Engineering Education Review

REVIEW ARTICLE

Mapping the Research Landscape of Artificial Intelligence Integration in Engineering Education: A Systematic Review From 2020 to 2025

Yuhang Li[1,3], Liang Wang[2,3,*], Zhaowei Chu[4]

[1]School of Economics and Management, Dalian University of Technology, Dalian 116024, Liaoning, China
[2]Graduate School of Higher Education, Dalian University of Technology, Dalian 116024, Liaoning, China
[3]Research Center for Comprehensive Higher Education Reform, Dalian University of Technology, Dalian 116024, Liaoning, China
[4]Faculty of Artificial Intelligence in Education, Central China Normal University, Wuhan 430079, Hubei, China

ABSTRACT

Artificial intelligence (AI) has become a major opportunity for advancing the deep transformation of engineering education. Drawing on publications from 10 international engineering education journals between 2020 and 2025, this study conducted a systematic literature review to map the diverse research landscape of AI integration in engineering education. The findings show that AI-related studies in engineering education have increased year by year. After 2022, propelled by generative artificial intelligence (GenAI), the volume of research grew rapidly, and the focus shifted from technology adoption to educational empowerment. Moreover, five major research themes are identified: a) In teaching practice, AI is reshaping engineering pedagogy and the role of engineering instructors, while encouraging a shift toward active exploration in engineering learning. b) In curriculum development, three pathways have emerged that include foundational AI courses, courses integrating AI with disciplinary knowledge, and courses integrating AI with engineering practice. c) In competency development, the literature emphasizes data science skills, advanced problem-solving, systems thinking, and human-AI collaboration. d) In assessment reform, studies focus on AI-supported multidimensional assessment, intelligent accreditation frameworks, and evaluative feedback. e) In ethical reflection, research addresses privacy and security, algorithmic bias, engineering ethics, and corresponding governance approaches. Based on these findings, this paper further discusses the relationship between AI and engineering knowledge, comprehensive evaluation, and engineering ethics education. Finally, in light of China's Emerging Engineering Education initiative, the paper proposes differentiated AI-embedding pathways to engineering education and highlights the need for further practical exploration and ethical governance.

Keywords: engineering education, artificial intelligence, systematic literature review, research landscape

INTRODUCTION

Artificial Intelligence (AI), as an important engine driving a new round of scientific and technological revolution and industrial upgrading, is being deeply integrated into various fields of social production and human life. Its technological boundaries continue to expand, showing deep empowerment, interdisciplinary integration and innovative breakthroughs. In the field of higher education, artificial intelligence is considered to have great potential to "revolutionize" higher education and research, not only for generating content and creating personalized learning experiences, but also for promoting deep student engagement (Ruano-Borbalan, 2024).

***Corresponding Author:**
Liang Wang, Graduate School of Higher Education, Dalian University of Technology, Dalian 116024, Liaoning, China; Research Center for Comprehensive Higher Education Reform, Dalian University of Technology, Dalian 116024, Liaoning, China. Email: wangliang9170@dlut.edu.cn; https://orcid.org/0009-0000-1328-5779
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In August 2025, the State Council issued the "Opinions on In-depth Implementation of the 'Artificial Intelligence +'Action", which clearly requires "the integration of artificial intelligence into all elements and processes of education and instruction", providing policy guidance for promoting the construction of a new form of education led by intelligence and cross-border integration. In this context, systematically promoting the deep integration of artificial intelligence and engineering education is not only a positive response to national policies, but also an inevitable choice for building a future-oriented engineering talent training system that meets industry needs. Therefore, how to scientifically understand the diverse landscape of the integration of artificial intelligence and engineering education, and explore effective paths for their coordinated development, has become an important issue that needs to be answered urgently in engineering education research. Based on this, this study will focus on responding to the following core questions: (1) What is the current publication status of artificial intelligence-related research in mainstream international engineering education journals? (2) What are the topics focused on in relevant research? What conclusions of common value have been formed? A systematic review of relevant literature will help clarify the diverse research landscape of the integration of engineering education and artificial intelligence, and will also help promote the rapid development of engineering education research and practice in China under the background of artificial intelligence-empowered education innovation.

RESEARCH DESIGN

Research Method

Systematic literature review (SLR) is a literature review method that defines and critically evaluates a comprehensive collection of literature on a clear topic (Gough et al., 2017), while minimizing bias in data selection and analysis (Snyder, 2019). This method systematically retrieves, screens, and evaluates relevant literature by formulating strict literature inclusion and exclusion criteria (Siddaway et al., 2019), thereby forming reliable research conclusions or insights and providing solid evidence support for practical applications and policy formulation. This study uses a systematic literature review method to sort out and integrate relevant literature from international mainstream engineering education journals from 2020 to 2025 around the theme of "Integration of Artificial Intelligence into Engineering Education". During the research process, the literature review was conducted in strict compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), which is the standard process of the four stages of literature retrieval, literature screening, literature inclusion, and literature coding (Moher et al., 2009).

Data Collection

Literature Search

The Scopus database was selected as the literature source, and the corresponding literature was retrieved according to the following conditions: (1) Journal limitation: The search scope was limited to 10 international mainstream engineering education journals (Table 1), covering internationally representative and mainstream engineering education journals such as the United States (4 types), the United Kingdom (4 types), Ireland (1 type), and Australia (1 type). Most of them are included in Journal Citation Reports (JCR), are highly authoritative and forward-looking in the engineering education research community, and can reflect the cutting-edge trends in engineering education research; (2) Restricted search scope: This study used a combination of keywords related to artificial intelligence and engineering education. The representative Boolean search expression was ("Artificial Intelligence" OR "AI" OR "AIGC" OR "GenAI" OR "generative artificial intelligence") AND ("engineering education" OR "engineering teaching" OR "engineering learning"). The document types were limited to "Article" and "Review", and the publication period was restricted to 2020–2025. The final literature search was conducted in January 2026, and a total of 109 relevant publications were identified.

Literature Screening and Inclusion

First, two researchers independently screened by reading titles and abstracts. Among them, 38 publications were agreed to be retained, 35 publications were agreed to be excluded, and 36 publications were disagreed on and needed further discussion. Secondly, after joint discussion and comparison between the two researchers, 5 of the papers left for discussion were finally included in the analysis set, and the remaining 31 papers were excluded for the following reasons: (1) the research object did not meet the field of engineering education or engineering teaching (such as pure technical research); (2) the research focus was not related to artificial intelligence; (3) the research design lacked empirical evidence or practical implementation contexts; (4) the research conclusion lacked a clear explanation of the integration of artificial intelligence and engineering education. Specifically, purely theoretical studies that only proposed conceptual perspectives or theoretical frameworks without examining specific AI applications in engineering education were excluded. This decision was consistent with the purpose of this review, which was to identify research patterns, application scenarios, and practical pathways of AI integration in engineering education. A

Table 1: Selection Results of Engineering Education Journals

Number	Journal	Country	Journal Citation Reports (JCR) Quartile	Impact Factor (IF)
1	*Journal of Engineering Education*	United States	Q1	3.4
2	*IEEE Transactions on Education*	United States	Q2	2.0
3	*European Journal of Engineering Education*	United Kingdom	Q1	2.8
4	*International Journal of Engineering Education*	Ireland	Q3	0.7
5	*Advances in Engineering Education*	United States	/	/
6	*Engineering Studies*	United Kingdom	Q1	1.3
7	*Australasian Journal of Engineering Education*	Australia	/	/
8	*Journal of Civil Engineering Education*	United States	Q2	1.8
9	*Education for Chemical Engineers*	United Kingdom	Q2	2.3
10	*Computer Science Education*	United Kingdom	Q1	2.2

Note: *Journal 5 was founded by the American Society for Engineering Education (ASEE), aiming to disseminate innovative experiences in engineering education practice; Journal 7 was founded by Engineers Australia (EA). Although these two journals have not entered the JCR division, they are generally regarded as important reference publications in the field of international engineering education, and therefore are retained in this study.*

total of 43 publications were finally included in the analysis, and the specific process is shown in Figure 1.

