deep insights into the benefits and challenges associated with their adoption (Diery et al., 2020; Kuleto et al., 2021). For example, the proposal of dynamic taxonomies based on KSAs promises to be a valuable tool for designing learning activities that cultivate higher-order thinking skills essential for navigating the complexities of Industry 4.0 (Caratozzolo et al., 2023a).

A pivotal aspect of this discussion is the ShapingSkills framework, which offers a comprehensive plan to integrate the principles of Education 4.0 into CEE (ShapingSkills, 2023a). By prioritizing student-centered learning, technology integration, and lifelong learning, this framework serves as a guiding light for reimagining engineering education in the digital age.

The integration of new technologies and innovative learning approaches is crucial for seeking to empower the future engineering workforce (Won et al., 2023). By seeking to leverage Industry 4.0 technologies, developing personalized learning experiences, and embracing Education 4.0 principles (Neaga, 2019), CEE programs can equip engineering professionals with the skills and expertise needed to thrive in an ever-evolving technological landscape (Hernandez-de Menendez et al., 2020). This research aims to contribute to the ongoing discourse on transforming engineering education to meet the demands of Industry 4.0.

3 Methodology

To develop this work, we explored the intersection between the new technologies of Industry 4.0 and the current pedagogical strategies in HE, aiming to design a comprehensive framework for CEE programs that are forward-looking and capable of addressing future challenges. Our methodology consists of several iterative steps, each designed to provide a robust foundation for integrating transformative technologies and innovative learning approaches into CEE programs.

The initial phase involved thoroughly reviewing the existing literature on CEE, Industry 4.0 technologies, and innovative learning methodologies. This review aimed to identify the current state of the art, existing gaps, and potential opportunities for improvement in CEE programs.

Following the literature review, we conducted a detailed analysis of case studies that demonstrated successful implementations of technology-enhanced learning approaches in engineering education. These case studies were selected based on their relevance, impact, and innovative use of AI and NLP technologies in educational settings. The case studies were analyzed to identify best practices, challenges, and lessons learned that could inform the design of our framework for CEE programs.

To complement the literature review and case studies findings, we conducted expert consultations with industry professionals, educators, and policymakers. These consultations aimed to gather valuable insights into the practical aspects of integrating new technologies into CEE programs and to understand the needs of the industry, as well as the pedagogical requirements and potential barriers to implementation.

Building on the insights gathered, we developed a dynamic KSA-based matrix taxonomy tailored for the INFOCOMM sector. This taxonomy was designed to be adaptive and responsive to the evolving requirements of the Industry 4.0 landscape. We utilized NLP and machine learning techniques to analyze data from various sources, including SkillsFuture, the Standard Occupational Classification (SOC), and the NESTA taxonomy, to ensure that the taxonomy remained dynamic and could evolve with changing occupational profiles (Caratozzolo et al., 2023a; ShapingSkills, 2023a).

The methodology was designed to be iterative, allowing for continuous refinement based on feedback and new insights. We used the ShapingSkills framework to create personalized and adaptive learning experiences for engineering professionals, continuously evaluating the effectiveness of integrating new technologies and learning approaches (ShapingSkills, 2023a). This iterative approach allowed us to address critical challenges in CEE and propose a holistic strategy to enhance the effectiveness and relevance of CEE programs.

Finally, we conducted a comprehensive analysis of the results to compare the proposed taxonomy with existing frameworks, addressing the research objectives and highlighting the study's limitations. The findings were validated through empirical data and expert feedback to ensure that the taxonomy met the operational needs of the INFOCOMM sector and supported future scenarios of occupational profiles based on KSAs.

Overall, this methodology provides a systematic approach to exploring the integration of transformative technologies and learning approaches into CEE programs, with the ultimate goal of equipping the future engineering workforce with the skills and knowledge necessary to thrive in the era of Industry 4.0.

4 Application of the ShapingSkills framework

In alignment with the transformative challenges described in the previous sections, we present a detailed case study of the ShapingSkills framework's innovative application within CEE. This framework aims to revolutionize how educational institutions prepare engineering professionals for the dynamic demands of Industry 4.0.

