SOCIO-TECHNICAL READINESS: BRIDGING AI BUILDING CAPACITY AND HUMAN-CENTRIC IN HIGHER EDUCATION PEDAGOGY

Nadia Safura Zabidin*
Faculty of Civil Engineering, Universiti Teknologi MARA, Jengka Campus,
26400 Bandar Tun Abdul Razak Jengka, Pahang, Malaysia
nadiasafura@uitm.edu.my

Siti Noor Aisyah Binti Hasnan*
Academy of Language Studies, Universiti Teknologi MARA, Jengka Campus,
26400 Bandar Tun Abdul Razak Jengka, Pahang, Malaysia

Evanna Devi A/P Seyapalan
Academy of Language Studies, Universiti Teknologi MARA, Jengka Campus,
26400 Bandar Tun Abdul Razak Jengka, Pahang, Malaysia

Abstract: The current landscape in higher education institutions towards Artificial Intelligence (AI) reflects a complex socio-technical efficiency between rapid technological adoption and the continuity of human-centric pedagogical values. While AI substantially offers significant potential to enhance teaching and learning proficiency, its accelerated adoption raises a critical concern in navigating the digital transformations in higher education. A significant research gap persists in aligning institutional building capacity initiatives with the reinforcement of human-centric values to ensure a balance transformation of higher education pedagogy. This research explores the concepts of socio-technical readiness and pedagogical values by focusing on the dynamic integration between digital infrastructure and human elements in pedagogy. This study utilises the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) methodology to systematically synthesis previous study published from 2019 to 2025 across global scholarly database. The systematic literature review analysis highlights current trends, challenges and best practices in AI adoption within institutions building capacity and human-centric pedagogical approaches in higher education. The key identification of socio-technical factors influencing a successful AI adoption to balance and sustain the technological efficiency with pedagogical values. By bridging the digital technology capabilities and pedagogical integrity, this study contributes to aligning the digital transformation with human ethics practices. The implications of this research provide a strategic framework for higher education leaders to foster an effective AI-driven transformation while maintaining human-centric pedagogy. Hence, this study underscores the importance of expanding institutional readiness to sustain a high-quality teaching and learning ecosystem in AI educational context.

Keywords: Artificial Intelligence, Building Capacity, Higher Education, Human-Centric, Socio-technical

1. Introduction

The rapid integration of Artificial Intelligence (AI) within higher education has transformed the conventional pedagogy into digitalisation driven that redefines teaching methodologies, learning engagement and academic assessment practices. As Generative AI and adaptive learning system become ubiquitous, universities face complex challenges in balancing socio-technical readiness with institutional building capacity and human-centric pedagogy. This pressure is particularly visible in the field of Civil Engineering, where the transformation towards Industry 5.0 and Education 5.0 competency demands in Building Information Modeling (BIM) and AI-assisted structural analysis tools (Schallert-Vallaster, S., 2025). Hence, the urgency to push towards sustainable AI technical infrastructure must be strategically aligned with robust data governance mechanism and comprehensive digital literacy framework (Malik et al., 2025). Despite rapid advancement, a primary responsibility remains crucial to align with human-centric pedagogy, which prioritises critical thinking, institutional ethics and purposeful instructor-peer relationship (Dong et al., 2026).

The fundamental discrepancy between the AI building capacity and human-centric pedagogy often execute in silos, resulting in insufficient socio-technical readiness towards AI integration in current pedagogical practices (Khoza & van der Walt, 2025). The nature of AI integration in higher education may be technically considered well-prepared, yet pedagogical capabilities in human-centric values remain inadequate (Yuliya, 2025.). In civil engineering perspectives, the human interference is crucial, while the algorithm may optimise the engineering design and project costs, but it cannot replace the ethical judgement required for safety and communication throughout different stakeholders (Khoza & van der Walt, 2025). Hence, this fragmentation creates extensive disparity between technological infrastructures and pedagogical. In order to bridge this gap, a strategic socio-technical readiness framework shall be developed, to align AI building capacity with human-centric pedagogical practices to ensure that AI serves as a catalyst for higher education.

This study explores a comprehensively socio-technical readiness in higher education pedagogy to critically bridge the gap between AI building capacity and human-centric values in Civil Engineering studies. To achieve the research objectives, this study adopts a Systematic Literature Review (SLR) in accordance with the PRISMA (Preferred Reporting Items for Systematic Literature Reviews and Meta-Analysis) guidelines. By synthesising global scholarly literature and best practices across dynamic databases, this method provides vigorous evidence based to identify socio-technical readiness factors that influence a successful AI adoption. Ultimately, this systematic approach allows for the development of strategic framework to support higher education sustain an excellent teaching and learning ecosystem.

2. Methodology

A Systematic Literature Review (SLR) is a meticulous and essential method to synthesis the previous research perspectives based on a specific research topics or area of interest. This technique is defined as a secondary study that utilises an explicit and transparent methodology to identify, evaluate and consolidate all accessible evidence related to a specific research investigation in an unbiased and replicable manner (Kitchenham, 2007) The primary characteristics of an SLR are to systematically identify the relevant publications that guided by predefined research questions, critically appraising evidence and analysing data through structured inclusion and exclusion principles to generate an impactful synthesis of existing knowledge (Sovacool et al,, 2018). The SLR of this study is based on the main questions: *What socio-technical readiness factors are required to bridge the gap between AI building capacity and human-centric in civil engineering pedagogy?* To provide a deeper finding, the following sub-questions are addressed:

- RQ1: What is the current state of AI building capacity components and human-centric pedagogical values within civil engineering perspectives?
- RQ2: How has the AI building capacity and human-centric implemented in the context of civil engineering?

2.1 *Preferred Reporting items for Systematic Review and Meta-Analysis (PRISMA)*

This study adopts the PRISMA methodology to systematically develop a thorough contextual understanding of previous studies ensuring transparency, scholarly accuracy and methodological reliability (Liberati, A. et al., 2009). The PRISMA statement enables a comprehensive review of the literature and provides a critically evaluated report of the current state of the field (Moher, D. et al., 2009). By adopting this methodology, the study facilitates a structured evaluation of information across specific stages, particularly focusing on the integration of AI building capacity and human-centric pedagogy in civil engineering discipline. The PRISMA stages consist of four-phases visualised in a structured flow diagram, including identification, screening, eligibility and inclusion (Sarker, S. et al., 2019). Figure 1 presents the PRISMA analysis flowchart.