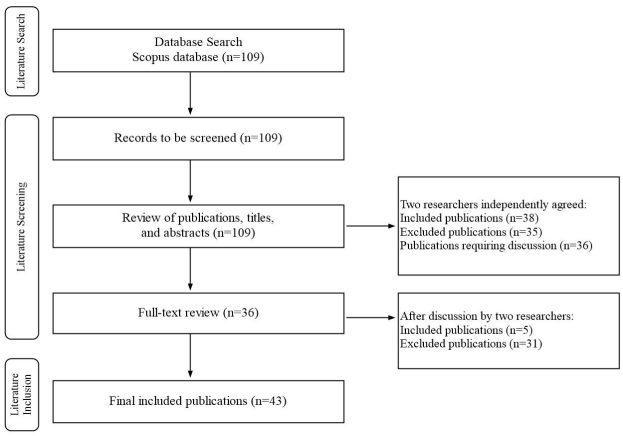

Figure 1. Literature screening and inclusion process

Literature Coding

First, the literature is classified according to publication time, regional and institutional distribution, as well as research questions and method use, etc., to present the stage characteristics, country and institution distribution characteristics, and methodological characteristics of relevant research. Subsequently, thematic coding analysis method was used to refine the recurring core issues and research conclusions (Borrego et al., 2014), and after multiple rounds of discussions, a consensus was reached, which was finally summarized into five important dimensions: teaching practice, curriculum construction, competency development, assessment reform, and ethical reflection (see Table 2).

DESCRIPTIVE CHARACTERISTICS OF INCLUDED STUDIES

Publication Trends and Stage Characteristics

As shown in Figure 2, relevant research shows an increasing trend year by year. Among them, 2022 can be regarded as an important watershed, with significant differences in the number of studies and research topics before and after it. There are a limited number of relevant studies from 2020 to 2022, with a total of 7 articles, mainly focusing on "how to cultivate the artificial intelligence knowledge and skills of engineering students". Most studies regard artificial intelligence as a competency goal, reflecting the characteristics of technology-based integration (Manikandan & Chinnadurai, 2020). Since 2022, influenced by general large language models such as ChatGPT, the research landscape has undergone significant changes. In terms of the number of publications, the number of publications increased rapidly from 2023 to 2025, reaching a total of 36 articles; in terms of content, unlike the previous emphasis on "artificial intelligence knowledge and skills", research at this stage began to emphasize "how to use artificial intelligence to empower education and instruction", that is, it no longer only regards artificial intelligence as a learning goal, but as an empowerment method that can change the engineering education and instruction model, which has widely penetrated into curriculum design, classroom teaching and complex engineering problem solving (Marquez et al., 2023), highlighting the multiple aspects of artificial intelligence in engineering education, and revealing the transformation logic from "technology adoption" to "educational reform", and from "objective object" to "subject agency".

Table 2: Analysis Themes and Coding Instructions

Primary Theme	Secondary Theme	Coding Description
Teaching practice	Teaching form, teaching process, learning feedback, content improvement, interaction improvement	Summarize the application performance and effectiveness of AI in classroom teaching, experimental training, learning methods, etc. in the literature
Curriculum construction	Course construction, interdisciplinary integration, innovative design, personalized recommendations, course optimization	Summarize the relevant practices of integrating AI into the curriculum system, course design and teaching resource development
Competency development	Critical thinking, scientific literacy, digital literacy, information analysis thinking, mathematical logic	Refining the requirements for cultivating students' critical thinking and interdisciplinary literacy in research
Assessment reform	Ability assessment, learning evaluation, learning progress monitoring, quality evaluation	Summarize the literature's exploration of learning evaluation, ability assessment and teaching quality supported by AI
Ethical reflection	Ethical challenges, privacy security, algorithm bias, fairness risks, gender bias	The overall study discusses ethical risks such as academic integrity, privacy security, and algorithmic bias.

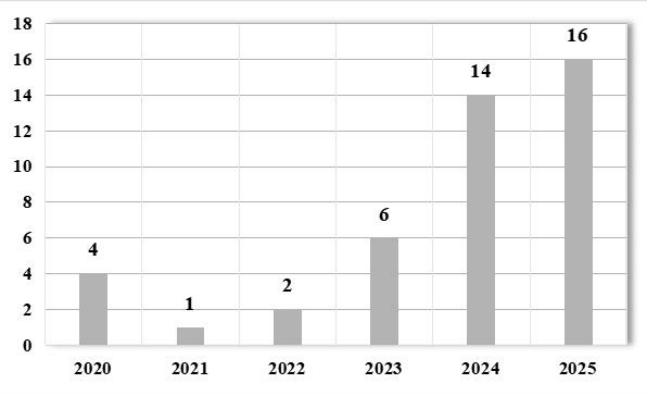

Figure 2. Annual distribution of the number of research publications on the integration of artificial intelligence into engineering education from 2020 to 2025

Country/Region and Institutional Characteristics

Statistics on the country/region and institutions of affiliation of all authors in the sample publications revealed that the authors of the publications on this topic cover a total of 20 countries and 65 institutions, as shown in Table 3. From the perspective of country distribution, Australia is the country with the highest publication count on this topic, with a total of 36 posts, accounting for 21.05% of the total publication count; the United States is closely followed, with 33 posts, accounting for 19.30%; the United Kingdom ranks third, with 22 posts, accounting for 12.87%. The above-mentioned country/region characteristics of publications are closely related to English as a common academic publication language, and also reflect the active participation of European and American countries in the research theme of integrating artificial intelligence into engineering education. After Australia, the United States, and the United Kingdom, Hong Kong SAR performs outstandingly. As a non-English native region, Hong Kong authors published 12 times, accounting for 7.02%.

Judging from the distribution of institutions, the issuing institutions show the characteristics of regional diversity in research on this topic. Among them, The Chinese University of Hong Kong ranks first, with a total of 10 publications, accounting for 5.85%; Universidad de los Andes in Colombia ranks second, with 9 publications, accounting for 5.26%. The University of Wollongong in Australia and the University of Strathclyde in the UK posted 7 times respectively, accounting for 4.09% and tied for third place. See Table 4 for details. Overall, compared with the countries/regions where the articles are published, the distribution of institutions is more diverse. There are institutions in Asia, Europe, America and Oceania that are actively paying attention to research related to artificial intelligence and engineering education topics. In particular, Hong Kong SAR in China, in Asia, is more active in this research field.