The ShapingSkills framework is a pioneering initiative synthesizing core functionalities from established models to provide a comprehensive approach to KSAs taxonomies. Traditional KSA-based taxonomies have historically profiled worker competencies (Seemiller and Whitney, 2020) but often fail to adapt to the rapid changes in the employment landscape (WEF, 2019). The ShapingSkills framework (ShapingSkills, 2023a) addresses this challenge with an innovative approach, introducing a dynamic KSA matrix taxonomy, developed through a systematic literature review from 2013 to 2023 and leveraging AI methods to maintain its adaptability and relevance (Caratozzolo et al., 2023a).

Using AI and machine learning tools, ShapingSkills predicts and prepares for changing labor market requirements (Caratozzolo et al., 2023a). This dynamic approach allows the framework to continuously update its taxonomy based on evolving occupational profiles and industry needs. The interactive web interface enhances usability, enabling users to explore and understand the complexities of future workforce demands (ShapingSkills, 2023a). This represents a significant shift in how occupations are conceptualized and prepared for, aligning with the evolving demands of Industry 4.0.

The ShapingSkills (2023a) interface offers seamless navigation and connectivity with official sites, universities, companies, and sponsors. Users can select the INFOCOMM sector, which provides a comprehensive overview of sub-sectors and detailed lists of associated occupations. Each occupation page includes graphical representations and detailed descriptions of relevant KSAs, facilitating a deep understanding of the skills required for various roles.

To illustrate the practical application, we examine the list of skills of the ICT sales professional occupation, such as is seen in Figure 1. The ShapingSkills framework allows users to compare skills across occupations, highlighting areas for reskilling or upskilling. For example, if an individual is considering a career transition within the same industry, they can compare their current skills with those required for three different occupations within the Business Intelligence and IT Systems Design subsector, as shown in Figure 2. This comparison facilitates the identification of specific

FIGURE 1
ShapingSkills occupation skills view (ShapingSkills, 2023b).

skills that need enhancement or development to successfully transition to a new role within the subsector.

Under the assumption that the user wants to transition to a marketing manager role, the framework identifies common skills, such as service orientation, leadership, and interpersonal skills, as seen in Figure 2, indicating areas where retraining may be sufficient rather than a comprehensive improvement of the abilities. Additional skills required for the new role, such as communication, creative thinking, and digital literacy, are highlighted for development. The framework seeks to support continuous learning and it is planned to have a section where relevant courses can be suggested to close these skills gaps.

This case study demonstrates how the ShapingSkills framework supports robust training options by leveraging its dynamic KSA taxonomy. It advocates a comprehensive training strategy that combines formal education, specialized programs, and continuing professional development to improve various skills. By offering a specialized KSA catalog for each occupation related to the INFOCOMM sector, it allows personalized learning experiences and adaptive learning paths to be developed, ShapingSkills aligning educational outcomes with the changing needs of the INFOCOMM sector.

ShapingSkills forms a consortium with universities, human resources companies, and online learning providers, creating a strategic alliance that addresses the workforce needs of Industry 4.0, including the INFOCOMM sector. This collaborative effort aims to understand the global industry's requirements, foster interdisciplinary collaboration, and achieve educational innovation that is aligned with future KSA needs. As a dynamic platform, ShapingSkills is poised to adapt to industry changes and contribute significantly to the evolution of continuing education.

This case study highlights the practical application and benefits of the ShapingSkills framework, demonstrating its potential to revolutionize CEE programs and support the continuous professional development of the engineering workforce in the dynamic landscape of Industry 4.0.

5 Results and discussion

Current research on empowering the workforce of the future through transformative technologies and innovative learning approaches in CEE has yielded significant results and insights. This section delves into key findings and their implications for advancing CEE programs in the context of Industry 4.0.