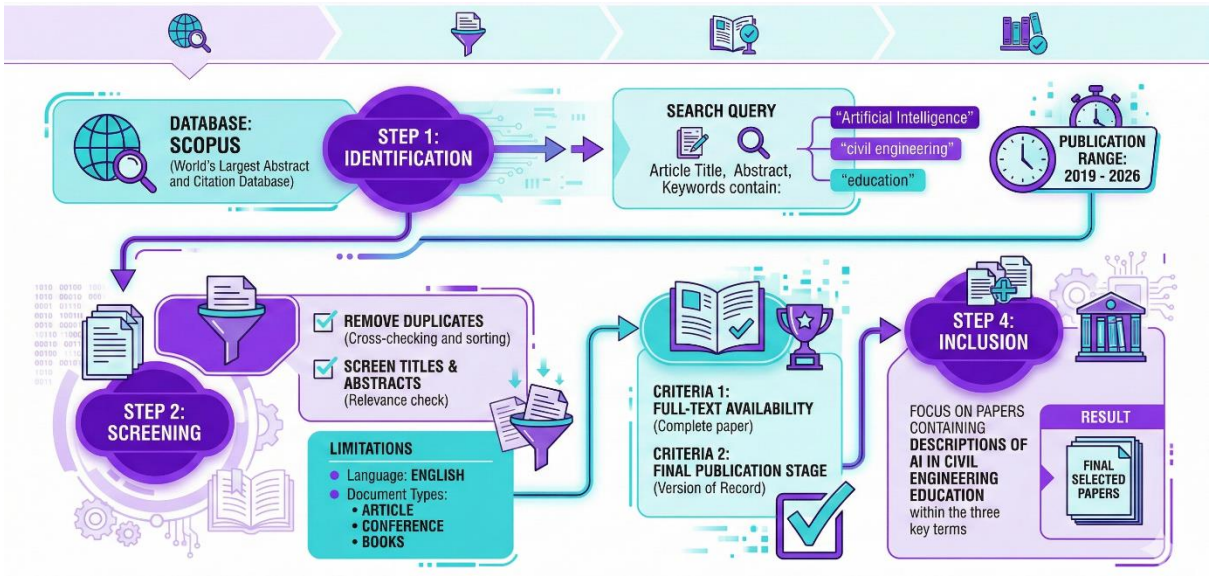

Figure 1: The PRISMA Systematic Literature Review Flowchart

2.2 *Exclusion and Inclusion Review Principle*

The systematic synthesis remains meticulous and significant to this study's objectives; a multi-stage exclusion and inclusion criteria were adopted. These criteria work as a methodological screen process to identify evidence in the context of AI within civil engineering and education domains. Through this structured process, the review established a reliable evidence base for developing the socio-technical readiness. A comprehensive search of "artificial intelligence", "civil engineering" and "education" was used in the Scopus database across publication title, abstract and keywords that yield a preliminary number of 206 publications. The Scopus database was chosen as it represents the world's largest research publications, offering extensive and reliable coverage across muti-disciplinary fields.

The exclusion criterion was applied by limiting the years of publication strictly between year 2019 until 2026. Subsequently, this study restricted to English-language documents processing only, thereby decreasing the total number to 144 publications. The accessibility of literature review was evaluated through exclude non full text publication, leaving 135 publications for further consideration. In order to maintain academic perspectives, the dataset was limited to specific document types such as journal articles, conference proceedings and books that further narrowed to 133 publications. Finally, content analysis was performed to eliminate publications content that does not align with the target keywords and yield a finalised dataset of 118 publications only. Table 1 illustrates the exclusion and inclusion criteria.

Table 1: Exclusion and Inclusion Criteria

Exclusion/ Inclusion	Criteria	Explanation	Results (No. of Publication)
Exclusion	Search Engine Reason (SER)	SER1: Scopus databased engine was used. Searching within article title, abstract and keywords on "Artificial Intelligence" and "civil engineering" and "education"	SER1: 206
		SER2: Searches were limited from year to 2019 until 2026	SER2: 206
		SER 3: Papers with relevant title, abstract and keywords in English only	SER3: 144
	Without Full text (WF)	Papers without full texts were assessed	WF: 135
	Non-Related (NR)	Limited to article, conference and books.	NR: 133

	Loosely Related (LR)	The content is irrelevant with keywords searched	LR: 118
Inclusion	Partially Related (PR)	Search mentioning based on the three keywords	PR: 118
	Closely Related (CR)	Focus on papers containing the descriptions of AI in Civil engineering education within keywords	CR: 118

3. Data Analysis and Results

This chapter present the analysis of the study focusing the integration of AI in civil engineering education from year 2019 to 2026. The data was systematically collected from Scopus database to ensure a global perspective on research output. The data analysis begins with investigate the annual publication output for a disperse and significant increasing path between year and number of publications. Initiating with only 2 publications in 2019, the number of publications increased gradually to 19 by 2023 and then expedite rapidly to attain a highest of 41 publications in 2025. However, the data for 2026 hit a severe deterioration to 6 publications, which may indicate that the year is still on going and the analysis for year 2026 is currently incomplete. Figure 2 shows the trend of publication year for AI in civil engineering education.

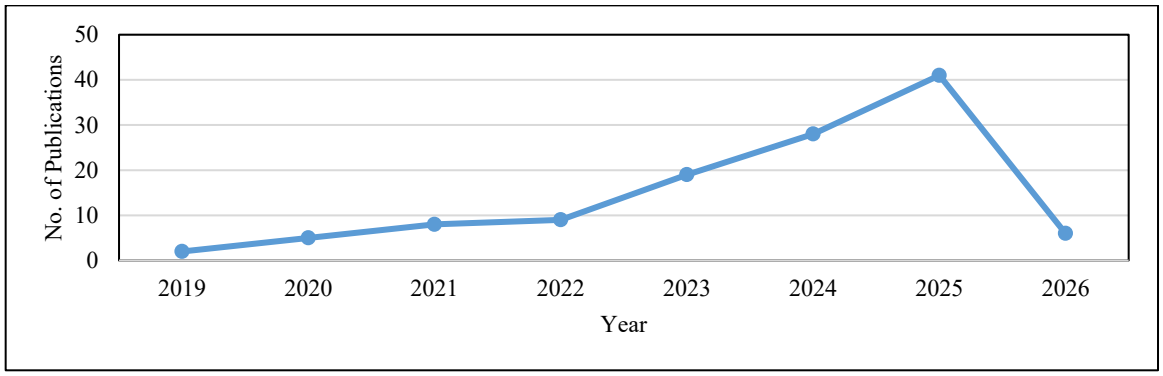

Figure 2: Publication Trends in Year

A geographical analysis of the research indicate that the United States is the leading contributor with 30 publications. Next, followed by India with 25 publications ranks as the second-highest contributor, while China 13 publications and Canada 8 publications which demonstrate a substantial study engagement within this domain. The remaining publication outputs are distributed across a various range of countries with moderately lesser individual contribution, reflecting globally interest in the subject yet remains contemplated within few advanced countries. Figure 3 illustrates the geographical distribution of research output publication trends across different countries.

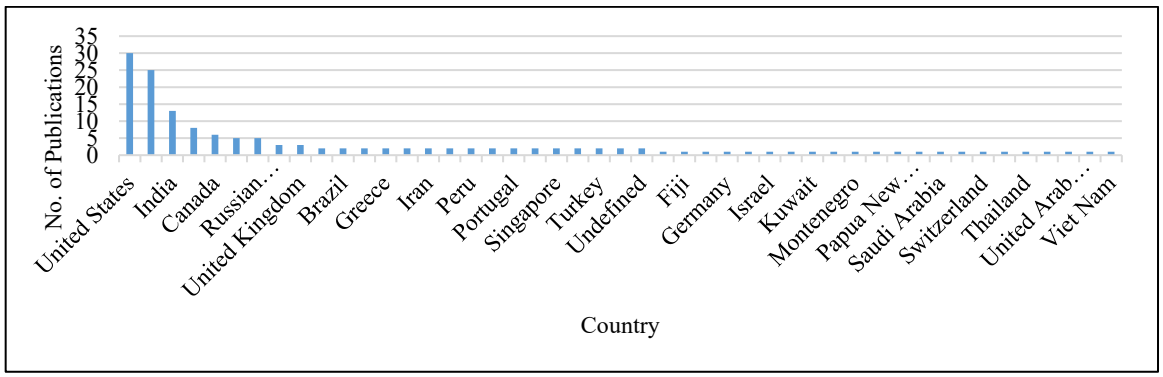

Figure 3: Publication Trends Across Different Countries

The overall composition of research distribution is significantly influenced by conference-based research publications. Conference papers portray for the majority of the publication documents at 55%, indicating that this field prioritises instant sharing of knowledge and professional networking through academic meetings. Journal articles represent 24% of the total number of publications document, whereas the remaining is distributed between books, 11% and book chapters, 10%. This output pattern signifies a reasonable consolidation of in-depth theoretical and conceptual development within this study domain. Figure 4 presents the publication types of distribution for this study.