Main Research Contexts, Questions, and Methods

Before comprehensively understanding the diverse research topics of integrating artificial intelligence into engineering education, we conducted a statistical analysis of the research background, research questions, and research methods involved in the sample literature. Overall, the research background can be summarized in terms of three dimensions: technology, organization, and environment (Table 5). The details are as follows: (1) From the technical dimension, the relevant literature is based on the rapid development and application of artificial intelligence technology. Issues of concern include how to effectively help students understand artificial intelligence technology, how to deploy large language models (LLMs) in engineering education systems, etc. These studies not only explore artificial intelligence teaching methods and curriculum design, but also focus on the application and practice of emerging artificial intelligence technologies such as large language models (Neumann et al., 2025) and intelligent tutoring systems (Liao et al., 2025) in the classroom. (2) From the organizational dimension, the relevant literature situates its discussion in the context of artificial intelligence, focus-

Table 3: Countries Publishing Research Papers on the Integration of Artificial Intelligence into Engineering Education From 2020 to 2025 (Top 15)

Number	Country/Region	Publication Count	Proportion (%)
1	Australia	36	21.05
2	United States	33	19.30
3	United Kingdom	22	12.87
4	Hong Kong, China	12	7.02
5	Colombia	9	5.26
6	Chile	8	4.68
7	Taiwan, China	7	4.09
8	Germany	7	4.09
9	Belgium	7	4.09
10	Spain	7	4.09
11	China	4	2.34
12	Denmark	4	2.34
13	Brazil	4	2.34
14	Canada	3	1.75
15	Ireland	3	1.75

Note: *Publication counts represent author-affiliation occurrences rather than unique publication numbers. A single publication may contribute multiple counts when its authors are affiliated with different countries/regions. This counting approach is used to reflect the geographical participation and collaboration patterns of AI-related engineering education research.*

Table 4: Situation of Institutions Publishing Research Papers on the Integration of Artificial Intelligence into Engineering Education From 2020 to 2025 (Top 15)

Number	Institution	Country/Region	Publication Count	Share of Publications (%)
1	The Chinese University of Hong Kong	Hong Kong, China	10	5.85
2	Universidad de los Andes	Colombia	9	5.26
3	University of Wollongong	Australia	7	4.09
4	University of Strathclyde	United Kingdom	7	4.09
5	National Changhua University of Education	Taiwan, China	6	3.51
6	University of New South Wales	Australia	6	3.51
7	KU Leuven	Belgium	6	3.51
8	RWTH Aachen University	Germany	5	2.92
9	University of Florida	United States	5	2.92
10	University of Melbourne	Australia	5	2.92
11	Technical University of Denmark	Denmark	4	2.34
12	Queen Mary University of London	United Kingdom	4	2.34
13	University of Birmingham	United Kingdom	4	2.34
14	Pennsylvania State University	United States	4	2.34
15	Virginia Tech	United States	4	2.34

Note: *Publication counts represent institution-affiliation occurrences rather than unique publication numbers. A single article may be associated with multiple institutions due to multi-institutional collaboration. Therefore, the counts reflect institutional participation patterns rather than the absolute number of publications.*

ing primarily on the transformation of engineering education models and the reshaping of the competency structure of engineering talent. Research questions include how artificial intelligence promotes the learning development (Rodriguez & Ross, 2025) and ability improvement (Gao et al., 2020), as well as the status quo and perception of artificial intelligence use among engineering practitioners (Cheng et al., 2025). (3) In the environmental dimension, the relevant literature is based on the resources, ethics and fairness challenges caused by artificial intelligence. The main key research issues include the threat of artificial intelligence to the security of academic evaluation and the policy norms, social needs and ethical constraints involved in how to effectively use artificial intelligence (Mburu et al., 2025). Some studies mentioned academic integrity risks, privacy ethics, etc. caused by artificial intelligence (Quince & Nikolic, 2025).

Table 5: Overview of Research Background and Issues on the Integration of Artificial Intelligence into Engineering Education From 2020 to 2025

Research Context	Examples of Specific Research Questions
Technical dimension: rapid development and application of artificial intelligence technology	(1) How receptive are students to MoodleBot (a large language model tool) as a learning aid? How accurate is the content it generates and how well does it fit with the course content (Neumann et al., 2025)? (2) How to design a question and answer robot based on generative artificial intelligence to provide support for teaching (Allen et al., 2024)?
Organizational dimension: Transformation of education model and reshaping of engineering talent capability structure	(1) What is the current status of the application of artificial intelligence in higher engineering education? What challenges have been faced and what lessons have been learned from the artificial intelligence module for electronics undergraduate students (Hao et al., 2025)? (2) How to use explainable artificial intelligence methods to explain classroom discourse models based on deep learning? What are teachers' perceptions of these models (Wang & Chen, 2024)? (3) To what extent does GPT-4 improve the quality of students' self-evaluation and peer evaluation (Sajadi et al., 2024)? (4) What is the knowledge of teachers in the School of Architecture about artificial intelligence? What are the attitudes of architecture school teachers toward the integration of artificial intelligence courses? How is artificial intelligence integrated into architecture curricula (Cheng et al., 2025)? (5) What external factors will teachers consider when designing primary school artificial intelligence courses? How can teachers adapt or redesign courses based on these factors (Dai et al., 2023)?
Environmental dimension: Resources, ethics and fairness challenges caused by artificial intelligence	(1) To what extent can students identify the social, economic, and environmental ethical impacts of artificial intelligence through embedded multi-stage assessment (Quince & Nikolic, 2025)? (2) How to deal with the illusion risks, data dependence and privacy issues caused by artificial intelligence in promoting educational changes to build a smart university ecosystem (Martín Núñez & Díaz Lantada, 2020)?

Relevant research involves a variety of research methods (see Figure 3): First, according to research type, it can be divided into experimental design (9 items), quasi-experimental design (15 items), and non-experimental design (19 items). Among them, experimental or quasi-experimental research methods are widely used to evaluate the impact of artificial intelligence technology on students' learning effects, such as the experimental design or quasi-experimental design adopted by Alqarni (2024). Based on artificial intelligence-assisted teaching and traditional teaching tools or models, the differences between the experimental group and the control group are compared in terms of engineering knowledge mastery (Chang et al., 2023) and digital skill improvement (Wang & Chen, 2024). The non-experimental design is represented by the literature review study of Hao et al. (2025), which systematically screens relevant literature, conducts an in-depth review of the application of artificial intelligence in engineering education, and summarizes the current application status and development direction of artificial intelligence technology in the field of engineering education. Secondly, according to the data analysis method, it can be divided into qualitative research (6 items), quantitative research (9 items) and mixed research (28 items). For example, Oyedoyin et al. (2025) collected students' visual and verbal expressions of computing concepts through qualitative drawing and interview surveys, and analyzed their cognition of computing concepts and understanding of computing systems. Quantitative research such as Fruett et al. (2024) used questionnaire surveys to deeply explore the use experience, functional evaluation and contribution level after the intervention of artificial intelligence tools. Mixed research methods combine quantitative and qualitative analysis to comprehensively collect and evaluate students' learning perceptions, engagement, and course effects, such as Chiu et al.'s (2022) mixed research design. A variety of research methods provide rich theoretical support for the application of artificial intelligence in engineering education, and provide important references for future research directions and practical innovations.

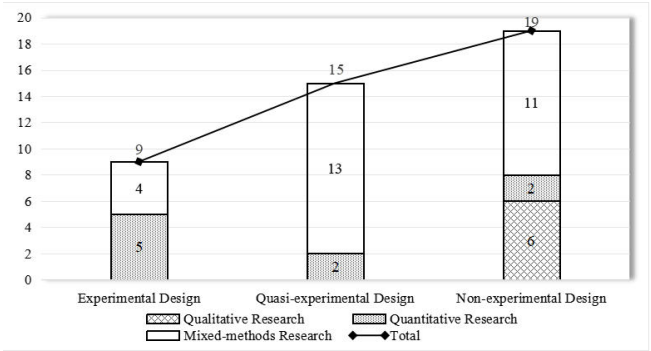

Figure 3. Frequency distribution of research methods for integrating artificial intelligence into engineering education from 2020 to 2025

FINDINGS

Based on literature coding, this study summarizes five important themes: teaching practice, curriculum construction, competency development, evaluation reform, and ethical reflection.