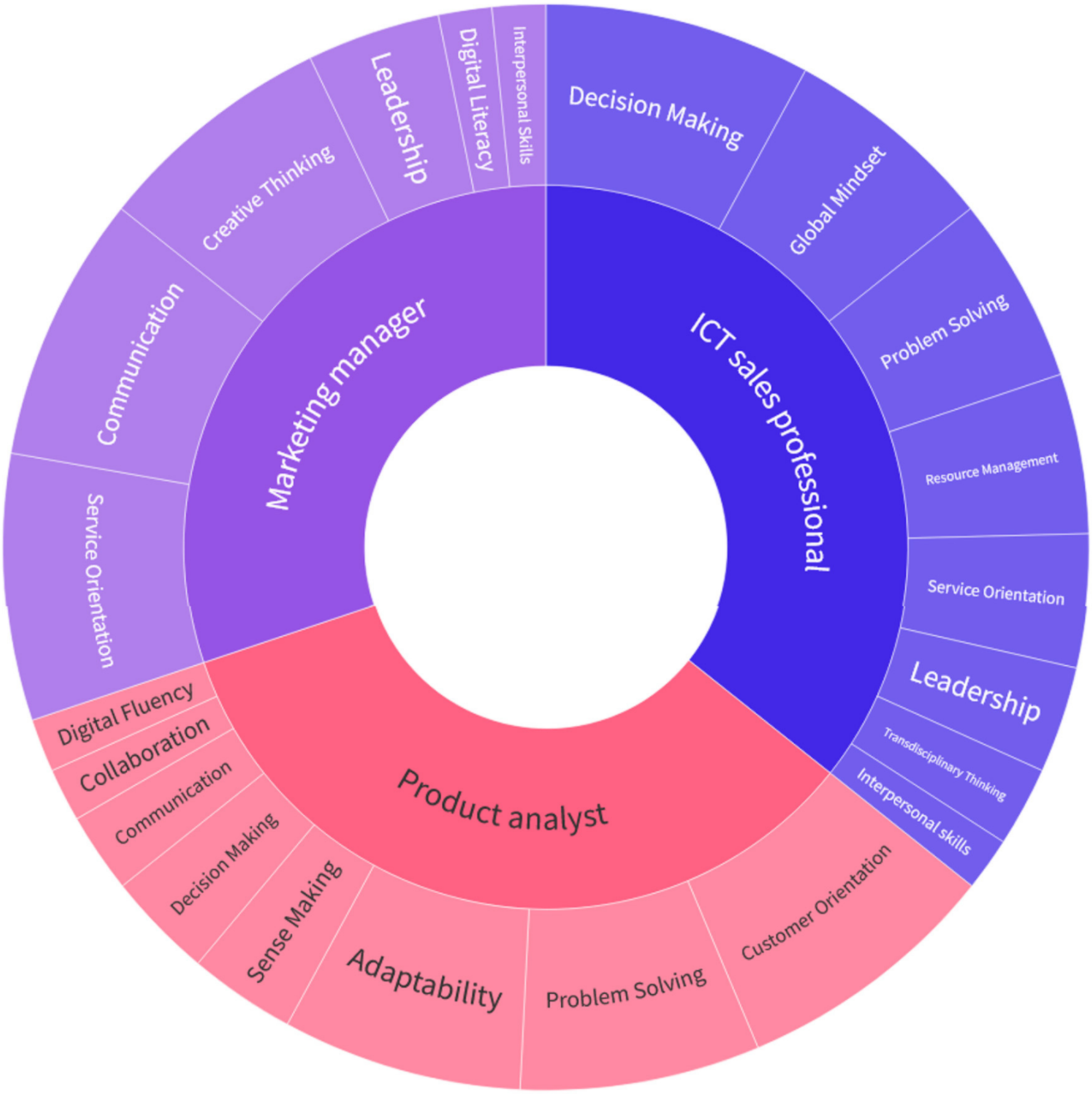

FIGURE 2
ShapingSkills occupations skills comparative view (ShapingSkills, 2023b).

Globalization, Artificial Intelligence, and recent global challenges like economic shifts or technological development are rapidly evolving, posing complex challenges to the engineering workforce. Preparing to overcome these requires continuous education and professional development, essential for maintaining or increasing employability in a dynamic landscape (Ahsan et al., 2022; Thwe and Kálmán, 2023).

Engineers transitioning from one occupation to another, as illustrated in our case study, must engage in reskilling or upskilling to meet new job requirements. Within a vast and complex landscape of competencies and learning opportunities, focused and efficient efforts are necessary to fulfill such demands at an accelerated pace (Chen L. et al., 2020; Krstić et al., 2022).