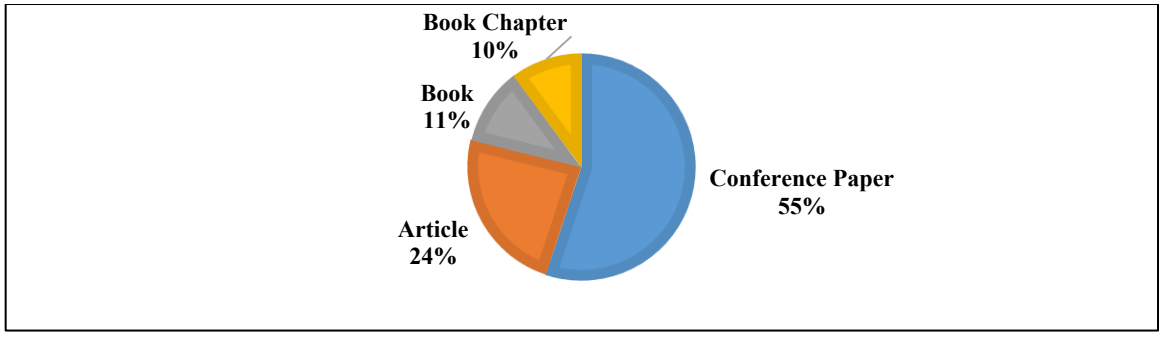

Figure 4: Type of Publication Document

A bibliometric mapping generated using VOSviewer software to provide a thorough overview of this study. These visualisation outputs represent the co-authorship and keyword co-occurrence analysis to illustrate the core thematic network cluster within this field of study. The co-authorship network map shows the structural patterns of relationship among researchers contributing to this study domains. The visualisation output establishes an intense and extremely interconnected research network that indicating a strong collaborative engagement rather than isolated research effort. Significantly, Novoselov, Konstantin S., Klimeck, Gerhard and Filipovic, Nenad D. arise as central nodes with several linkages, indicating their prominent role in relating varied research cluster. The adjacent and wide interlinkages between authors reflect an active collaboration of practice in regards of knowledge exchange across global institutional boundaries. Figure 5 shows the co-authorship network mapping on AI in civil engineering education.

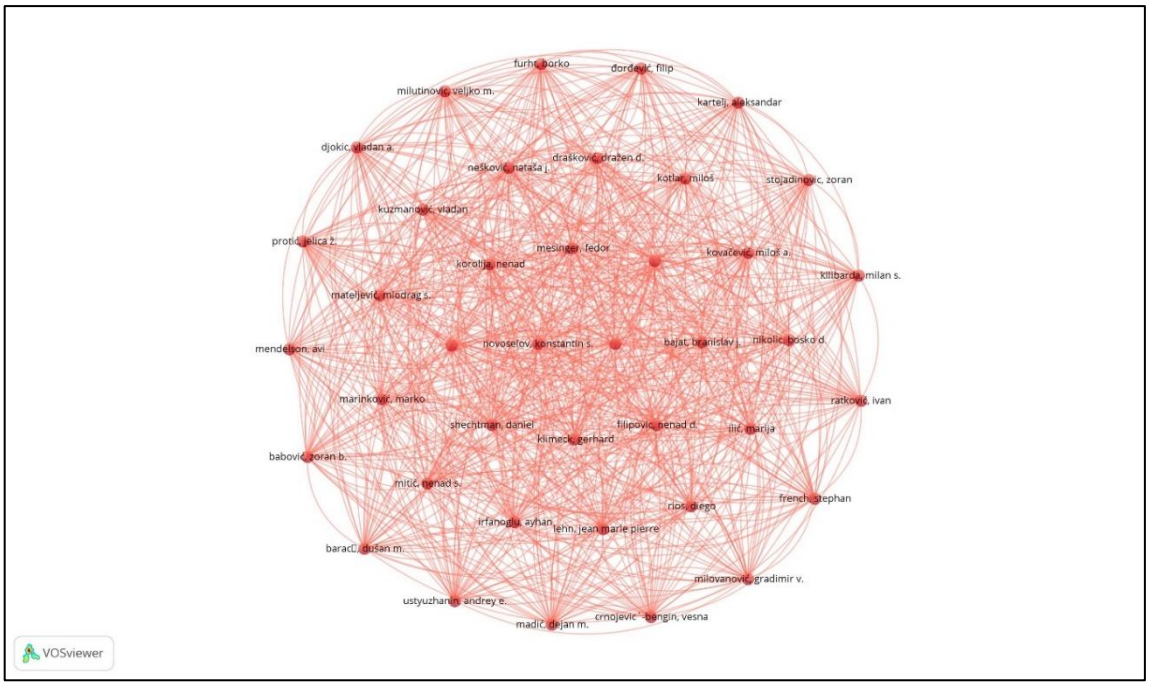

Figure 5: Co-authorship of Author Network Mapping

The density visualisation further emphasizes influential research domain by illustrating the frequency and intensity of key terms within the dataset output. The primary thematic cluster is "artificial intelligence" which acts as the primary node linking to others related cluster such as "civil engineering" and "engineering education", which serves the centre pillar of the data set. Further high-density cluster contains "machine learning", "ChatGPT" and "higher education". Indicating a strong scholarly focus on integrating AI technologies into academic pedagogy. Surrounding these central cluster, secondary density cluster such as "deep learning", "active learning" and "sustainable development" appear as peripheral significance that reflects the broaden pedagogical utilisation and interdisciplinary directions of this study. Figure 6 illustrates the density visualisation of author keywords focusing in AI in civil engineering pedagogy.

