Integration and Deployment of AI Technologies in Engineering Education: A Scoping Literature Review

Mohammed TAHIRI
LRI,ENSEM
University of Hassan II Casablanca
Casablanca, Morocco
mohammed.tahiri.doc22@ensem.ac.ma

Bahia Alaoui Ismaîli
LRI,ENSEM
University of Hassan II Casablanca
Casablanca, Morocco
b.alaoui@ensem.ac.ma

Soumia Bakkali
LRI,ENSEM
University of Hassan II Casablanca
Casablanca, Morocco
s.bakkali@ensem.ac.ma

***Abstract*—Recently, the integration of New Information and Communication Technologies (ICTs) and AI technologies in the field of higher education has generated a great interest on the part of both academic and industrial actors. There are many approaches to introducing AI technologies into engineering students' education programs, to better develop their innovation and creativity, in order to meet the eminent needs of industries 4.0 and 5.0. The present study focuses on a recent literature review of the best approaches to integrating AI into the education of engineering students. To conduct a scoping review, we exploited the "Scopus" and "Web of Science" databases to identify recent articles published between 2018 and 2023. We are interested in research aimed at improving the skills of engineering students through the integration of AI-powered approaches and tools. The integration of AI tools in the education of engineering students is a fast-growing field of research worldwide. Such approaches are promising and can help teachers to better understand students' needs and adapt their teaching methods in light of them.**

***Index Terms*—New Information and Communication Technologies (ICTs), Artificial Intelligence (AI) in higher education, Engineering Education, Teaching innovation, Engineering skills, Industry 4.0 and 5.0, AIED, AI-enhanced learning**

I. Introduction

In the current era of artificial intelligence, many fields are experiencing revolutionary advances thanks to the exploitation of big data and high data processing capacity. As in the industrial sector, many AI-assisted solutions are being experimented with in the engineering education sector, with the aim of improving curricula, and the education process in general. Developing countries face sustainability challenges. Quality education is one of the 17 SDGs set out in the United Nations' Agenda 2030 [1], and where countries need to increase their efforts. Several success stories have been identified in these countries, which were the subject of our previous research work [2]. The aim of this study is to explore the possibilities of deploying artificial intelligence in the undergraduate engineering education through the most recent research work, and to identify the teaching methods implemented to prepare future engineers to assimilate the challenges of AI based on the needs of the industrial environment and sustainability objectives.

In fact, in the context of emerging industry 4.0 and 5.0, as well as the growing adoption of technologies such as the Internet of Things, augmented reality and artificial intelligence, engineering schools are being forced to significantly revise their traditional academic curricula to meet the changing needs of industry. However, the use of AI tools for the general public, in higher education and for innovative development in industry, requires the application of good practices and critical thinking towards effective solutions, while avoiding falling into the plagiarism trap or the automatic adoption of proposed solutions [3].

In this study, and in order to better understand the main ways in which AI can be integrated into education programs, we thought it would be interesting to first explore the relevant studies carried out in the specific field of future engineers' education, in order to achieve the set objectives.

It's true that AI is making remarkable progress thanks to the emergence of generative AI, which is now widespread in all fields [4]. Tools such as generative neural networks, GANs (Generative Adversarial Networks) or language models like GPT (Generative Pre-trained Transformer), have considerably enriched the creative capabilities of computer systems. For example, GANs are now capable of generating realistic images from text descriptions, thus opening up promising horizons in the design of visual teaching material. Similarly, language models like GPT can automatically write texts from simple primers, simplifying the creation of teaching materials and course content [3].