Theme 1: The Impact of Artificial Intelligence on Engineering Teaching Practice

Artificial Intelligence Is Reshaping the Teaching Model in Engineering Education and Changing the Role of Engineering Teachers

Artificial intelligence technology is gradually reshaping the interaction model of engineering classrooms. Roldán-Álvarez and Mesa (2023) found that engineering students use artificial intelligence tools to obtain instant answers, code explanations, and complex concept explanations, breaking teachers' monopoly on engineering knowledge and the time and space limitations of teaching feedback, making learning support more continuous. In their research, Neumann et al. (2025) introduced a chatbot (LLM-Driven Chatbot, a large model-driven chat agent) based on a large language model. After evaluation, it was found that this type of tool can provide students with an interactive experience similar to that of a real tutor. It has the advantages of instant response and around-the-clock availability. The accuracy of course assistance reaches 88%, and students have positive feedback on its use (Neumann et al., 2025). It can be seen from the above research that in the context of artificial intelligence, the traditional teacher-centered engineering teaching model is changing. The role of engineering teachers has undergone a transformation, from the traditional "knowledge transmitter" to a more diverse "learning guide." The student-centered teaching model has gradually become a new paradigm of engineering education and instruction.

Artificial Intelligence Changes the Way Engineering Students Learn and Improves Students' Learning Outcomes

Diverse artificial intelligence tools are widely embedded in engineering learning scenarios, showing outstanding advantages in student assistance, homework answers, and exam preparation. Survey data from Callejo-Pinardo et al. (2024) show that after students use LLMs, the overall average score of engineering subjects is improved by about 36%, among which the performance improvement of the student group with relatively weak foundation is more obvious. When engineering students use artificial intelligence tools such as ChatGPT, common feedback helps them understand knowledge points from multiple perspectives and enhance their willingness to continue learning (Chiu et al., 2022). Research by Sajadi et al. (2024) has confirmed that artificial intelligence can capture students' learning status and learning effectiveness through behavioral data such as speech analysis, and can also effectively improve team collaboration capabilities, marking engineering education entering a new stage of digitalization. From these research conclusions, it can be found that integrating artificial intelligence into engineering education opens up new possibilities for personalized learning and automated feedback. Artificial intelligence not only promotes the transformation of engineering learning methods, but also changes the traditional engineering learning paradigm to a certain extent and further improves the learning effects of engineering students, which has a positive impact on the transformation of future engineering learning models.

Artificial Intelligence Can Integrate With Problem-Based or Project-Based Learning Models

Judging from the specific implementation of engineering education teaching practices, artificial intelligence tools can play a significant role in promoting problem-based or project-based learning. Research conducted by Acuña et al. (2025) in the field of chemical engineering shows that generative artificial intelligence (GenAI) can be organically integrated into the project-oriented problem-based learning (PO-PBL) model, and has a significant role in improving students' research capabilities and writing skills. It can not only effectively improve the quality of students' article writing, but also significantly improve the clarity and coherence of research design, attribute argumentation, and attribute evaluation. Students subjectively perceive the artificial intelligence-assisted literature review as highly useful (Highly useful) or very useful (Acuña et al., 2025).

Theme 2: Artificial Intelligence Curriculum Construction in Engineering Education

Design of Basic Artificial Intelligence Courses for Engineering Students

Current research generally agrees that the undergraduate curriculum needs to be updated as soon as possible to incorporate artificial intelligence education into the engineering teaching system to prepare students for the key role that artificial intelligence plays in solving modern engineering problems. Based on literature review and actual project evaluation, Hao et al. (2025) developed an artificial intelligence course module for first-year students, highlighting the use of simple programming languages (mainly MATLAB), entry-level intelligent algorithms (genetic algorithms and K-nearest neighbor algorithms for reducing complexity, etc.), combining lectures with team collaboration practice, case analysis teaching of "first theory before practice", and course content design ideas oriented toward completing specific engineering problems. After evaluation, this type of basic course with artificial intelligence knowledge as the core can effectively enhance students' understanding of key concepts, and students generally feel the improvement in learning effectiveness.

Integration of Artificial Intelligence and Engineering Expertise

The construction of artificial intelligence courses in the field of engineering education shows interdisciplinary and practice-oriented characteristics, and artificial intelligence knowledge is being actively integrated into specific professional and technical courses (Cheng et al., 2025). This type of course focuses on the systematic integration of artificial intelligence knowledge with professional knowledge in specific engineering fields such as chemical

engineering, architecture, and biology, forming a teaching framework in the form of problem-based learning (PBL) and project practice centered learning (PPLC) with interdisciplinary knowledge as the core. Specifically, artificial intelligence knowledge is not centered on isolated algorithms, but is organized around real engineering application scenarios such as intelligent identification systems, structural detection, and medical diagnosis. For example, in the course case of Vargas et al. (2020), the technical knowledge point of "Convolutional Neural Network" was placed in the engineering situation of "Ocean Navigation and Obstacle Avoidance", achieving an organic integration of key artificial intelligence technical content and engineering problem situations.

Integration of Artificial Intelligence With Engineering Design and Practical Courses

With design being the core of engineering activities, design and practice courses serve as important features of engineering education that distinguish it from other disciplines. The current penetration and application of artificial intelligence technology in the field of engineering education provides opportunities to cultivate students' design capabilities. For example, optimization algorithms can be used in the design process to find the best problem solutions under constraints (Hao et al., 2025). A survey conducted by Murray et al. on the use of artificial intelligence large model tools for engineers in enterprise scenarios found that companies currently need to use artificial intelligence tools to improve the work efficiency of engineers, especially integrating artificial intelligence with specific engineering design processes. This puts further demands on universities to promote the integration of artificial intelligence with engineering design and practical courses. However, most universities still lack a clear implementation path on how to integrate artificial intelligence technology into practical courses (Murray et al., 2025).

Theme 3: Cultivating AI Literacy Among Engineering Talents

Cultivation of Data Science Skills and AI Literacy

As one of the indispensable core competencies of engineering talents, data science skills have attracted much attention in international engineering education, and the specific ways in which they are embedded in engineering education have become the focus of current research. One is to integrate data science skills into the construction of engineering curriculum systems, such as adding introductory data science courses to professional courses such as construction engineering, materials science engineering, and chemical engineering. Reinhart et al. (2025) advocate combining programming technology, statistical learning with visualization and case analysis to form a data science competency development model of "theoretical teaching + situational practice". Höper and Schulte (2025) further emphasized the learning activity method in which students accumulate experience in real engineering scenarios and establish an overall framework and basic conceptual understanding of data science, which helps to achieve a smooth connection between knowledge and abilities. From the perspective of technical applications, Python and Jupyter Notebooks have become the main choices for data teaching tools. Some colleges and universities use cloud programming environments such as Google Colab to lower the entry threshold for students' artificial intelligence, especially for students who lack programming experience, effectively easing the challenges of installing the environment and obtaining documentation support (Wu et al., 2023). The second aspect concerns the integration and development of engineering curriculum resources. Traditional programming courses mostly emphasize the mastery of grammar and tools. Data science education in the context of artificial intelligence highlights the in-depth integration with professional cases. It also requires students to gradually understand the role of data science in the process of solving engineering problems and improve their data science application capabilities in the practice of engineering projects. Specifically, the research of Reinhart et al. (2025) is rooted in the construction of modular and transferable course resources, and proposes the "Data Science Corps" teaching model, which emphasizes sharing data sections, experimental resources, and teaching cases, so that originally scattered teaching resources can be circulated and reused on a large scale, thereby improving the efficiency and quality of data science engineering course construction. Finally, research points out that integrating artificial intelligence literacy into higher education is crucial, but students need to maintain critical thinking when using large artificial intelligence models. They must not only master how to use large models, but also need to understand why large model technology is used, identify which tasks are more suitable for AI assistance, and critically evaluate the output results of large models (Xiao et al., 2025).