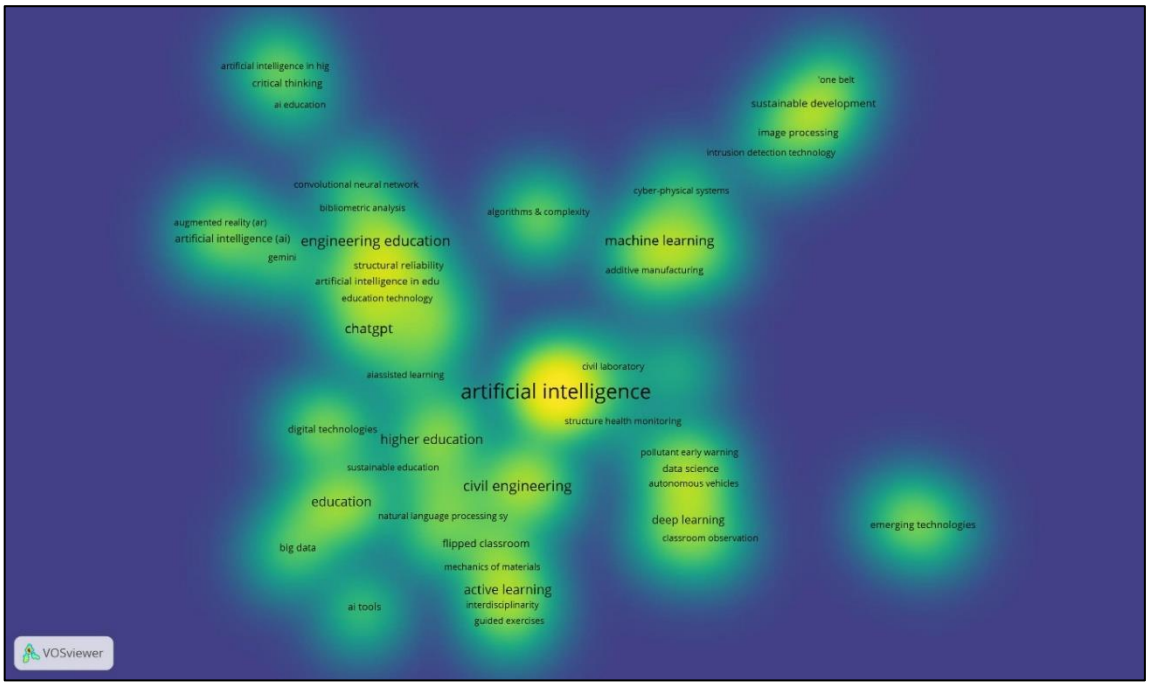

Figure 6: Author Keywords Co-occurrence Density Visualisation

A comprehensive content analysis components of 118 closely related selected publications was conducted using multi stage thematic analysis and PRISMA process to exposes a complex research environment focused on the integration of AI in civil engineering pedagogy. The rapid transformation of intelligent civil engineering technologies necessitates a strategic readiness factor to bridge the gap between AI building capacity and human-centric in pedagogy. This publication synthesis uncovers that lacking a multi-dimensional method, the AI adoption continues fragmented and may risking the future engineer graduates who lack of socio-technical maturity to oversee automated system. The identification of five independent readiness factor is essential for the transformation of civil engineering pedagogy were identified through a systematic synthesis of the literature review from the PRISMA method according to recurring themes which categorised into higher-order.

The first factor, Pedagogical alignment highlights a shift from deterministic approaches to probabilistic student-centred models to ensure AI-generated output are align with pedagogy standards. Subsequently, the Technical Competency & Literacy factor were identified to measure students' ability to critically validate the AI usage to avoid any inaccurate and misleading outputs. The third factor, Ethical and Integrity Governance establish the essential institutional safety and consistent practices to prevent misinformation and misconduct while encouraging responsible in AI usage. The readiness factor is grounded in Institutional and Digital Infrastructure, including the integration of smart laboratories and cloud-based learning system that enable real-time data driven. Finally, Socio-technical Maturity focuses on embracing the pedagogy gaps by strengthening the competencies required to effectively apply and

interpret AI outputs. This readiness factor form an integrated socio-technical literacy by adopting ethical utilisation and robust institutional building capacity. Table 2 shows the synthesis of readiness factor.

Table 2: Synthesis of Socio-technical Readiness Factor

Readiness Factor	Description	Authors
Pedagogical Alignment	Adaptive and student-centred delivery	Zhang, J. (2026), Macedo, J. & Oliveira, P.C. (2024), Hachani, A. & Ajailia, N. (2023), Sangree, R.H. (2022), Le, T. (2019), García-Ramírez, Y., et al. (2019)
Technical Competency & Literacy	Proficiency in AI evaluation and prompt design	Xu, G., Wang, D., & Chang, G. K. (2026), Ahmed, A., et al. (2025), Wijesinghe, P., et al. (2025), Lukhmanov, Y., et al. (2025), Yang, K., et al. (2025), Olano Alvarado, S.A., et al. (2024), Sykora, M., et al. (2019)
Ethical & Integrity Governance	Regulatory policies for ethical AI use	Awolusi, A.F., et al. (2026), Xu, G., et al. (2026), Harper, M. & McCall, C. (2024), Meshcheryakova, A.V., et al. (2024), Zhang, R. & He, M. (2022), Cannarsa, M. (2021), Ulnicane, I., et al. (2021), Filipe, J., & Bozzon, A. (2019)
Institutional & Digital Infrastructure	Cloud-based labs and immersive platforms	Selvaraj, G., et al. (2025), Wang, X. (2025), Matthew, A.O., et al. (2025), Cercone, C., et al. (2025), Hadizadeh, M., et al. (2025)
Socio-technical Maturity	Soft skills and Industry 5.0 alignment	Ahankoob, A., et al. (2025), Luna Villarreal, K., et al. (2025), Saienko, N., et al. (2024), Krishna, P. & R Iyer, N.R. (2023), Andrade-Zurita, S., et al. (2022), Pino Tarragó, J.C., et al. (2025)

4. Discussions

The transformation of digitalisation requires a transition in civil engineering education into the era of AI. The identification of SLR output is a strategic necessary for identifying high-impact research trends and bridge the gap between AI and human-centric values. The results of this study, allows higher education institutions to classify by their exact engineering and pedagogical purposes. A primary finding of the content analysis indicates that the higher education must shift from a rigid conventional teaching to student-centred adaptive models that require for modern reliability-based design (Zhang, 2026). This study reveals that pedagogical alignment is not merely about adding AI tools to a pedagogy but a fundamental shift in build student understanding (Hernandez-Herrera, 2026). The integration of AI acts as crucial bridge mechanism, ensuring that while student engaging with AI's capabilities, they remain prepared to the strict technical standards requires to preserve consistent safety practices.

The second factor of technical competency and literacy emphasizes an increasing concern in the literature review considering misconduct and unethical behaviour. The findings propose that readiness is defined by a students' capability to serve as a critical validator which is involve the competencies to discover errors in AI domain tasks (Vasques-Monteros, 2024). This role transforms future engineer fundamental knowledge and skills towards capacity to validate and judgement AI-generated outputs. This study highlights the third factor of ethical and integrity governance, and fourth factor of institutional and digital infrastructure are interdependent rather than independent in silos domains. The presence of smart laboratories provides an empirical environment where ethical preserve is assessed (Wang, 2025). This technology provided with real-time risk detection and visual recognition to authentic ethical problems involving data privacy, algorithm bias and liability in safety management. Hence, this proves that ethical literacy cannot be develop conceptually but, it must be embedded within technological practices.

The last factor is socio-technical maturity suggest that global readiness is currently unbalanced within technology-oriented program (Pino Tarrago, 2025). In contrast, higher education institutions are advancing in adopting cloud learning ecosystem and Ai-enhanced applications to remove the disparities in current pedagogy (Mao et al,. 2025). Bridging the gap involves more than developing future graduates' soft skills but also demands capabilities in AI-driven risk assessment, multidisciplinary coordination, administrative compliance and stakeholder communications. The readiness factor develops from the dynamic interaction between technical literacy, ethical governance, pedagogical restructuring and infrastructure capacity. Hence, this factor serves as an integrated socio-technical ecology, where the deficiency of one factor disrupts the entire higher education institutions system.

5. Conclusions and Recommendations

This study emphasises that the successful integration of AI in higher education, specifically within civil engineering disciplines is a complex socio-technical transformation rather than discrete technological task. The findings expose a critical disintegration where institutional digital infrastructure often progresses more promptly than the development of human-centred pedagogical values. Through the systematic synthesis of five core readiness factors consist of pedagogical alignment, technical competency and literacy, ethical and integrity governance, institutional and digital infrastructure and socio-technical maturity. These integration functions as socio-technical ecosystem synchronised within each factor. Hence, the findings of this study proves that AI integrations enhance digital competencies in civil engineering disciplines, yet the ethical decline and contextual judgement remain excluding the human competencies. In order to foster an effective and sustainable AI-driven transformation in civil engineering, higher education institutions shall disrupt a holistic pedagogical approach by adopt a suitable future strategy framework to align socio-technical pedagogy. Institutions shall shift the current education to adaptive student-centred pedagogical models in which AI functions serve as catalyst for critical inquiry rather than just only ordinary output generator.