The report by UNESCO [1] highlighted various uses of generative AI in higher education, including teaching, student learning, research, administration and community engagement. Potential uses for learning include the possibility of generating a work or research plan, multiplying responses in several versions and also asking the machine to play the role of trainer in a very specific field. The rapid evolution of large-scale language models (LLMs) represents a revolution in the field of generative artificial intelligence. These advances offer powerful tools that can imitate human thinking with outstanding accuracy. These tools, called "co-pilots" in the new jargon of the field, act as assistants to engineers, significantly increasing their productivity by solving problems in more efficient and innovative ways. These tools can automate repetitive tasks and analyze huge volumes of data at unequalled speed [5]. According to the mentioned report, it is essential for the user to have an understanding of generative AI tools. The case study focuses on the use of ChatGPT, the principles however apply to other similar tools. The use of these tools must be innovative and focused on maximizing their positive impact on students, while respecting an ethical approach and taking into account the desired learning outcomes. Our study aims to explore approaches and methodologies for integrating and exploiting AI, with an emphasis on generative AI, in the education of future engineers. The aim is to improve their skills and ability to solve problems within a framework of creativity and innovation. We are mainly interested in generative AI tools that do not require prior programming knowledge. The non-perfect nature of generative AI tools requires careful use and the establishment of community guidelines for ethical use. The adoption of these tools in the education of future engineers highlights the need to adapt evaluation methods to avoid unethical behavior and optimize efficiency at the same time [5]. Nowadays, in order to enhance students' skills and improve teaching efficiency, several universities are implementing specific pedagogical methods and approaches based on AI tools and designed to facilitate the learning process [6]. As part of this research work, it would be relevant to explore how these approaches are applied to the implementation of student use of AI tools. The results of this study will serve as a useful examples for teachers in engineering schools. We thus formulate our research question: what pedagogical approaches, theories and tools for integrating AI into the training of future engineers with a view to improving their creativity and innovation skills?

II. Methodology

We conducted our literature review following the PRISMA protocol for scoping reviews, the template for which is available on the website http://www.prisma-statement.org/Extensions/ScopingReviews.

- **Search criteria**

Eligible works for our scoping literature review are SCOPUS and WoS articles published between 2018 and 2023. The articles included are written in English and include the keywords (Artificial intelligence), education, engineer , as well as terms with the same root as the terms creativity or innovation. This query in the cited databases resulted in 531 articles. The query used was as follows: TITLE-ABS-KEY ("artificial intelligence" education AND engineer* AND (creativ* OR innov*)) AND PUBYEAR >2017 AND PUBYEAR <2024 AND KEY (educati*) (LIMIT-TO (EXACTKEYWORD , "Engineering Education"))

- **Inclusion and exclusion criteria**

Excluded articles concern the training of kids and teenagers in primary and secondary education. Also excluded are literature reviews and articles that do not concern the engineering education in a higher education context according to their abstracts. In a second selection phase, we targeted articles whose abstracts contained one of the following terms: "skills", "competence" or "ability". This choice stemmed from the aim of our research, which was to identify work on improving students' skills. To organize the articles and apply the chosen criteria, we used the Rayyan.ai tool. We analyzed the bibliographic data of the articles found, in particular their titles, abstracts, keywords, authors, year of publication and journal of publication.

The selection process for our scoping review based on the PRISMA method is summarized in the diagram in Figure 1, representing the framework proposed by this method.

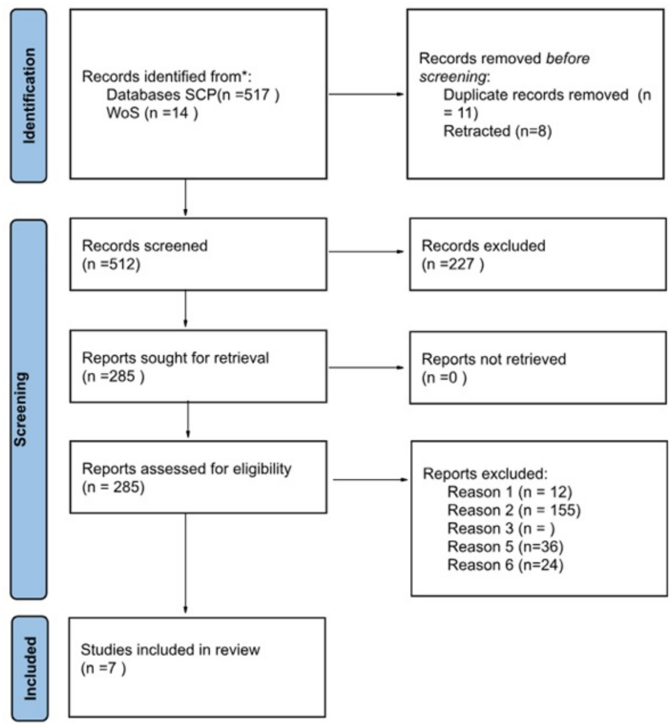

Figure 1. Selection process for literature reviews according to the PRISMA protocol