A key outcome of this research was to illustrate the diverse applications and advantages of skill visualization offered by the ShapingSkills (2023a) platform. The taxonomy, derived from a comprehensive review of AI literature and methods, provides a dynamic framework to understand and address evolving skill requirements in the engineering domain (Caratozzolo et al., 2023a). This platform aims to demonstrate the possible synergies between the technical advances of Industry 4.0 and the pedagogical strategies of HE, enabling the creation of personalized and adaptive learning experiences for engineering professionals, addressing their individual needs and preferences. The example described earlier (Figure 2) underscores the relevance of the ShapingSkills platform as a valuable tool for lifelong learners, helping them to efficiently identify the skills needs to achieve their career goals.

Our research highlights the importance of collaborative efforts and strategic alliances in promoting CEE programs. By bringing together universities, industry stakeholders, and online learning providers, initiatives like ShapingSkills can address the diverse needs of the engineering workforce. In the previously evaluated example (Figure 2), the platform assists professionals in identifying educational institutions, training opportunities, or online programs that align with their preferences and objectives.

The aforementioned collaboration and alliances foster interdisciplinarity, educational innovation, and adaptability, ensuring that CEE programs remain relevant and effective in the face of technological advancements and industry changes (Armstrong et al., 2020). Regarding an implementation plan with international stakeholders, some of the steps required for integrating the proposed platform and taxonomy into CEE programs could be the design of an initial assessment and stakeholder engagement, the pilot testing and iterative refinement, and a final assessment together with a full-scale deployment and the commitment of a continuous improvement. Regarding the required resources, we considered not only the human resources (educators and content developers) but also the financial resources, including the training, maintenance, and probably the funding for the development. The main stakeholders have specific roles necessary in successfully implementing and scaling the proposed solutions. Educators will have an essential role in developing curriculum, delivering content, and providing feedback. Industry Partners will be crucial in providing insights into industry needs, funding, and collaboration on curriculum design.

Our research underscores the effectiveness of online courses, virtual laboratories, collaborative platforms, and industry-aligned projects in CEE programs. By incorporating these elements, CEE can bridge the theoretical-practical gap and meet the dynamic needs of Industry 4.0. Online courses offer flexibility and accessibility, allowing engineering professionals to engage in continuous learning while balancing their work commitments (Yousuf and Wahid, 2021). Virtual laboratories provide hands-on experience in a simulated environment, enhancing practical skills and knowledge acquisition (Marín et al., 2020). Collaborative platforms facilitate peer-to-peer learning and knowledge sharing, fostering a sense of community and collaboration among students (Zawacki-Richter et al., 2019). Industry-aligned projects offer real-world context and relevance, preparing engineering professionals for the challenges of the modern workforce (Chen et al., 2021). All those implementations implicate potential challenges related to the resistance to changes and barriers, probably related to costs and technical limitations, that will be overcome. The implementation roadmap must take into account, on the one hand, management strategies such as involving educators in development, providing incentives, and showcasing success stories, and on the other hand, the possibility of funding from industry partners and the options for long-term cost savings.

In addition to these practical implications, our research highlights the pivotal role of Education 4.0 principles in shaping the future trajectory of CEE programs. These principles, including sustainability technologies and practices, learner-centeredness, collaborative learning, technology-enhanced learning experiences, and lifelong learning, advocate for a student-centered approach, the integration of technology, and continuous learning (Caratozzolo et al., 2023a). By adopting these principles, CEE programs can be reinvented to meet the evolving needs of engineering professionals in the digital age. Incorporating principles of sustainability into the curriculum promotes responsible consumption and production, enhancing the understanding of the global challenges and their potential solutions (Cuevas-Cancino et al., 2024). Learner-centered approaches ensure that education is tailored to individual needs and preferences, improving engagement and motivation (Neaga, 2019). Technology-enhance pedagogies enable the use of innovative tools and platforms to improve learning outcomes and experiences (Krstić et al., 2022). Lifelong learning fosters a culture of continuous improvement and adaptability, equipping engineering professionals with the skills and resilience necessary to thrive in a rapidly changing environment (Hernandez-de Menendez et al., 2020).