AI-Supported Advanced Problem-Solving, Systems Thinking, and Human-AI Collaboration Literacy

In the era of artificial intelligence, the role of engineers is changing from direct operators to designers and coordinators of intelligent systems. This means that engineering talents need to possess a new quality, that is, they can scientifically plan the division of labor and collaboration between "humans" and "machine" in engineering tasks based on the overall effectiveness of the system. The research of Balart and Shryock (2025) has verified this direction. They believe that the value of artificial intelligence lies in forming a cooperative partnership with humans. In specific engineering practices, engineers first act as designers and decomposers, responsible for

proposing design intentions and boundary conditions. Then artificial intelligence acts as executors and explorers, using its powerful computing and pattern recognition capabilities to train "statistical models" in massive amounts of data, efficiently generate a large number of solutions and conduct simulations. Finally, engineers act as decision makers and judges again, making final judgments and decisions based on comprehensive considerations of artificial intelligence output and their own experience. This organic collaborative ability under the guidance of systems thinking is becoming the core quality for future engineering talents to master complex engineering challenges and lead engineering innovation and development.

Theme 4: Assessment Reform in Engineering Education in the AI Era

Utilizing Artificial Intelligence Tools to Develop a Multidimensional Approach to Practical Competency Assessment

Compared with the traditional assessment methods that mainly focus on tests, experimental reports and written assignments, engineering education has always been hampered in the measurement of practical ability, and issues such as "what to assess" and "how to assess" have never been effectively resolved. Although the current evaluation system has gradually paid attention to the process evaluation link, it still focuses on knowledge mastery and result presentation as a whole, and it is difficult to fully reflect the innovation, collaboration and other abilities demonstrated by students in the learning process. The widespread application of artificial intelligence tools has provided the possibility for new evaluation methods, making engineering education evaluation no longer limited to result-oriented, but advancing in the direction of process and multi-dimensionality. In specific practice, Nikolic et al. (2024) divided assessment types into nine categories, including online tests, numerical calculations, programming, oral reports, etc., and tried to test students' ability performance through standardized task design and process tracking to achieve refined measurement of students' comprehensive abilities. The research results reveal that artificial intelligence technology and tools bring ample opportunities to future evaluation work in the field of engineering education, but it is necessary to build an evaluation system based on the comprehensive use of a variety of artificial intelligence tools to more effectively present students' comprehensive abilities and qualities in engineering practice.

Exploring an Intelligent Accreditation Framework for Engineering Practice Competencies

In the engineering education accreditation framework, how to obtain real, valid and verifiable evidence has always been a difficult problem in the accreditation process. The traditional peer review mechanism is difficult to provide effective evidence support for accreditation due to uneven feedback quality and lack of objectivity. Against this background, artificial intelligence has been proposed as an evidence-based guarantee for the accreditation mechanism. On the one hand, referring to the views of Sajadi et al. (2024), introducing artificial intelligence tools for auxiliary processing on the basis of peer evaluation can make the originally scattered and vague evaluation more specific, reduce bias and invalid information, thereby improving the usability of data in accreditation. These data can not only reflect students' performance in team collaboration and self-reflection, but also be converted into data required for accreditation through traceable process records. This shows that the feedback mechanism based on artificial intelligence assistance has become an important evidence-based support for building a practical competency accreditation framework. On the other hand, artificial intelligence-driven emotion and topic analysis provides new evaluation ideas for engineering education accreditation. The current psychological and emotional evaluation system for individual students in engineering education is still in the exploratory stage, lacking effective standards and unified consensus (Nikolic et al., 2025). Emotional computing and topic analysis based on artificial intelligence provide new possibilities for this. For example, research by Dehbozorgi and Kunuku (2023) shows that students' positive emotions in team discussions are significantly positively related to academic performance, and an increase in the proportion of course-related topics is also positively related to performance. This means that extracting and quantifying students' emotional changes and communication quality in team interactions can form reliable process evidence with the help of artificial intelligence tools, and serve as supplementary support to the engineering practice competency accreditation framework, thereby more comprehensively and objectively assessing students' comprehensive abilities and real performance in complex engineering situations.

AI-Enabled Innovation in Feedback and Diagnostic Functions in Engineering Teaching Assessment

Unlike traditional evaluation, which focuses on "screening and selection", the introduction of artificial intelligence promotes the transformation of its functions to "diagnosis and development". Specifically, this transformation is reflected in two aspects: In dynamic feedback, the value of artificial intelligence lies in "instant response" to the learning process, as confirmed by Nikolic et al. (2023): through the continuous capture and analysis of students' learning process data, it can help teachers accurately locate weak links in the knowledge system students have learned, generate operational improvement suggestions and path guidance, and directly transform the evaluation results into effective scaffolding to promote students' cognitive development. In

terms of in-depth diagnosis, its value lies in providing "in-depth insights" into teaching effectiveness. For example, Keith et al. (2025) integrated artificial intelligence into the teaching evaluation cycle. Through pre- and post-test surveys and intelligent analysis of academic data, it provides teachers with data-based decision-making reference, helps to improve teaching design and course arrangements, and achieves continuous iteration and optimization of teaching strategies. However, while embracing technological innovation, it is also necessary to carefully examine its inherent limitations (Keith et al., 2025). As scholars have pointed out, when artificial intelligence handles complex calculations or covers more cognitive content tasks, its internal algorithm bias may cause fairness issues and risks (Caccavale et al., 2024).

Theme 5: Ethical Reflection on the Use of Artificial Intelligence in Engineering Education

Data Privacy and Security Issues

Data privacy risks have become one of the most prominent concerns in the engineering education scenario. When students and teachers use generative AI platforms, the academic materials and personal data they provide may be stored, accessed, and reused by these platforms, raising concerns about privacy and data security. When generating responses, generative AI platforms process and reorganize existing data. However, AI-generated outputs often lack clear source attribution and traceability, making it difficult to clarify "responsibility" and potentially leading to data breaches and infringement of research outputs. Research by Murray et al. (2025) confirms this concern: 33.9% of respondents are worried that the output of artificial intelligence is unreliable or may be misused, and 26.6% are worried about the leakage of intellectual property, highlighting the real pressure of privacy and security issues. It is worth noting that the emergence of such risks not only reflects the realistic lag of the regulatory mechanism, but also reflects the blurred boundaries of ethical awareness among educational subjects. Quince and Nikolic (2025) incorporated 32 social, economic and environmental impact items into the staged assessment design to present students' multi-dimensional ethical awareness levels and reveal the limitations of their potential risk perceptions in the use of generative artificial intelligence.

Algorithmic Bias and Hallucination in AI

Another issue that has attracted much attention in the literature is the issue of algorithmic bias brought about by generative artificial intelligence. Its performance is first due to its high dependence on training data. The inequalities and biases hidden in the original corpus are often reproduced or even amplified, which can easily lead to fairness issues in engineering education applications. The research of Mburu et al. (2025) has raised alarm about this. At the same time, large language models often have problems such as redundancy, double expressions, or inappropriate technical terms when generating questions, which reflects the inherent limitations of their generation mechanism. What's more prominent is that, referring to the research views of Honig et al., artificial intelligence systems also have hidden dangers such as gender bias and output quality fluctuations (Honig et al., 2025), making their reliability and stability questionable. With the in-depth application of artificial intelligence tools in education, these problems arising from algorithmic bias not only affect the accuracy and effectiveness of knowledge acquisition, but also restrict the trust and acceptance of technology in engineering education scenarios to a certain extent.