During the identification stage, the search on Scopus generated 517 publications and 14 publications on WoS. We identified 11 duplicate publications and 8 retracted publications. 227 publications did not contain any of the key terms "skills", "competence" or "ability". The titles and abstracts of the remaining 285 articles were read to exclude ineligible articles according to the exclusion criteria detailed in Table 1. Finally, 7 articles were retained.

III. Results

The evolution of the number of articles published between 2018 and 2023 is shown in figure 2. Figure 2 shows a significant increase of over 500 per cent from 2018 to 2023. A slight stagnation is observed between 2021 and 2022, but the trend continues until the end of 2023.

Table I
INCLUSION AND EXLUSION CRITERIA

Inclusion criteria	exclusion criteria
Engineering students in university context Skills competencies Works enhancing Innovation and creativity Experimentation on groups of students	Reason 1: K-12, primary and high school Reason 2: not concerning undergraduate students in engineering fields Reason 3: Literature reviews Reason 4: not Artificial intelligence applications Reason 5 : not focusing on AI learning or curriculum Raison 6 : not containing student groups for experimentations

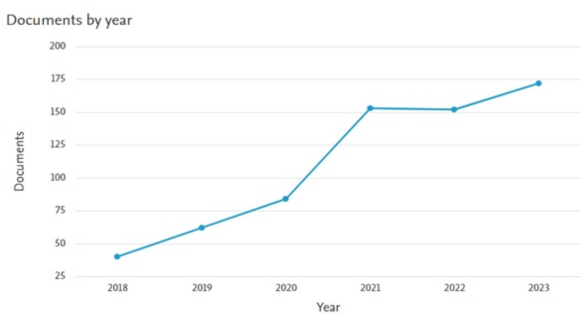

Figure 2. Evolution of scientific publications between 2018 and 2023 according to Scopus search criteria