Our results demonstrate the transformative potential of integrating new technologies and learning approaches in CEE programs. By leveraging Industry 4.0 technologies, developing personalized learning experiences, and embracing Education 4.0 principles, CEE programs can empower the workforce of the future to thrive in an increasingly complex and dynamic landscape.

6 Conclusions and future work

The integration of transformative technologies and innovative learning approaches has immense potential to empower the future engineering workforce through CEE programs. This study has highlighted several key findings and insights, underscoring the critical importance of this integration in the context of Industry 4.0.

One of the primary outcomes of this research was to demonstrate the various applications and benefits of skill visualization provided by the ShapingSkills platform. This platform demonstrates how technological advancements can be effectively synergized with pedagogical strategies in HE. It enables the creation of personalized and adaptable learning experiences for engineering professionals, addressing their individual needs and preferences while providing a dynamic framework to comprehend evolving skills requirements.

This study also underscores the effectiveness of online courses, virtual laboratories, collaborative platforms, and industry-aligned projects in CEE programs. These elements are crucial in bridging the gap between theoretical knowledge and practical application, offering flexibility and accessibility, enhancing practical skills, and fostering knowledge exchange and collaboration. The integration of these components is pivotal for developing a workforce that is agile and equipped to meet the challenges of the Industry 4.0 era.

Collaborative efforts and strategic alliances, as illustrated by initiatives like ShapingSkills, play a vital role in maintaining the relevance and effectiveness of CEE programs. By uniting universities, industry stakeholders, and online learning providers, these alliances seek to foster innovation, interdisciplinary collaboration, and educational adaptability. They ensure that CEE programs remain responsive to technological advances and industry changes.

In conclusion, the integration of new technologies and innovative learning approaches is essential for ensuring the future readiness of the engineering workforce. Flexible, accessible, and interactive educational pathways, coupled industry-aligned projects and student-focused, technology-driven methodologies, are critical for maintaining the relevance and sustainability of CEE in the era of Industry 4.0.

The findings of this study also highlight several avenues for future research and development in the field of CEE. Further refinement and validation of frameworks like ShapingSkills, which have shown promising results, is necessary to guarantee their effectiveness and applicability across various engineering disciplines and educational contexts. Additionally, there is a need to actively investigate how these technologies can enhance learning experiences, facilitate skill development, and simulate real-world scenarios. Research should explore innovative approaches, such as gamification and experiential learning, to foster communication, teamwork, and leadership skills among engineering professionals.

Finally, promoting international collaboration and knowledge exchange between universities, industrial partners and policymakers is essential for the continuous improvement of CEE programs. Such collaboration can facilitate the exchange of best practices, resources, and experiences, ensuring that CEE programs remain relevant and responsive to the evolving needs of the engineering workforce in the context of Industry 4.0 and beyond. By addressing these areas, we can enhance the quality and relevance of CEE programs worldwide, ensuring they continue to meet the changing needs of the engineering workforce and contribute to a more dynamic and innovative future.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Author contributions

JA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. VR-C: Methodology, Writing – review & editing. CC-Z: Validation, Writing – review & editing. GC: Validation, Writing – review & editing. JM-H: Validation, Writing – review & editing. PC: Supervision, Validation, 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.

Publisher's note

References

Ahsan, K., Akbar, S., and Kam, B. (2022). Contract cheating in higher education: a systematic literature review and future research agenda. *Assess. Eval. High. Educ.* 47, 523–539. doi: 10.1080/02602938.2021.1931660

Ambiyar, A., Wulansari, R. E., Dewi, F. K., Ananda, Y. F., and Zumroh, Z. (2024). Trends of project based learning in engineering education from 2008 to 2023: a systematic literature review approach. *J. Pendidikan Tambusai* 8, 6328–6337. doi: 10.31004/jptam.v8i1.13375

Araiza-Alba, P., Keane, T., Chen, W. S., and Kaufman, J. (2021). Immersive virtual reality as a tool to learn problem-solving skills. *Comp. Educ.* 164:104121. doi: 10.1016/j.compedu.2020.104121