References

Adeika, B. I., Abiodun, P. O., & Owolabi, O. A. (2024). Transforming Pedagogical Assessment: AI and Computer Vision-Enhanced Classroom Observations for Experiment-Centric Learning Environments. *ASEE Annual Conference and Exposition, Conference Proceedings*.

Adeli, H. (2020). Four Decades of Computing in Civil Engineering. In *Lecture Notes in Civil Engineering* (pp. 3-11). Springer. https://doi.org/10.1007/978-981-15-0802-8_1

Ahankoob, A., Abbasnejad, B., & Aranda-Mena, G. (2025). Building Information Modelling (BIM) Acceptance and Learning Experiences in Undergraduate Construction Education: A Technology Acceptance Model (TAM) Perspective—An Australian Case Study. *Buildings, 15*(11). https://doi.org/10.3390/buildings15111804

Ahmed, A., Katikaneni, S., & Gunda, A. (2025). Harnessing Generative AI for Educators: Case Study of Accurate Wildfire Location Mapping. *ASEE Annual Conference and Exposition, Conference Proceedings.* https://doi.org/10.18260/1-2--56683

Ajay, A., Rani, S., Kumar, K. D., & Jain, M. (2025). *Handbook of AI in engineering applications: Tools, techniques, and algorithms*. CRC Press. https://doi.org/10.1201/9781032724508

Alkabaa, A. S. & Alamri, N. M. (2025). Exploring the Effectiveness of Generative AI as a Learning Tool in Engineering Education: An Analysis of Student Experiences and Perceptions. *Computer Applications in Engineering Education, 33*(6). https://doi.org/10.1002/cae.70110

Andrade-Zurita, S., Armas-Arias, S., Nunez-l, R., & Arévalo-Peralta, J. (2022). Decision Trees and Gender Stereotypes in University Academic Desertion. *Lecture Notes in Networks and Systems*, 514 LNNS, 321-331. https://doi.org/10.1007/978-3-031-12413-6_25

Arora, K., Sharma, H., & Mahesh, A. (2025). *Artificial Intelligence and Machine Learning Algorithms for Engineering Applications.* CRC Press. https://doi.org/10.1201/9781003563440

Awolusi, A. F., Oluwatuyi, O. E., Finbarrs-Ezema, B. C., Folorunsho, R., & Azab, M. (2026). Impact of Artificial Intelligence in Civil Engineering Education. In *Studies in Systems, Decision and Control* (pp. 511-540). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-032-07738-7_25

Babović, Z., Bajat, B., Barač, D., Crnojevic´-Bengin, V., Djokic, V.,. (2023). Teaching computing for complex problems in civil engineering and geosciences using big data and machine learning: synergizing four different computing paradigms and four different management domains. *Journal of Big Data, 10*(1). https://doi.org/10.1186/s40537-023-00730-7

Bagherimajd, K. & Khajedad, K. (2025). Designing a model of sustainable education based on artificial intelligence in higher education. *Computers and Education: Artificial Intelligence*, 9. https://doi.org/10.1016/j.caeai.2025.100439

Ballen, S. D., Camino, D. A., & Guerra, M. A. (2024). Board 40: Work in Progress: Generative AI to Support Critical Thinking in Water Resources Students. *ASEE Annual Conference and Exposition, Conference Proceedings*.

Barreto, I. B. L. R. & Huaricallo, Y. H. (2024). Exploration and Integration Potential of ChatGPT in Civil Engineering: Advances, Challenges and Application Prospects. *Lecture Notes in Networks and Systems*, 1000 LNNS, 407-418. https://doi.org/10.1007/978-981-97-3289-0_33

Bazrafshan, P., Melag, K., & Ebrahimkhanlou, A. (2025). Assessing Semantic Similarity in Automated Civil Engineering Image Descriptions: Evaluation of Pre-trained Vision Language Models. *Proceedings of SPIE - The International Society for Optical Engineering*, 13438. https://doi.org/10.1117/12.3051543

Bhardwaj, R. G. & Bedi, H. S. (2025). ChatGPT as an education and learning tool for engineering, technology and general studies: performance analysis of ChatGPT 3.0 on CSE, GATE and JEE examinations of India. *Interactive Learning Environments, 33*(1), 321-334. https://doi.org/10.1080/10494820.2024.2344054

Broberg, M. R., Khalifah, S., Gupta, A., & Nafakh, A. J. (2021). An Evaluation of a University-Level, High School Course Taught to Foster Interest in Civil Engineering (Evaluation). *ASEE Annual Conference and Exposition, Conference Proceedings.*

Camarillo, M. K., Lee, L. S., & Swan, C. (2024). Student Perceptions of Artificial Intelligence and Relevance for Professional Preparation in Civil Engineering. *ASEE Annual Conference and Exposition, Conference Proceedings.*

Cannarsa, M. (2021). Ethics Guidelines for Trustworthy AI. In *The Cambridge Handbook of Lawyering in the Digital Age* (pp. 283-297). Cambridge University Press. https://doi.org/10.1017/9781108936040.022

Cercone, C., Mendrinos, K. A., Volovski, M., Lee, J., Fathi, M., Omidvar, M., & Quayyum, S. (2025). Leveraging AI-Generated Supplemental Videos to Enhance Undergraduate Engineering Education. *ASEE Annual Conference and Exposition, Conference Proceedings*. https://doi.org/10.18260/1-2--56923

Chassiakou, P., Tsikas, P., & Chassiakos, A. (2025). The Integration of ChatGPT in Construction Project Management Education: Student Perspectives and Implications. *International Conference on Construction in the 21st Century.*

Chen, Z. & Chen, Y. (2024). Advancing AI-Driven BETC Models for Transformative Educational Data Mining and Learning Analytics. *ACM International Conference Proceeding Series*, 495-500. https://doi.org/10.1145/3700297.3700382

Chiadighikaobi, P. C., Hematibahar, M., Kharun, M., Stashevskaya, N. A., & Camara, K. (2024). Predicting mechanical properties of self-healing concrete with Trichoderma Reesei Fungus using machine learning. *Cogent Engineering, 11*(1). https://doi.org/10.1080/23311916.2024.2307193

Chiang, T. (2021). Estimating the artificial intelligence learning efficiency for civil engineer education: A case study in taiwan. *Sustainability (Switzerland), 13*(21). https://doi.org/10.3390/su132111910

Cline, E. C., Dillon, H., Sesko, A. K., Nahmani, M., Kmail, Z., Dinglasan-Panlilio, J., Lee, S.-J., Cilli-Turner, E., & Björling, E. A. (2024). Board 317: Institutional Practices to Close the Equity Gap. *ASEE Annual Conference and Exposition, Conference Proceedings*.