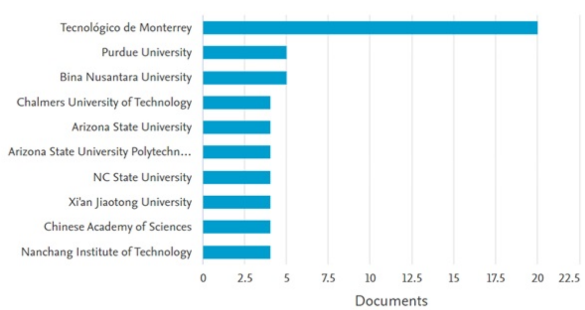

Figure 3. authors' affiliations ranked by number of publications

Using the same Scopus database, we analyzed authors' affiliations. The results shown in Fig. 3 reflect the remarkable activity of the Monterrey Institute of Technology and Advanced Studies, better known as Tecnológico de Monterrey, located in Mexico, which is, according to our findings, the best source of scientific research for our field of interest, if only by the criterion of the number of publications (Fig.3). Identified and selected papers deal with applications in the field of engineering education for students enrolled in university engineering programs. We have identified the theories and concepts applied by the research groups and their approaches to integrating AI techniques and tools into the engineering education curriculum in a context aimed to meet the Industry needs. The article [7] proposes a teaching model based on a combination of Challenge-based-learning, Project-based-learning and Computer-Aided technologies . The aim is to assess the correlation between the positive effect of the implementation of computer-based tools (CAx) combined with these pedagogical approaches on the SDG-oriented skills of industrial engineering students. The integration of these methodologies with CAx tools has significantly improved learning outcomes, offering a holistic approach to engineering education that aligns with today's technology and sustainability requirements. Project-based learning (PjBL) often overlaps with problem-based learning, since both learning strategies are based on collaboration and self-direction. However, PjBL is more oriented towards knowledge mobilization, while problem-based learning is more oriented towards knowledge acquisition. Moreover, PjBL activities are generally closer to real work activities [8]. The process most often comprises five stages (or even seven, for some authors), such as: Orientation, identification and definition of the project object, process planning, implementation, reporting and evaluation [9]. In the research work by (Pérez-Rodríguez et al., 2020) [7], students are asked to develop smart and sustainable solutions. The application of computer-based learning (CBL) by students to design and manufacture a new product incorporating positive attributes, functions and social impacts is framed by the application of approaches such as the integrated product, process, and manufacturing system development (IPPMD) and the theory of sensing, smart, and sustainable systems (S3 Systems). The experiments cited in this research work were carried out at the University of Holguin in Cuba and the Universidad Tecnológica de Monterrey (ITESM) in Mexico. These institutions were used to implement and evaluate the framework integrating challenge-based learning, project-based learning and computer-assisted technologies (CAx) into industrial engineering education, with a focus on sustainable development.

In the article by [10], AI and virtual reality (VR) technologies are implemented in petroleum engineering education to enhance student learning and engagement by simulating field trips, which are essential for connecting theoretical knowledge with real-world applications. VR-based field trips enable students to virtually experience real-life petroleum facilities, overcoming the logistical, safety and accessibility limitations of traditional field trips.

In the article by (Oveissi AND Ghadi, 2021) [11], the authors attempt to introduce a course module on applied digital technologies for Industry 4.0 for the benefit of Chemical Engineering students by integrating skills in programming, data-based modeling, digital twins, predictive data analysis, artificial intelligence and deep learning. The experiment described in the article was conducted at the School of Chemical and Biomolecular Engineering at the University of Sydney, Australia. The skills developed mainly concern the fields of IoT, AI, digital twin, deep learning, etc., through practical activities aimed at developing digital solutions for the chemical industry.

The paper [12] offers a smart product design course as part of a new master's degree The new Master's course Smart Products, Engineering and Services (SPES). Students take theoretical courses in engineering, business development, innovation and marketing. A period of individual learning begins with flipped-classroom exercises, where groups of students prepare short presentations. This is followed by a hands-on intelligent solution design workshop, where students apply their acquired knowledge. AI was applied in the development project phase, where students created an intelligent product to perform a control task, integrating AI for data analysis and prediction of system behavior, demonstrating the practical application of AI in engineering education. The flipped classroom is a method for teaching problem-solving skills for more complex tasks. Developed by Bergmann and Sams (2012) [13], the flipped classroom is essentially based on the before-class stage: Students discover new notions at home, usually by watching short, interactive video vignettes, reading articles or listening to podcasts. Classroom time is then dedicated to more interactive and collaborative activities, such as discussions, projects, role-playing, educational games or problem-solving. The teacher can thus focus on the individual needs of each student and guide them in their learning (Werner et al., 2018). Cho et al. (2021) [14] compiled a list of studies that highlighted various advantages and disadvantages of using flipped classrooms in mechanical engineering education.

In the article [15] a NingboTech University research dedicated to sustainable teaching models for computer science and technology students, artificial intelligence (AI) is implemented as part of a new teaching model aimed at improving learning effectiveness and efficiency. This model integrates AI tools and methods to foster initiative, teamwork, innovation skills and sustainability awareness among students. By using AI, the study seeks to improve educational outcomes in engineering disciplines, demonstrating the potential of AI to advance sustainable education and encouraging further exploration of its effectiveness in developing students' skills. This integrated approach, based on the power of AI's digital tools, is applied on several levels: teaching, learning, assessment and management.