Engineering Ethics and Social Responsibility

The focus of the sample literature research is mainly on the lack of reality and training performance of engineering ethics in the context of artificial intelligence. First, survey data by Quince and Nikolic (2025) show that students have limited ability to identify ethical risks in artificial intelligence, with an average ability to identify only about 21% of potential impacts (Quince & Nikolic, 2025). In engineering education courses and practices, Martín Núñez and Díaz Lantada (2020) also believe that students are more likely to notice the performance and efficiency of artificial intelligence, but often ignore the hidden gender bias, privacy issues, and data dependence. This not only weakens students' judgment, but also prevents them from forming sustained critical reflection. Secondly, another theme that has been focused on in the literature is the cultivation of social responsibility in engineering. For example, Honig et al. (2024) divided students into several groups to discuss engineering safety accident cases, participated in real industry consultant meetings, and used artificial intelligence tools to conduct engineering problem simulation training, and finally tested students' learning results in the form of an "engineering conference" oral examination. Compared with traditional written examinations or written assignments, these advisory meetings and oral examinations simulated by artificial intelligence tools introduce expert communication and on-site defense situations into the classroom, which not only allow students to comprehensively exercise their subjective thinking and engineering logical argumentation, but also forces them to reflect and question when facing the "black box" and accuracy limitations of artificial intelligence tools, and enhance social responsibility considerations in the use of tools (Wang & Chen, 2024). The survey results show that 83% of students have used artificial intelligence consultant tools, and 71% of students have used artificial intelligence oral examination practice tools. 59% of students believe that artificial intelligence tools are indeed helpful for learning, but some students are worried about their

accuracy and information limitations (Honig et al., 2024).

DISCUSSION

Froyd et al. (2012) described five major shifts in 100 years of engineering education brought by information and communication technology (ICT). As a technology capable of transforming future productivity, artificial intelligence is profoundly influencing the overall system and future development of engineering education. In recent years, China has vigorously promoted the digitalization and intelligent reform of higher education, actively advocated the application of artificial intelligence technology in the field of education and the cultivation of related talents, accumulated strength for the continuous promotion of engineering education reform in the artificial intelligence era, and further highlighted the important value and application potential of conducting research on multiple themes of artificial intelligence integration into engineering education. Combined with the aforementioned series of findings, this study further discusses the important issues involved.

Discussion for Findings of the Literature Review

Effective integration of artificial intelligence and engineering expertise. From the perspective of curriculum system design, this study found that the integration of artificial intelligence into engineering education involves basic courses, professional courses, and design-focused practical courses. Some studies have discussed the feasibility of resetting artificial intelligence courses in the current engineering curriculum system. As far as the actual situation of engineering education is concerned, most engineering majors have intensive courses and large knowledge capacity. Therefore, the accessibility of completely redesigning artificial intelligence courses in engineering education is not high, and artificial intelligence courses that are divorced from specific engineering problems and engineering situations may be difficult to produce better learning effects. Judging from existing research conclusions, about 65% of construction engineering teachers have failed to effectively integrate artificial intelligence into their professional courses. Most courses are still completed through lectures or experience using artificial intelligence tools, indicating that the integration of artificial intelligence into engineering education still lacks the necessary contextual depth. The main reason is that current engineering teachers still lack the necessary artificial intelligence literacy (Cheng et al., 2025). Therefore, how to realize the organic integration of artificial intelligence and engineering professional courses has become an important issue of research concern. Meanwhile, the integration pathways of AI may vary across engineering disciplines due to differences in knowledge structures and practical requirements. For example, disciplines closely related to computational methods may emphasize programming, intelligent systems, and data-driven applications, while other engineering fields may require AI applications in simulation, optimization, and engineering decision-making processes. How to effectively apply interdisciplinary teaching frameworks based on artificial intelligence and artificial intelligence technology applications based on real engineering situations are issues that need to be considered in promoting the intelligent transformation of engineering education, and should also become an area of focus for future research.

The relationship between artificial intelligence and comprehensive evaluation of engineering education. This study found that the use of artificial intelligence technology has brought new opportunities to engineering education, especially the evaluation of engineering practice abilities. Multidimensional evaluation methods and intelligent evaluation tools based on artificial intelligence can help achieve process evaluation that goes beyond a single result dimension. Current international engineering education research mostly bases the evaluation methods of artificial intelligence empowerment on the level of individual learning and ability development. In fact, the future trend of engineering education evaluation is to establish comprehensive evaluation and smart evaluation based on sufficient technical support. The former effectively integrates multiple levels of evaluation systems such as individual learning, scientific research and innovation, discipline construction, school development, etc., while the latter uses technical means to carry out process-free data collection and evaluation. Engineering education has become a key area of evaluation reform due to its large scale and outstanding role. Therefore, when discussing the topic of artificial intelligence and engineering education evaluation, it is not only necessary to keep artificial intelligence at the technical application level, but to further regard artificial intelligence as an enabling means and enabling tool and apply it to the design of comprehensive evaluation programs for engineering education involving different levels and dimensions. Artificial intelligence can even be used as an important opportunity to coordinate and synthesize different types of evaluation, serving the feedback improvement of the quality of engineering education.

The multi-dimensional impact of artificial intelligence on engineering ethics education. Engineering ethics education is one of the important contents of engineering education and has attracted more and more attention from engineering educators. It includes value issues such as culture, ecology, integrity, safety, and responsibility. Its core goal is to cultivate engineers' ability to identify, analyze, and solve ethical issues in professional practice, so that they can become responsible

engineering practitioners. The use of artificial intelligence has a dual impact on engineering ethics education: on the one hand, artificial intelligence technology, as a powerful tool for engineering ethics education, can provide more possible cases and topics for engineering ethics education, especially to promote the expansion of engineering ethics from "human-nature" to "human-AI-society" and other more complex dimensions, extending the breadth and depth of engineering ethics education; on the other hand, the application of artificial intelligence also brings further challenges to engineering ethics education. The emergence of new forms of engineering ethics such as algorithm fairness, transparency and explainability, privacy and data ethics, etc., means that engineering ethics education needs to further keep pace with the times. The intuitive manifestation of the negative impact of artificial intelligence on engineering ethics education is that academic integrity problems caused by artificial intelligence are more difficult to prevent. If there is a lack of appropriate regulatory methods, the irresponsible use of artificial intelligence tools in engineering fields that are more closely related to public interests may have a serious impact on engineering practice and even harm the welfare of the public. This poses a great challenge to future engineering education.

Recommendations for Theory and Practice

The results of this study show that artificial intelligence has huge application potential and development prospects in the field of engineering education. In fact, integrating artificial intelligence into engineering curricula is not just about adopting new technologies, but preparing students for a future when artificial intelligence becomes a ubiquitous part of life. At the theoretical level, future research should further clarify the dual-track construction logic of "artificial intelligence technology general course" and "artificial intelligence professional integration course". The former aims to cultivate the general artificial intelligence technology usage ability of all engineering students, while the latter focuses on the deep embedding and professional innovation of artificial intelligence technology in specific engineering fields. On this basis, it is also necessary to conduct in-depth research and discussions on topics such as the artificial intelligence literacy of engineering talents and engineering educators, so as to form appropriate literacy training standards and plans as soon as possible. In addition, with the widespread application of artificial intelligence in engineering education, future research needs to further redefine the boundaries of engineering responsibilities and develop a new ethical framework that can respond to algorithmic uncertainty and its social impact, providing a theoretical basis for engineering education in a "human-AI symbiosis" environment.

At the practical level, based on the contextualized teaching data accumulated in China's "new engineering" construction and the realistic foundation of the widespread application of artificial intelligence, differentiated deployment strategies should be established based on knowledge types in engineering education. For example, in teaching scientific knowledge, artificial intelligence can be used as a technical efficiency tool, while in engineering practice training, artificial intelligence can be regarded as a generative partner that inspires innovation. At the same time, attention should be paid to monitoring and evaluating the effectiveness of artificial intelligence-empowered engineering education and teaching. In engineering practice, it is also necessary to strictly clarify the primary and secondary roles of artificial intelligence in the two types of courses, accelerate the construction of a modular and transferable artificial intelligence course system, promote the organic combination of artificial intelligence and engineering knowledge and experience, and achieve the endogenous development of multi-dimensional artificial intelligence literacy. Meanwhile, the artificial intelligence literacy of engineering educators should be improved. For front-line teaching and scientific researchers in engineering education, improving new literacy, such as digital literacy, data literacy, and artificial intelligence literacy, is of great significance for the all-round integration of artificial intelligence and the empowerment of engineering education. Finally, engineering ethics education should pay more attention to cultivating the ethical leadership of future engineers, enabling them to make prudent judgments in a "human-AI symbiosis" environment and respond to the complex challenges brought by the development of artificial intelligence.