Armstrong, M. E., Jones, K. S., Namin, A. S., and Newton, D. C. (2020). Knowledge, skills, and abilities for specialized curricula in cyber defense: results from interviews with cyber professionals. *ACM Transact. Comp. Educ.* 20, 1–25. doi: 10.1145/3421254

Caratozzolo, P., Azofeifa, J., Mejia, A., Rueda-Castro, V., Noguez, J., Magana, A., et al. (2023a). "A matrix taxonomy of knowledge, skills, and abilities (KSA) shaping 2030 labor market," in *2023 IEEE Frontiers in Education Conference (FIE)*, 1–8.

Caratozzolo, P., Nørgaard, B., and Rodriguez-Ruiz, J. (2023b). "Curriculum adaptation in continuing education programs to prepare industry 4.0 workforce," in *2023 World Engineering Education Forum-Global Engineering Deans Council (WEEF-GEDC)* (IEEE), 1–6.

Chakrabarti, S., Caratozzolo, P., Norgaard, B., and Sjoer, E. (2021). "Preparing engineers for lifelong learning in the era of industry 4.0," in *2021 World Engineering Education Forum/Global Engineering Deans Council (WEEF/GEDC)* (IEEE), 518–523.

Chen, J., Kolmos, A., and Du, X. (2021). Forms of implementation and challenges of PBL in engineering education: a review of literature. *Eur. J. Eng. Educ.* 46, 90–115. doi: 10.1080/03043797.2020.1718615

Chen, L., Chen, P., and Lin, Z. (2020). Artificial intelligence in education: a review. *IEEE Access* 8, 75264–75278. doi: 10.1109/ACCESS.2020.2988510

Chen, X., Xie, H., Zou, D., and Hwang, G.-J. (2020). Application and theory gaps during the rise of artificial intelligence in education. *Comp. Educ.* 1:100002. doi: 10.1016/j.caeai.2020.100002

Chiu, T. K., Xia, Q., Zhou, X., Chai, C. S., and Cheng, M. (2023). Systematic literature review on opportunities, challenges, and future research recommendations of artificial intelligence in education. *Comp. Educ. Artif. Intell.* 4:100118. doi: 10.1016/j.caeai.2022.100118

Cuevas-Cancino, M. O., Peña-Becerril, M., Mondragon-Estrada, E., and Camacho-Zuñiga, C. (2024). Incorporating vertical collaboration to address sustainable development goals: the monarch route project. *Front. Educ*. 9:1246889. doi: 10.3389/feduc.2024.1246889

Daniela, L., Strods, R., and Kalniçna, D. (2019). "Technology-enhanced learning (TEL) in higher education: Where are we now?," in *Knowledge-Intensive Economies and Opportunities for Social, Organizational, and Technological Growth* (IGI Global), 12–24.

Diery, A., Vogel, F., Knogler, M., and Seidel, T. (2020). Evidence-based practice in higher education: teacher educators' attitudes, challenges, and uses. *Front. Educ*. 5:62. doi: 10.3389/feduc.2020.00062

Diogo, R. A., dos Santos, N., and Loures, E. F. (2023). Digital transformation of engineering education for smart education: a systematic literature review. *Reliabil. Model. Ind*. 4, 407–438. doi: 10.1016/B978-0-323-99204-6.00002-9

Ekren, B. Y., and Kumar, V. (2020). "Engineering education towards industry 4.0," in *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 10–12.

Hernandez-de Menendez, M., Escobar Díiaz, C. A., and Morales-Menendez, R. (2020). Engineering education for smart 4.0 technology: a review. *Int. J. Interact. Des. Manuf*. 14, 789–803. doi: 10.1007/s12008-020-00672-x

Hernández-Muñnoz, G. M., Habib-Mireles, L., García-Castillo, F. A., and Montemayor-Ibarra, F. (2019). Industry 4.0 and engineering education: an analysis of nine technological pillars inclusion in higher educational curriculum. *Best Pract. Manuf. Process*. 525–543. doi: 10.1007/978-3-319-99190-0_24

Krstić, L., Aleksić, V., and Krstić, M. (2022). *Artificial Intelligence in Education: A Review*. Čačak: Faculty od Technical Sciences.