IV. Discussion

In this paper [16], the authors examine future scenarios for information and communication technologies (ICT) and education and training technologies (ETT) in their work, focusing on implications for teaching methodologies and educational content development. The document mentions DigCompEdu, the European Digital Competence Framework for Educators, to underline the importance of developing digital competences among educators in the context of technology-enhanced learning (TEL) and technology-enhanced teaching (TET). DigCompEdu provides a scientifically sound framework that describes what it means for educators to be digitally competent, supporting the development of educator-specific digital skills across Europe. Referring to DigCompEdu, the document highlights the need for educators to improve their digital skills to navigate the changing educational landscape. These include the ability to create and manage digital learning content, analyze learner data for personalized teaching, and use digital systems for more interactive and engaging learning experiences. An experiment conducted by the authors of this paper [17] at the University of North Carolina Wilmington (UNCW) by integrating a computer thinking course into the engineering curriculum to prepare students for the AI era. This pedagogical approach, deployed through a Learning Management System (LMS), aimed to enhance students' computer thinking skills, essential for future careers in AI and technology. Computational thinking, being an approach to complex problem solving, relies on the fact that problems in every discipline can be solved by computational tools such as algorithmic thinking, decomposition, abstraction, pattern recognition. For example, one of the pillars of computational thinking is algorithmic thinking, which is the use of series of step-by-step instructions to complete a task.

The paper by [18] proposes the DC4DM (Digital Creativity for Developing Digital Maturity) model as a comprehensive framework aimed at developing the digital maturity skills needed to navigate and innovate in the digital age in this case AI. This model includes the integration of digital creativity skills aligned with the needs of digitally mature businesses, preparing students to tackle complex real-world challenges through cross-functional teamwork across design, engineering and business disciplines. The DC4DM model is structured to enable students to: - Understand the potential of digital technologies and apply them to the design of solutions with a human-centered approach. - Develop creative self-enrichment skills and a digital mindset. - Acquire forward-thinking and anticipation skills to generate long-term strategic visions. The following Table 2 summarizes the studies carried out in the above-mentioned articles, with reference to the approach used to educate the engineering students, the experimental groups and the experimental results. As students actively engage with AI technologies, they can better understand their potential, cultivate a critical mindset towards their use, and adapt more effectively to the changing demands of the professional world. This hands-on approach encourages not only the acquisition of technical knowledge, but also the development of skills in problem-solving, creativity, and innovation, preparing future engineers to make a significant contribution to sustainable development and technological advancement. The teaching methods discussed in the articles identified, such as the flipped classroom, hands-on experience and project-based learning, are gradually establishing themselves as standard approaches. These student-centered pedagogical strategies encourage deeper understanding and active engagement in the learning process. The integration of artificial intelligence (AI) tools into these methodologies, as highlighted in the articles

Table II
SYNTHESIS OF RESULTS OF CLASSROOM EXPERIMENTS BASED ON IDENTIFIED ARTICLES

Reference	Experience	Test group	Controle group	Result
Pérez-Rodriguez and all, 2022	PBL and CAx applied in the "Project III" course at the University of Holguin in Cuba	Nine students who received the integrated PBL and CAx	nine were trained traditionally	integrating CAx with CBL and PBL, can be an effective method to increase students perceptibility of SDGs
Retnanto, A.; Fadlelmula, M.; Alyafei, N.; Sheharyar, A. (2019)	VR-based field trips in petroleum engineering education	34 petroleum engineering undergraduate students	Not explicitly mentioned as a separate group	Positive student feedback on VR-based field trips, showing enhanced learning experiences, increased interest, and better understanding of petroleum engineering concepts
Oveissi, F.; Ghadi, A.E. (2021)	Hands-on experience	groups of 3-4 students	Not explicitly mentioned as a separate group	Positive Feedback
Schmitt, F.; Rudolph, K.; Kirchner, E.; Blat Belmonte, B.; Kappes, A.B.; Rinderknecht, S. (2022)	Flipped-classroom exercises	25 students. Groups of five	Not explicitly mentioned as a separate group	Positive Feedback
Zheng, W; Wen, ST; Lian, B; Nie, Y (2023)	Sustainable teaching model in computer science and technology education	259 students aged 18-22, including 219 males and 40 females	Students taught with traditional teaching methods	Enhanced learning outcomes, including improved initiative, teamwork, innovation skills, and sustainable development awareness
Dogan, G.; Song, Y.; Surek, D. (2021)	CT Course Implementation	Students enrolled in four different courses, including CS1 and AI special topics	Not explicitly mentioned as a separate group	Increased engagement and performance in CT skills, especially for newer students. Veteran students showed quicker completion times, indicating a solid foundation in computational concepts