Coronado-Apodaca, K. G. & Barrios-Piña, H. A. (2025). Enhancing Educational Innovation: Evaluating the Accuracy of AI-Generated Assessments for Engineering Course Reports. *Communications in Computer and Information Science*, 2480 CCIS, 90-104. https://doi.org/10.1007/978-3-032-02672-9_7

Estrella, Q. M. & Florencio, J. B. (2025). *Utilizing Artificial Neural Network to Analysis of Academic Performance and Retention in Civil Engineering Education*. 2025 13th International Conference on Information and Education Technology, ICIET 2025, 149-153. https://doi.org/10.1109/ICIET66371.2025.11046293

García-Ramírez, Y. (2019). Pavements course: Is the flipped classroom model effective in all cases? A case study in a developing country. *WEBIST 2019 - Proceedings of the 15th International Conference on Web Information Systems and Technologies*, 509-516. https://doi.org/10.5220/0008397705090516

García-Ramírez, Y. (2024). Implementing Multiple Different Active Learning Techniques In Online Road Geometric Design Courses. *Advances in Engineering Education, 12*(1), 25-44. https://doi.org/10.18260/3-1-1153-36052

Graf, W., Fleischhauer, R., Storm, J., & Wollny, I. (2025). *Advances and Challenges in Computational Mechanics*. Springer Nature. https://doi.org/10.1007/978-3-031-93213-7

Guala, I., Camino, D. A., Guerra, M. A., & Durán-Ballén, S. (2024). ChatGPT to Support Critical Thinking in Construction-Management Students. *ASEE Annual Conference and Exposition, Conference Proceedings.*

Guo, X., Huang, S., Jiang, J., Pavlovic, M., Ding, S., Vilotic, M., & Li, Y. (2023). Environment Monitoring Along China-Europe Railway Express With Remote Sensing And Artificial Intelligent Technology: A Regional Collaboration Project Between China And Serbia. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 10*(5/W1-2023), 31-36. https://doi.org/10.5194/isprs-annals-X-5-W1-2023-31-2023

Hachani, A. & Ajailia, N. (2023). *Towards New Generation of Civil Engineers in the IoT Era: PBL as a Tool for Integrating IoT in Civil Engineering Curricula*. IEEE Global Engineering Education Conference, EDUCON, 2023-May. https://doi.org/10.1109/EDUCON54358.2023.10125234

Hadizadeh, M., Rastgoo, N., Ghasemi, Z., & Ryshtein, I. (2025). Sustainability in the Digital Era: The Role of Digital Platforms. In *Business Sustainability: Strategies, Practices and Global Implications* (pp. 41-67). Nova Science Publishers, Inc..

Hamad, A. A. (2025). Integrating Modern Mathematics and Sensor Technologies in Civil Engineering. *IGI Global.* https://doi.org/10.4018/979-8-3373-5248-0

Hariri-Ardebili, M. A., Mahdavi, G., Nuss, L. K., & Lall, U. (2023). The role of artificial intelligence and digital technologies in dam engineering: Narrative review and outlook. *Engineering Applications of Artificial Intelligence,* 126. https://doi.org/10.1016/j.engappai.2023.106813

Harper, M. & McCall, C. (2024). Faculty Perspectives on Undergraduate Use of Generative Artificial Intelligence (GAI) Assistance: A Work-in-Progress. *ASEE Annual Conference and Exposition, Conference Proceedings.*

Hernández-Herrera, J. R., Ortiz-Bejar, J., & Ortiz-Bejar, J. (2026). Adaptive and Personalized Learning in Higher Education: An Artificial Intelligence-Based Approach. *Education Sciences, 16*(1). https://doi.org/10.3390/educsci16010109

Kim, D. & Riley, C. (2025). Exploring the Capability of Generative AI as an Engineering Lab Report Assessment Assisting Tool. *ASEE Annual Conference and Exposition, Conference Proceedings.* https://doi.org/10.18260/1-2--56525

Kitchenham, B., & Charters, S. (2007). Guidelines for performing Systematic Literature Reviews in Software Engineering. *Technical Report EBSE 2007-001*. Keele University and University of Durham.

Kolathayar, S., Menon, N. V. C., & Sreekeshava, K. S. (2024). Civil engineering innovations for sustainable communities with net zero targets. *CRC Press*. https://doi.org/10.1201/9781032686899

Khoza, N. N. G., & van der Walt, F. (2025). A systematic review on AI-enhanced pedagogies in higher education in the Global South. *Frontiers in Education, 10*, Article 1667884. https://doi.org/10.3389/feduc.2025.1667884

Kruckeberg, D., Vujnovic, M., Swiatek, L., & Galloway, C. (2025). AI, Activism, and Strategic Communication: Grappling with Evolving Power Dynamics. In *AI and Strategic Communication* (pp. 71-81). wiley. https://doi.org/10.1002/9781394275434.ch3

Kumar, A. & Mor, N. (2021). An Approach-Driven: Use of Artificial Intelligence and Its Applications in Civil Engineering. In *Studies in Big Data* (pp. 201-221). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-981-33-6400-4_10

Kundu, M., Sangwan, S., Sharma, A., & Gupta, R. (2025). Chat GPT: Growth and challenges in technical education. In *Progressive Computational Intelligence, Information Technology and Networking* (pp. 420-424). CRC Press. https://doi.org/10.1201/9781003650010-69

Li, L., Ma, M., & Ma, Z. (2025). Research on the Relationship between Modern Educational Technology and Social Science in Intelligent Construction. *Proceedings of 2024 2nd International Conference on Information Education and Artificial Intelligence, ICIEAI 2024*, 863-868. https://doi.org/10.1145/3724504.3724644

Li, S.-Q. (2024). *Empirical Seismic Vulnerability and Resilience Assessment of Building Clusters*. Elsevier. https://doi.org/10.1016/C2022-0-03327-4

Li, Y. & Yu, J. (2023). Application of Artificial Intelligence Virtual Reality Technology in Civil Aviation Safety Education and Training. *Proceedings - 2023 International Conference on Computer Applications Technology,* CCAT 2023, 69-73. https://doi.org/10.1109/CCAT59108.2023.00020

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *PLOS Medicine, 6*(7), e1000100. https://doi.org/10.1371/journal.pmed.1000100

Liu, H., Li, Y., & Duan, Z. (2025). Data Science in Air Quality Monitoring. In *Engineering Applications of Computational Methods* (pp. 1-239). Springer Nature. https://doi.org/10.1007/978-981-96-5777-3

Lukhmanov, Y., Perveen, A., & Tsakalerou, M. (2025). *ChatGPT in Engineering Teaching & Learning: Student and Faculty Perspective.* IEEE Global Engineering Education Conference, EDUCON. https://doi.org/10.1109/EDUCON62633.2025.11016423

Macedo, J. & Oliveira, P. C. (2024). Use of ICT to implement an active learning strategy in soil mechanics courses at undergraduate level. *Soils and Rocks, 47*(2). https://doi.org/10.28927/SR.2024.007323

Mao, W., Huang, Y., Zheng, H., Li, X., He, X., & Xu, C. (2025). Report on the 2024 annual academic conference of the committee on earthquake hazard chain, Seismological Society of China,6–9 December 2024, Shanghai, China. *Natural Hazards Research, 5*(4), 719-727. https://doi.org/10.1016/j.nhres.2025.02.005

Marupov, A., Makhsimov, K., Mirzaev, R., Tursunov, O., Bakhromov, M., & Eminchaev, B. (2024). Smart Structures: *Leveraging Artificial Intelligence for Sustainable Solutions in Civil Engineering*. 2024 4th International Conference on Advancement in Electronics and Communication Engineering, AECE 2024, 867-871. https://doi.org/10.1109/AECE62803.2024.10911280

Matthew, A. O., Kazaure, J. S., Matthew, U. O., Chinenye, M. F., Oyedemi, O. A., Onyedibe, O. N., Muhammed, I. H., & Haruna, K. (2025). AI-Powered VR/AR Environments for Experiential Civil Engineering Education. In *Exploring Digital Models and Immersive Spaces in Architecture and Construction* (pp. 323-358). IGI Global. https://doi.org/10.4018/979-8-3373-3256-7.ch008

Mayer, S. J. (2026). Bridging pedagogy and technology: Integrating artificial intelligence into elementary classroom practice. *Essays in Education, 32*(1), Article 1. https://openriver.winona.edu/eie/vol32/iss1/1