Kuleto, V., Ilić, M., Dumangiu, M., Ranković, M., Martins, O. M., Păun, D., et al. (2021). Exploring opportunities and challenges of artificial intelligence and machine learning in higher education institutions. *Sustainability* 13:10424. doi: 10.3390/su131810424

Maisiri, W., and van Dyk, L. (2020). "Industry 4.0 competence maturity model design requirements: a systematic mapping review," in *2020 IFEES World Engineering Education Forum-Global Engineering Deans Council (WEEF-GEDC)* (IEEE), 1–6.

Marín, V. I., de Benito Crosetti, B., and Darder, A. (2020). Technology-enhanced learning for student agency in higher education: a systematic literature review. *IxD&A* 45, 15–49. doi: 10.55612/s-5002-045-001

Miranda, J., Navarrete, C., Noguez, J., Molina-Espinosa, J.-M., Ramírez-Montoya, M.-S., Navarro-Tuch, S. A., et al. (2021). The core components of education 4.0 in higher education: three case studies in engineering education. *Comp. Electr. En*. 93:107278. doi: 10.1016/j.compeleceng.2021.107278

Neaga, I. (2019). "Applying industry 4.0 and education 4.0 to engineering education," in *Proceedings of the Canadian Engineering Education Association (CEEA)*.

Newton, P. M., Da Silva, A., and Peters, L. G. (2020). A pragmatic master list of action verbs for bloom's taxonomy. *Front. Educ*. 5:107. doi: 10.3389/feduc.2020.00107

Santana, A. L. M., and de Deus Lopes, R. (2020). "Active learning methodologies and industry 4.0 skills development-a systematic review of the literature," in *2020 XV conferencia latinoamericana de tecnologias de aprendizaje (LACLO)* (IEEE), 1–10.

Seemiller, C., and Whitney, R. (2020). Creating a taxonomy of leadership competency development. *J. Leadersh. Educ*. 19, 119–132. doi: 10.12806/V19/I1/R5

ShapingSkills (2023a). *Shaping Skills*. Available online at: https://shapingskills.mx/ (accessed November 29, 2023).

ShapingSkills (2023b). *Shaping skills home / infocomm / business intelligence and it systems design / ict sales professional*. Available online at: https://shapingskills.mx/ocupacion?id=2 (accessed January 9, 2024).

Sukackė, V., Guerra, A. O. P. C., Ellinger, D., Carlos, V., Petronienė, S., Gaižiūnienė, L., et al. (2022). Towards active evidence-based learning in engineering education: a systematic literature review of PBL, PjBL, and CBL. *Sustainability* 14:13955. doi: 10.3390/su142113955

Thwe, W. P., and Kálmán, A. (2023). Lifelong learning in the educational setting: a systematic literature review. *Asia Pac. Educ. Res*. 33, 1–11. doi: 10.1007/s40299-023-00738-w

Treviño-Elizondo, B. L., and García-Reyes, H. (2023). What does industry 4.0 mean to industrial engineering education? *Proc. Comput. Sci*. 217, 876–885. doi: 10.1016/j.procs.2022.12.284

WEF (2019). *Towards a Reskilling Revolution: Industry-Led Action for the Future of Work*. Available online at: https://www.weforum.org/publications/towards-a-reskilling-revolution-industry-led-action-for-the-future-of-work/ (accessed December 8, 2023).

Won, M., Ungu, D. A. K., Matovu, H., Treagust, D. F., Tsai, C.-C., Park, J., et al. (2023). Diverse approaches to learning with immersive virtual reality identified from a systematic review. *Comp. Educ*. 195:104701. doi: 10.1016/j.compedu.2022.104701

Yousuf, M., and Wahid, A. (2021). "The role of artificial intelligence in education: current trends and future prospects," in *2021 International Conference on Information Science and Communications Technologies (ICISCT)* (IEEE), 1–7.

Zawacki-Richter, O., Marín, V. I., Bond, M., and Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education-where are the educators? *Int. J. Educ. Technol. High. Educ*. 16, 1–27. doi: 10.1186/s41239-019-0171-0