cited, represents a significant development. AI offers unprecedented possibilities for personalizing learning, optimizing classroom interaction and solving complex problems in real time. Thus, thanks to the introduction of AI, the practice of these pedagogical approaches is not only being experimented with, but also significantly improved - the results of these experiments provide the best evidence of this. The project-based pedagogical approach described by Pérez-Rodríguez et al. (2022) [7]could be optimized by introducing validated tools to assess the effect of artificial intelligence technologies on engineering students' creativity. This optimization would enable personalized supervision of students' progress within their training.

Tanveer [3]discussed challenges facing the integration of AI in Education and how policymakers and schooling administration can support students and facilitate the implementation of an AI-powered environment as a new learning experience.

For this, we are conducting in the first section a research on Scopus and WoS for papers published between 2012 and 2022 where we explain our methodology and expose some statistics. In the second section we are explaining our methodology and trying to find relevant AI applications in engineering education through a classification of applications divided in three categories : direct applications, potential application and enhancing application factors. The third section concerns a discussion of findings before a conclusion in the last section.

V. CONCLUSION

The introduction of artificial intelligence (AI) tools into educational environments opens up an important field of research, particularly the study of their impact on student creativity. Such research could not only reveal AI's potential as a catalyst for creativity in education, but also guide the development of pedagogical practices, particularly in Moroccan Engineering Schools, that maximize the benefits of these advanced technologies while cultivating learners' creative abilities. The identified works concerning the introduction of artificial intelligence (AI) tools in the training of future engineers aims to enhance their creative capacity, while taking careful consideration of established and recognized pedagogical approaches. This is part of a continuous improvement approach to teaching methods, where AI tools do not replace existing teaching methods, but complement them by enriching the educational experience with new perspectives. The use of AI as a means of enriching with ideas and facilitating the execution of automatic tasks is proving crucial, particularly following the demands of the world of employment. The main aim of integrating these tools is to provide personalized teaching tailored to the needs and abilities of each engineering student. Thus, the adoption of AI in technical education aims not only to optimize learning processes, but also to prepare future engineers to make effective and creative use of AI tools in their respective professional fields. As a perspective and following this bibliographical work, we plan to implement and test these tools within a Moroccan engineering school according to one of the identified approaches. The aim is to stimulate students' creativity in the face of technical challenges linked to sustainability, while developing appropriate evaluation methods.

References

[1] Pedro, F., Subosa, M., Rivas, A., Valverde, P. (2019). Artificial intelligence in education: Challenges and opportunities for sustainable development.

[2] M. Tahiri, B. A. Ismaîli and S. Bakkali, "Applications of AI in higher education: a review of the literature engineering education from developing countries," 2023 7th IEEE Congress on Information Science and Technology (CiSt), Agadir - Essaouira, Morocco, 2023, pp. 456-461, doi: 10.1109/CiSt56084.2023.10409934.

[3] Rudolph, J., Tan, S., Tan, S. (2023). ChatGPT: Bullshit spewer or the end of traditional assessments in higher education?. Journal of applied learning and teaching, 6(1), 342-363, doi:10.37074/jalt.2023.6.1.9.

[4] R. Michel-Villarreal, E. Vilalta-Perdomo, D. E. Salinas-Navarro, R. Thierry-Aguilera, and F. S. Gerardou, "Challenges and Opportunities of Generative AI for Higher Education as Explained by ChatGPT," Education Sciences, vol. 13, no. 9, p. 856, Aug. 2023, doi: 10.3390/educsci13090856.