CONCLUSION

The current systematic literature review shows that artificial intelligence is actively integrated into the diverse themes of engineering education, covering multiple dimensions and levels such as teaching practice, curriculum construction, competency development, assessment reform, and ethical reflection. Specifically, teaching practice represents the application dimension, where AI directly influences classroom interaction, learning processes, and instructional approaches. These changes further promote curriculum transformation and provide a foundation for cultivating new engineering competencies. Subsequently, the development of AI-related competencies requires corresponding assessment reforms to evaluate students' abilities in AI-supported engineering environments, while ethical reflection serves as a cross-cutting dimension throughout the integration process by addressing issues such as responsible AI use, privacy, and fairness. Overall, the findings show a development and evolution logic from technological integration to all-round AI empowerment for engineering education.

Despite its contributions to understanding the current research landscape of AI integration in engineering education, this review has several limitations that should be acknowledged. First, the analysis was based on ten representative international engineering education journals indexed in Scopus. While these journals capture important developments in this research field, additional studies from other relevant journals or databases may provide complementary perspectives. Second, AI integration in engineering education remains an emerging and rapidly evolving area, and the current body of literature within the selected scope is still developing. Future research could incorporate broader data sources and conduct longitudinal analyses to further examine the evolution of AI integration in engineering education.

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About the Authors
Yuhang Li is a PhD candidate at the School of Economics and Management, Dalian University of Technology, and a member of the Research Center for Comprehensive Higher Education Reform. Her research interests include higher engineering education. Email: 18844735150@163.com

Liang Wang is an Assistant Professor at the Graduate School of Higher Education, Dalian University of Technology, and a member of the Research Center for Comprehensive Higher Education Reform. He holds a PhD in public administration. His research interests include higher engineering education and university strategic planning. Email: wangliang9170@dlut.edu.cn

Zhaowei Chu is a Lecturer at the Faculty of Artificial Intelligence in Education, Central China Normal University. He holds a PhD in management. His research interests include artificial intelligence education policy. Email: chuzhaowei@ccnu.edu.cn

Author Contributions
Yuhang Li: Conceptualization, Writing—Original draft. Liang Wang: Supervision, Writing—Reviewing and Editing. Zhaowei Chu: Writing—Reviewing and Editing.

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REFERENCES

Acuña, O. L., Santos Carvajal, D. M., Bolanos-Barbosa, A. D., Torres-Vanegas, J. D., Alvarez Solano, O. A., Cruz, J. C., & Reyes, L. H. (2025). Fostering technical proficiency and professional skills: A multifaceted PO-PBL strategy for unit operations education. *Education for Chemical Engineers, 51*, 64–78. https://doi.org/10.1016/j.ece.2025.01.001

Allen, M., Naeem, U., & Gill, S. S. (2024). Q-Module-Bot: A generative AI-based question and answer bot for module teaching support. *IEEE Transactions on Education, 67*(5), 793–802. https://doi.org/10.1109/te.2024.3435427

Alqarni, A. S. (2024). Effect of ChatGPT on undergraduates' cognitive and performance skills of database management learning. *International Journal of Engineering Education, 40*(5), 1013–1023. https://www.ijee.ie/contents/c400524.html

Balart, T. S., & Shryock, K. J. (2025). A framework for integrating artificial general intelligence into engineering education. *International Journal of Engineering Education, 41*(1), 171–194. https://www.ijee.ie/contents/c410125.html

Borrego, M., Foster, M. J., & Froyd, J. E. (2014). Systematic literature reviews in engineering education and other developing interdisciplinary fields. *Journal of Engineering Education, 103*(1), 45–76. https://doi.org/10.1002/jee.20038

Caccavale, F., Gargalo, C. L., Gernaey, K. V., & Krühne, U. (2024). Towards Education 4.0: The role of large language models as virtual tutors in chemical engineering. *Education for Chemical Engineers, 49*, 1–11. https://doi.org/10.1016/j.ece.2024.07.002

Callejo-Pinardo, P., Alario-Hoyos, C., & Delgado-Kloos, C. (2024). Evaluating the impact of ChatGPT on programming learning outcomes in a big data course. *International Journal of Engineering Education, 40*(4), 863–872. https://www.ijee.ie/contents/c400424.html

Chang, S.-H., Yao, K.-C., Chung, C.-Y., Nien, S.-C., Chen, Y.-T., Ho, W.-S., Lin, T.-C., Shih, F.-C., & Chung, T.-C. (2023). Integration of artificial intelligence and machine learning content in technology and science curriculum. *International Journal of Engineering Education, 39*(6), 1343–1357. https://www.ijee.ie/contents/c390623.html

Cheng, J.-Y., Devkota, A., Gheisari, M., Jeelani, I., & Franz, B. W. (2025). AI integration in construction education: A survey on awareness, attitudes, and implementation of AI among U.S. and international faculties. *Journal of Civil Engineering Education, 151*(4), Article 04025009. https://doi.org/10.1061/jceecd.eieng-2223

Chiu, T. K.-F., Meng, H., Chai, C.-S., King, I., Wong, S., & Yam, Y. (2022). Creation and evaluation of a pretertiary artificial intelligence (AI) curriculum. *IEEE Transactions on Education, 65*(1), 30–39. https://doi.org/10.1109/te.2021.3085878

Dai, Y., Liu, A., Qin, J., Guo, Y., Jong, M. S.-Y., Chai, C.-S., & Lin, Z. (2023). Collaborative construction of artificial intelligence curriculum in primary schools. *Journal of Engineering Education, 112*(1), 23–42. https://doi.org/10.1002/jee.20503

Dehbozorgi, N., & Kunuku, M. T. (2023). Exploring the influence of emotional states in peer interactions on students' academic performance. *IEEE Transactions on Education, 67*(3), 405–412. https://doi.org/10.1109/te.2023.3335171

Froyd, J. E., Wankat, P. C., & Smith, K. A. (2012). Five major shifts in 100 years of engineering education. *Proceedings of the IEEE, 100*(Special Centennial Issue), 1344–1360. https://doi.org/10.1109/jproc.2012.2190167

Fruett, F., Pereira Barbosa, F., Cardoso Zampolli Fraga, S., & Ivo Aragão Guimarães, P. (2024). Empowering STEAM activities with artificial intelligence and open hardware: The BitDogLab. *IEEE Transactions on Education, 67*(3), 462–471. https://doi.org/10.1109/te.2024.3377555

Gao, Z., Wanyama, T., & Singh, I. (2020). Project and practice centered learning: A systematic methodology and strategy to cultivate future full stack artificial intelligence engineers. *International Journal of Engineering Education, 36*(6), 1760–1772. https://www.ijee.ie/contents/c360620.html

Gough, D., Thomas, J., & Oliver, S. (2017). *An introduction to systematic reviews* (2nd ed.). SAGE. https://doi.org/10.4135/9781036234942

Hao, Y., Liu, Y., Liu, B., Amarantidis, G., & Ghannam, R. (2025). Integrating AI in engineering education: A comprehensive review and student-informed module design for U.K. students. *IEEE Transactions on Education, 68*(2), 173–185. https://doi.org/10.1109/te.2025.3536105

Honig, C. D. F., Desu, A., & Franklin, J. (2024). GenAI in the classroom: Customized GPT roleplay for process safety education. *Education for Chemical Engineers, 49*, 55–66. https://doi.org/10.1016/j.ece.2024.09.001