Melhem, S. & Richani, D. D. (2025). Empowering the digital workforce: government initiatives, industry partnerships, and educational reforms. In *Building Digital Technological Capabilities* (pp. 14-38). Edward Elgar Publishing Ltd.. https://doi.org/10.4337/9781803922362.00007

Meshcheryakova, A. V., Mazurenko, A. P., & Orobinskaya, V. N. (2024). Policy of Using Digital Technologies in Jurispudence: Russian and Foreign Experience. *Proceedings - 2024 6th International Conference on Control Systems, Mathematical Modeling, Automation and Energy Efficiency*, SUMMA 2024, 196-201. https://doi.org/10.1109/SUMMA64428.2024.10803878

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Annals of Internal Medicine, 151*(4), 264–269. https://doi.org/10.7326/0003-4819-151-4-200908180-00135

Murugan, M. & Natarajan, M. N. (2023). *The Influence of Digital Reality with Automated System in Business Transformation and Operational Excellence on Entrepreneur's Performance in the Engineering Service Industry*. 2023 Intelligent Computing and Control for Engineering and Business Systems, ICCEBS 2023. https://doi.org/10.1109/ICCEBS58601.2023.10448758

Naser, M. Z. & Ross, B. (2022). An opinion piece on the dos and don'ts of artificial intelligence in civil engineering and charting a path from data-driven analysis to causal knowledge discovery. Civil *Engineering and Environmental Systems, 39*(1), 1-11. https://doi.org/10.1080/10286608.2022.2049257

Oblitas, L., Adeeb, S., & Cruz-Noguez, C. (2025). Performance of AI Chatbots on the fundamentals of engineering civil exam. *Discover Artificial Intelligence, 5*(1). https://doi.org/10.1007/s44163-025-00646-6

Oje, A. V., Hunsu, N., May, D., & Baffour, R. A. (2022). Using a theoretical model to understand how virtual reality influences engineering student's learning processes - A work in progress. *ASEE Annual Conference and Exposition, Conference Proceedings.*

Olano Alvarado, S. A., Naumets, S., Lu, M., & Gonzalez, V. A. (2024). Comparison of Two Simulation Platforms Based on Learning and Application Experiences of a Civil Engineering Trainee: SDESA versus SIMPHONY. *Computing In Civil Engineering 2024: Building Information Modeling, Digital Twins, and Simulation and Visualization* - Selected Papers from the ASCE International Conference on Computing in Civil Engineering 2024, 204-214. https://doi.org/10.1061/9780784486122.022

Ortiz, R. A., Gadea, I. S., & Schenk, J. M. L. (2026). Application of Generative Artificial Intelligence in Intersection Design: A Case Study in Road Design. *Lecture Notes in Mechanical Engineering,* 18, 515-523. https://doi.org/10.1007/978-3-032-08108-7_39

Pino Tarragó, J. C., Domínguez Gálvez, D. L., Regalado-Jalca, J. J., & Villavicencio Cedeño, E. G. (2025). Artificial intelligence and soft skills in civil engineering education: A Latin American curriculum gap with global implications. *Research in Globalization*, 11. https://doi.org/10.1016/j.resglo.2025.100307

Plevris, V., Ahmad, A., & Lagaros, N. D. (2023). Artificial Intelligence and Machine Learning Techniques for Civil Engineering. *IGI Global*. https://doi.org/10.4018/978-1-6684-5643-9

Qin, Y. (2022). Application and Research of Artificial Intelligence Technology in Civil Architecture Teaching. *Lecture Notes on Data Engineering and Communications Technologies*, 130, 96-102. https://doi.org/10.1007/978-3-030-99581-2_12

Renugadevi, T., Thamaraiselvi, A., Muthukumar, K., & Sujatha, M. (2025). Harnessing Generative AI Tools and Techniques: Beyond Algorithms for a Smarter Future. In *Generative AI and Creativity: From Theory to Practice* (pp. 154-178). CRC Press. https://doi.org/10.1201/9781003533009-11

Rodriguez-Paz, M. X., González-Mendívil, J. A., Zamora-Hernandez, I., & Sayeg-Sanchez, G. (2024). *Students' Perceptions on the Use of Artificial Intelligence Tools in Engineering Education for the Digital Transformation*. IEEE Global Engineering Education Conference, EDUCON. https://doi.org/10.1109/EDUCON60312.2024.10578326

Rodriguez-Paz, M. X., González-Mendívil, J. A., Zamora-Hernandez, I., Sayeg-Sanchez, G., Carrasco, L. H. H., Núñez, M. E., & Paz, G. D. R. (2025). The Digital Transformation of Structural Analysis Courses: Implemented Changes in Recent Years. *ASEE Annual Conference and Exposition, Conference Proceedings*. https://doi.org/10.18260/1-2--57211

Saienko, N., Ilienko, O., Solodovnyk, T., Ptushka, A., & Bogdan, Z. (2024). The Experience of Developing Social Responsibility in the Next Generation of Engineers at Ukrainian Universities. *Vide. Tehnologija. Resursi - Environment, Technology, Resources*, 2, 474-480. https://doi.org/10.17770/etr2024vol2.8070

Sangree, R. H. (2022). Student performance, engagement, and satisfaction in a flipped Statics and Mechanics of Materials classroom: A Case Study. *ASEE Annual Conference and Exposition, Conference Proceedings.*

Sarker, S., Sarker, S., & Sahay, G. P. (2019). Systematic Literature Reviews: A Guide for Beginners. *Journal of the Association for Information Systems, 20*(1), 1–25. https://doi.org/10.17705/1jais.00533

Sayat, M., Sammavuthichai, R., Wijeratne, H. S., Jitklongsub, S., Ghatole, P., & Lo, B. I. (2022). Quantum technology, artificial intelligence, machine learning, and additive manufacturing in the Asia-Pacific for Mars exploration. *Proceedings of the International Astronautical Congress, IAC,* 2022-September.

Schmitt, M. (2023). Securing the digital world: Protecting smart infrastructures and digital industries with artificial intelligence (AI)-enabled malware and intrusion detection. *Journal of Industrial Information Integration*, 36. https://doi.org/10.1016/j.jii.2023.100520

Schulz, A., Stathatos, S., Shriver, C., & Moore, R. (2023). Utilizing Online & Open-Source Machine Learning Toolkits to Leverage the Future of Sustainable Engineering. *ASEE Annual Conference and Exposition, Conference Proceedings.*

Schallert-Vallaster, S., Nüesch, C., Papageorgiou, K., Herrmann, L., Hofmann, M., & Buchner, J. (2025). Enhancing AI literacy of educators in higher education. *Zeitschrift für Hochschulentwicklung, 20*(SH-KI-1), 147–166. https://doi.org/10.21240/zfhe/sh-ki-1/09

Selvaraj, G., Gayathri, P., Thilagavathy, J., & Kowshika, R. (2025). Educational Cyber-Physical System for Future Engineering Education. WEEF-GEDC 2025 - World Engineering Education Forum - Global Engineering Deans Council Annual Conference, in conjunction with the KSEE Annual Conference 2025: *Engineering Education We Need, Conference Proceedings*. https://doi.org/10.1109/WEEF-GEDC66748.2025.11256295

Sobchenko, V., Bashynskyi, A., Piatkov, M., Shaforost, S., & Chmyr, V. (2024). Artificial Intelligence for Enhancing Engineering Project Management During Emergencies: Perception-based Analysis. *Quality Innovation Prosperity, 28*(3), 46-62. https://doi.org/10.12776/qip.v28i3.2048