[5] J. Qadir, "Engineering Education in the Era of ChatGPT: Promise and Pitfalls of Generative AI for Education," 2023 IEEE Global Engineering Education Conference (EDUCON), May 2023, doi: 10.1109/educon54358.2023.10125121.

[6] Ezzaim, A., Kharroubi, F., Dahbi, A., Aqqal, A., Haidine, A. (2022). Artificial intelligence in education - State of the art. International Journal of Computer Engineering and Data Science (IJCEDS), 2(2). http://www.ijceds.com/ijceds/article/view/37

[7] R. Pérez-Rodríguez et al., "Integrating Challenge-Based-Learning, Project-Based-Learning, and Computer-Aided Technologies into Industrial Engineering Teaching: Towards a Sustainable Development Framework," Integration of Education, vol. 26, no. 2, pp. 198–215, Jun. 2022, doi: 10.15507/1991-9468.107.026.202202.198-215.

[8] I. Zergout, S. Ajana, C. Adam, and S. Bakkali, "Modelling Approach of an Innovation Process in Engineering Education: The Case of Mechanical Engineering," International Journal of Higher Education, vol. 9, no. 2, p. 25, Dec. 2019, doi: 10.5430/ijhe.v9n2p25.

[9] Jeon, K., Jarrett, O. S., Ghim, H. D. (2014). Project-based learning in engineering education: is it motivational. International Journal of Engineering Education, 30(2), 438-448.)

[10] A. Retnanto, M. Fadlelmula, N. Alyafei, and A. Sheharyar, "Active Student Engagement in Learning - Using Virtual Reality Technology to Develop Professional Skills for Petroleum Engineering Education," Day 2 Tue, October 01, 2019, Sep. 2019, doi: 10.2118/195922-ms.

[11] F. Oveissi and A. Ebrahimi Ghadi, "Preparing Chemical Engineers for Industry 4.0: An Interactive Education Approach," 9th Research in Engineering Education Symposium (REES 2021) and 32nd Australasian Association for Engineering Education Conference (REES AAEE 2021), 2022, doi: 10.52202/066488-0008.

[12] F. Schmitt, K. Rudolph, E. Kirchner, B. Blat Belmonte, A. Kappes, and S. Rinderknecht, "Smart Products, Engineering and Services. An example of modern engineering education," Towards a new future in engineering education, new scenarios that european alliances of tech universities open up, Sep. 2022, doi: 10.5821/conference-9788412322262.1197.

[13] Bergmann, J., Sams, A. (2012). Flipped classroom webinar series.

[14] Cho, H. J., Zhao, K., Lee, C. R., Runshe, D., Krousgrill, C. (2021). Active learning through flipped classroom in mechanical engineering: improving students' perception of learning and performance. International Journal of STEM Education, 8, 1-13.

[15] Zheng, W.; Wen, S.; Lian, B.; Nie, Y. Research on a Sustainable Teaching Model Based on the OBE Concept and the TSEM Framework. Sustainability 2023, 15, 5656. https://doi.org/10.3390/su15075656

[16] T. Kohler, H.-W. Wollersheim, and C. Igel, "Scenarios of Technology Enhanced Learning (TEL) and Technology Enhanced Teaching (TET) in Academic Education A Forecast for the Next Decade and its Consequences for Teaching Staff," 2019 8th International Congress on Advanced Applied Informatics (IIAI-AAI), Jul. 2019, doi: 10.1109/iiai-aai.2019.00055.

[17] G. Dogan, Y. Song, and D. Surek, "Computational Thinking: A Pedagogical Approach Developed to Prepare Students for the Era of Artificial Intelligence," 2021 ASEE Virtual Annual Conference Content Access Proceedings, doi: 10.18260/1-2–36827.

[18] M. R. Canina and C. Bruno, "DESIGN AND CREATIVITY FOR DEVELOPING DIGITAL MATURITY SKILLS," DS 110: Proceedings of the 23rd International Conference on Engineering and Product Design Education (EPDE 2021), 2021, doi: 10.35199/epde.2021.46.