Honig, C., Rios, S., & Desu, A. (2025). Generative AI in engineering education: Understanding acceptance and use of new GPT teaching tools within a UTAUT framework. *Australasian Journal of Engineering Education, 30*(1), 80–92. https://doi.org/10.1080/22054952.2025.2467500

Höper, L., & Schulte, C. (2025). ReVEAL model and its application to revealing viewpoints on educational approaches to learning about data and AI. *Computer Science Education, 36*(3), 428–460. https://doi.org/10.1080/08993408.2025.2516957

Keith, M., Keiller, E., Windows-Yule, C., Kings, I., & Robbins, P. (2025). Harnessing generative AI in chemical engineering education: Implementation and evaluation of the large language model ChatGPT v3.5. *Education for Chemical Engineers, 51*, 20–33. https://doi.org/10.1016/j.ece.2025.01.002

Liao, C.-W., Lin, E.-S., Chen, B.-S., Wang, C.-C., Wang, I.-C., Ho, W.-S., Ko, Y.-Y., Chu, T.-H., Chang, K.-M., & Luo, W.-J. (2025). AI-assisted personalized learning system for teaching chassis principles. *International Journal of Engineering Education, 41*(2), 548–560. https://www.ijee.ie/contents/c410225.html

Manikandan, S., & Chinnadurai, M. (2020). Evaluation of students' performance in educational sciences and prediction of future development using TensorFlow. *International Journal of Engineering Education, 36*(6), 1783–1790. https://www.ijee.ie/contents/c360620.html

Marquez, R., Barrios, N., Vera, R. E., Mendez, M. E., Tolosa, L., Zambrano, F., & Li, Y. (2023). A perspective on the synergistic potential of artificial intelligence and product-based learning strategies in biobased materials education. *Education for Chemical Engineers, 44*, 164–180. https://doi.org/10.1016/j.ece.2023.05.005

Martín Núñez, J. L., & Díaz Lantada, A. (2020). Artificial intelligence aided engineering education: State of the art, potentials and challenges. *International Journal of Engineering Education, 36*(6), 1740–1751. https://www.ijee.ie/contents/c360620.html

Mburu, T. K., Rong, K., McColley, C. J., & Werth, A. (2025). Methodological foundations for artificial intelligence-driven survey question generation. *Journal of Engineering Education, 114*(3), Article e70012. https://doi.org/10.1002/jee.70012

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & the PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLOS Medicine*, *6*(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097

Murray, M., Maclachlan, R., Flockhart, G. M. H., Adams, R., Magueijo, V., Goodfellow, M., Liaskos, K., Hasty, W., & Lauro, V. (2025). A 'snapshot' of engineering practitioners' views of ChatGPT: Informing pedagogy in higher education. *European Journal of Engineering Education, 51*(1), 104–129. https://doi.org/10.1080/03043797.2025.2492736

Neumann, A. T., Yin, Y., Sowe, S., Decker, S., & Jarke, M. (2025). An LLM-driven chatbot in higher education for databases and information systems. *IEEE Transactions on Education, 68*(1), 103–116. https://doi.org/10.1109/te.2024.3467912

Nikolic, S., Daniel, S., Haque, R., Belkina, M., Hassan, G. M., Grundy, S., Lyden, S., Neal, P., & Sandison, C. (2023). ChatGPT versus engineering education assessment: A multidisciplinary and multi-institutional benchmarking and analysis of this generative artificial intelligence tool to investigate assessment integrity. *European Journal of Engineering Education, 48*(4), 559–614. https://doi.org/10.1080/03043797.2023.2213169

Nikolic, S., Sandison, C., Haque, R., Daniel, S., Grundy, S., Belkina, M., Lyden, S., Hassan, G. M., & Neal, P. (2024). ChatGPT, Copilot, Gemini, SciSpace and Wolfram versus higher education assessments: An updated multi-institutional study of the academic integrity impacts of generative artificial intelligence (GenAI) on assessment, teaching and learning in engineering. *Australasian Journal of Engineering Education, 29*(2), 126–153. https://doi.org/10.1080/22054952.2024.2372154

Nikolic, S., Suesse, T. F., Grundy, S., Haque, R., Lyden, S., Lal, S., Hassan, G. M., Daniel, S., & Belkina, M. (2025). Assessment integrity and validity in the teaching laboratory: Adapting to GenAI by developing an understanding of the verifiable learning objectives behind laboratory assessment selection. *European Journal of Engineering Education, 50*(4), 673–701. https://doi.org/10.1080/03043797.2025.2456944

Oyedoyin, M., Sanusi, I. T., & Ayanwale, M. A. (2025). Young children's conceptions of computing in an African setting. *Computer Science Education, 35*(2), 378–413. https://doi.org/10.1080/08993408.2024.2314397

Quince, Z., & Nikolic, S. (2025). Student identification of the social, economic and environmental implications of using generative artificial intelligence (GenAI): Identifying student ethical awareness of ChatGPT from a scaffolded multi-stage assessment. *European Journal of Engineering Education, 51*(1), 43–62. https://doi.org/10.1080/03043797.2025.2482830

Reinhart, W. F., Williams, R., Solnosky, R., & Napolitano, K. (2025). Opinion: Preparing engineers for the data-driven world: The case for contextualized data science engineering education. *Advances in Engineering Education, 13*(2), 2–15. https://doi.org/10.18260/3-1-1153-36075

Rodriguez, S. L., & Ross, A. (2025). How offering a free introductory AI computing course at a Hispanic-serving community college influences computing interests for enrolled students. *Computer Science Education, 35*(3), 523–549. https://doi.org/10.1080/08993408.2024.2429082

Roldán-Álvarez, D., & Mesa, F. J. (2023). Intelligent deep-learning tutoring system to assist instructors in programming courses. *IEEE Transactions on Education, 67*(1), 153–161. https://doi.org/10.1109/te.2023.3331055

Ruano-Borbalan, J.-C. (2024). The transformative impact of artificial intelligence on higher education: A critical reflection on current trends and future directions. *Tsinghua Journal of Education, 45*(5), 13–24. https://tje.ioe.tsinghua.edu.cn/oa/darticle.aspx?type=view&id=202405002

Sajadi, S., Huerta, M., Ryan, O., & Drinkwater, K. (2024). Harnessing generative AI to enhance feedback quality in peer evaluations within project-based learning contexts. *International Journal of Engineering Education, 40*(5), 998–1012. https://www.ijee.ie/contents/c400524.html

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to do a systematic review: A best practice guide for conducting and reporting narrative reviews, meta-analyses, and meta-syntheses. *Annual Review of*

Psychology, 70(1), 747–770. https://doi.org/10.1146/annurev-psych-010418-102803

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research, 104*, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Vargas, M., Núñez, T., Alfaro, M., Fuertes, G., Gutierrez, S., Ternero, R., Sabattin, J., Banguera, L., Duran, C., & Peralta, M. A. (2020). A project-based learning approach for teaching artificial intelligence to undergraduate students. *International Journal of Engineering Education, 36*(6), 1773–1782. https://www.ijee.ie/contents/c360620.html

Wang, D., & Chen, G. (2024). Making AI accessible for STEM teachers: Using explainable AI for unpacking classroom discourse analysis. *IEEE Transactions on Education, 67*(6), 907–918. https://doi.org/10.1109/te.2024.3421606

Wu, M., Di Caprio, U., Vermeire, F., Hellinckx, P., Braeken, L., Waldherr, S., & Leblebici, M. E. (2023). An artificial intelligence course for chemical engineers. *Education for Chemical Engineers, 45*, 141–150. https://doi.org/10.1016/j.ece.2023.09.004

Xiao, Z., Lee, E., Yuan, S., Ding, R., & Tang, Y. J. (2025). Generative AI in graduate bioprocess engineering exams: Is attention all students need? *Education for Chemical Engineers, 52*, 133–140. https://doi.org/10.1016/j.ece.2025.05.006