Soboleva, E. V., Gorev, P. M., Shadrina, N. N., & Shilova, Z. V. (2024). Using generative neural networks when training digital engineers to improve the quality of their training; Применение генеративных нейросетей в обучении цифровых инженеров для повышения качества их подготовки. *Perspektivy Nauki i Obrazovania, 71*(5), 662-679. https://doi.org/10.32744/pse.2024.5.39

Sovacool, B. K., Axsen, J., & Sorrell, S. (2018). Promoting novelty, rigor, and style in energy social science: Towards codes of practice for appropriate methods and research design. *Energy Research & Social Science*, 45, 12–42. https://doi.org/10.1016/j.erss.2018.07.007

Toscano, R., Guerra, M. A., Durán-Ballén, S., & Valarezo, B. M. (2024). WIP - Development of Critical Thinking in AEC Students Aided by Artificial Intelligence. *Proceedings - Frontiers in Education Conference*, FIE. https://doi.org/10.1109/FIE61694.2024.10893092

Vidalis, S. M., Subramanian, R., & Najafi, F. T. (2024). Revolutionizing Engineering Education: The Impact of AI Tools on Student Learning. *ASEE Annual Conference and Exposition, Conference Proceedings.*

Villalba-Morales, J. D., Jerez, S., Parra, R., Obando, J. C., Guzmán, A., Benjumea, J. M., Arroyo, O., & Cundumí-Sanchez, O. (2026). Emerging Trends in Structural Mechanics Education: A Bibliometric Approach from the Perspective of Colombian Professors. *Buildings, 16*(1). https://doi.org/10.3390/buildings16010219

Vyas, V., Bi, X., Pandey, D., Xu, Z., & Pandey, B. K. (2025). AI's Role in Enhanced Automotive Safety. *IGI Global.* https://doi.org/10.4018/979-8-3373-0442-7

Vásquez-Monteros, J. & García-Ramírez, Y. (2024). Beyond the Books: A Study on AI Augmentation in Civil Engineering Pedagogy for Pavement Design. *Proceedings of International Conference on Research in Education and Science, 10*(1), 1887-1900.

Wang, H., Tang, Y., Lv, G., Yu, Y., Lan, Q., & Zhou, Z. (2024). Application of System Engineering in Aircraft System Design. *ACM International Conference Proceeding Series*, 187-192. https://doi.org/10.1145/3669721.3674517

Wang, L., Wu, B., & Yuan, J. (2022). Application of Computer Virtual Reality Technology in Civil Engineering. *Lecture Notes on Data Engineering and Communications Technologies,* 136, 790-796. https://doi.org/10.1007/978-3-031-05237-8_98

Wang, X. (2025). Research on the strategy of building a smart laboratory under the background of artificial intelligence. *Proceedings of The 2nd International Conference on Intelligent Education and Computer Technology*, IECT 2025, 150-156. https://doi.org/10.1145/3764206.3764229

Wang, X., Cai, L., Jiao, S., Tang, L., Luo, C., & Cheng, K. (2023). Simple talk about structural health monitoring research progress and prospect. *Proceedings of 2023 CAA Symposium on Fault Detection, Supervision and Safety for Technical Processes*, SAFEPROCESS 2023. https://doi.org/10.1109/SAFEPROCESS58597.2023.10295644

Wijesinghe, P., Parker, H. A. B., & Stein, E. Z. (2025). BOARD # 47: A Case Study: Students' Perception of the Use of Generative AI in Learning and the Civil Engineering Profession. ASEE *Annual Conference and Exposition, Conference Proceedings*. https://doi.org/10.18260/1-2--55852

Xia, L. (2022). Development and Design of Legal Service Assistance System under the Background of Artificial Intelligence. *ACM International Conference Proceeding Series*, 107-112. https://doi.org/10.1145/3589860.3589874

Xie, C. (2023). Research on the Application of Artificial Intelligence in Civil Engineering Monitoring. *Proceedings of SPIE - The International Society for Optical Engineering*, 12793. https://doi.org/10.1117/12.3006398

Xie, M., Meng, F., Zou, J., Feng, W., & Ma, S. (2020). Application of Artificial Intelligence in Civil Engineering Education. *Journal of Physics: Conference Series, 1575*(1). https://doi.org/10.1088/1742-6596/1575/1/012225

Xing, J., Yang, X., Cao, C., Meng, L., Ning, Y., Liu, H., & Wang, S. (2024). Construction of Beidou Space Time Technology Application Micromajor and Practice of Characteristic New Engineering Education. *Lecture Notes in Electrical Engineering*, 1092 LNEE, 242-251. https://doi.org/10.1007/978-981-99-6928-9_21

Xu, G., Wang, D., & Chang, G. K. (2026). *Pioneer of Intelligent Construction - Intelligent Compaction.* Springer Nature. https://doi.org/10.1007/978-981-95-4184-3

Yang, K., Wang, J., Lu, S., Liu, Q., Cheng, Y., Xia, X., Gao, T., Wu, J., & Dong, J. (2025). *Research on the Application of Online Programming Platforms and Generative Artificial Intelligence in the Programming Education of Prospective Chinese Engineers.* 2025 International Conference on Artificial Intelligence and Education, ICAIE 2025, 439-444. https://doi.org/10.1109/ICAIE64856.2025.11158705

Yukui, H. U. (2020). Practical Teaching and Vocational Integration Orientation of Applied Undergraduate Civil Engineering : - Take Fuzhou University of International Studies and Trade as an example. *Proceedings - 2020 International Conference on Big Data, Artificial Intelligence and Internet of Things Engineering, ICBAIE 2020*, 431-434. https://doi.org/10.1109/ICBAIE49996.2020.00096

Zeng, W., Hu, S., Tang, W., & Zhang, H. (2025). *Evaluating the Public Safety Education APP's Impact on Emergency Awareness and Competency - A Case study from "Qiang'an" platform in Shenzhen, China*. 2025 16th International Conference on E-Education, E-Business, E-Management and E-Learning, IC4e 2025, 333-339. https://doi.org/10.1109/IC4e65071.2025.11075397

Zhang, C., Wang, X., & Zhou, C. (2025). AI Technology Empowering Teaching Innovation in Civil Engineering at Local Universities: Practical Exploration in the Concrete Structure Design Course. *Proceedings of 2025 International Conference on AI-enabled Education*, AIEE 2025, 382-390. https://doi.org/10.1145/3768421.3768487

Zhang, J. (2026). Scaffolding Probabilistic Reasoning in Civil Engineering Education: Integrating AI Tutoring with Simulation-Based Learning. *Education Sciences, 16*(1). https://doi.org/10.3390/educsci16010103

Zhang, R. & He, M. (2022). Impact of the Off-Campus Tutoring Industry on Engineering Education. *ICSIT 2022 - 13th International Conference on Society and Information Technologies, Proceedings*, 31-36. https://doi.org/10.54808/ICSIT2022.01.31

Zhu, J., Li, Y., & Zhu, P. (2023). Damage Security Intelligent Identification of Wharf Concrete Structures under Deep Learning and Digital Image Technology. *International Journal of Advanced Computer Science and Applications, 14*(6), 1019-1026. https://doi.org/10.14569/IJACSA.2023.01406109

Zhu, K. & Zheng, L. (2021). Based on Artificial Intelligence in the Judicial Field Operation Status and Countermeasure Analysis. *Mathematical Problems in Engineering*, 2021. https://doi.org/10.1155/2021/9017181

Zou, Y. & Wei, Z. (2025). Exploration of the Application of Educational Robots in Civil Aviation Flight Specialty. *Proceedings of 2024 4th International Conference on Big Data, Artificial Intelligence and Risk Management,* ICBAR 2024, 688-693. https://doi.org/10.1145/3718751.3718861