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A Brief Review of the Impact of Generative Artificial Intelligence (AI) on Engineering Education

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Abstract

Engineering education is evolving continuously since its inception. The rise of generative artificial intelligence (GAI) has marked a transformative era in engineering education. This review presents the multifaceted impact of GAI on teaching approaches, learning experiences, and skill development within engineering education. GAI technologies, such as machine learning algorithms and natural language processing, have revolutionised curriculum design by enabling personalised learning pathways, adaptive assessment methods, and enhanced problem-solving capabilities. These technologies facilitate interactive and immersive learning environments through virtual labs and simulations, assisting students with hands-on experience. Moreover, GAI aids in bridging the gap between theory and practice, fostering innovation and creativity among engineering students. Challenges such as ethical considerations, the need for technical literacy among educators, and the integration of GAI tools into existing educational frameworks are also discussed. This review underscores the potential of GAI to recast engineering education by training students in such a way that they can work effectively in an increasingly AI-driven world. This study also presents future research needs on GAI in engineering education to make this technology an effective mode of engineering education.

Keywords: Engineering education, generative AI, Chat GPT, blended learning, professional engineer.

1. INTRODUCTION

The rapid advancement of generative artificial intelligence (GAI) is reshaping numerous fields, including engineering education. As GAI technologies, particularly generative models evolve, they are beginning to influence how engineering students learn, how educators teach, and how institutions design their course curricula. Understanding the implications of GAI in engineering education is crucial for preparing the next generation of engineers to become successful in an increasingly complex and AI-driven world. The AI-driven tools have the potential to automate routine tasks, enhance personalised learning experiences, and foster creativity and innovation among students. However, alongside these opportunities come significant challenges, such as ethical considerations, the risk of over-reliance on AI, and the need for educators to adapt to a new teaching paradigm.

ChatGPT is a new AI based technology, which is based on a natural language processing model. Its basis is generative pre-trained transformer (GPT) architecture. This was initiated to model language related tasks under AI framework. ChatGPT can create new conversations and linguistic expressions like a human (Qadir, 2023). ChatGPT learns via training based on a huge data set of conversational

terms and styles. Use of ChatGPT is not limited to a particular field, its use is even noticed in artistic media for visual arts, music, video, animation and literature (Epstein and Hertzmann, 2024). Moorhouse et al. (2023) noted that GAI based tools (e.g., ChatGPT) are creating challenges on assessment of students' tasks and many top-graded universities have already formulated policies on the effective use of GAI based techniques to write assignments and theses.

This paper presents a brief review of the impacts of GAI on engineering education covering its current applications, benefits, and challenges. It provides examples of AI application to fluid mechanics education and practice. By analysing recent developments and trends, we aim to offer some insights into how AI is transforming the educational landscape, identify gaps in existing research, and propose directions for future research.

2. AI IN FLUID MECHANICS EDUCATION

AI is profoundly transforming fluid mechanics education by enabling more dynamic and interactive learning environments. Through AI-driven simulations and computational tools, students are able to visualise complex fluid behaviors in real-time, enhancing their understanding of concepts like turbulence, mass flow dynamics, and pressure distribution. AI also facilitates the automation of fluid data analysis and modeling, allowing students to focus on problem-solving and innovation. By integrating GAI into fluid mechanics curricula, educational institutions are preparing students to tackle real-world challenges with advanced analytical skills and a deeper comprehension of fluid mechanics principles. For example, Brunton et al. (2020) mentioned that machine learning can be used to gather and create data related to experimental fluid mechanics. For example, AI based algorithms are capable to enhance knowledge on flow control, simulation and dynamics of both liquids and gases. Kashefi (2024) examined the outputs obtained from well-known GAI applications with real world common fluid motion problems such as Von Kármán vortex street, flow past an airfoil, Kelvin-Helmholtz instability and shock waves on a sharp-nosed supersonic body. He noted that these tools might challenge students in managing copyright issues such as use of online images in their assignments.

Ayre and Zhao (2023) noted that physical laboratory experiments are crucial in engineering education, providing future engineers with hands-on experience. The increasing demand for laboratory time has surpassed the available physical resources at many universities. As a solution, virtual reality (VR) labs have emerged, retaining many of the benefits of physical labs while offering unique advantages and flexibility in learning. To enhance the VR environment, an AI assistant powered by the GPT-4 language model was introduced, offering reliable instructions and troubleshooting support. This effectively simulates the presence of a real-life lab assistant.

Drikakis and Sofos (2023) mentioned that due to the rapid rise of AI and application of machine learning (ML) and deep learning (DL), numerous prospects have been emerged in fluid mechanics and other fields of science, engineering, and medicine. This development highlights the potential for future improvements in existing research on ML and DL in fluid dynamics, outlines the associated algorithmic, and identifies potential future directions. Wang and Wang (2021) applied AI in computational fluid mechanics across five key areas on aerodynamic models, turbulence models, specific flow scenarios, and mass and heat transfer. They noted that without physical mechanisms, existing frameworks and physical approaches on AI applications can provide a significant success in fluid mechanics learning and teaching. AI can tackle common fluid motion problems; however, it might mislead students unless they have a good understanding on fluid mechanics theory. The above study suggests that these technologies will continue to shape future advancements in the fluid mechanics education.

3. USE OF GAI IN LEARNING

Wang et al. (2023) mentioned that now-a-days many international students encounter multiple

challenges such as language barriers and part-time work to earn money to pay tuition fee. To improve academic results, students tend to use GAI tools in writing their assignments and research papers. Bearman et al. (2023) identified two key discourses related to GAI in education. The first, "discourse of imperative change," stresses that AI is an unavoidable force that demands adequate responses. The second, "discourse of altering authority," discusses how AI is shifting authority from formal teachers to a broader range of actors such as academics of other institutions and independent course content developers. They recommended further research on social implications of GAI, accountability in AI-mediated practices and relationships among instructors and students in academia.

As per Airaj (2024), a human-centered approach is needed to integrate AI in higher education, which would assist in providing equitable access to knowledge where privacy and ethical standards need to be maintained. Using third-generation activity theory, the study examines the interaction among AI teachers, human teachers, and students. They noted that it is important to understand how GAI influences its users and how it can be applied ethically in teaching and learning. Caillaud and Skec (2024) mentioned that over the last few years, the field of academic design has acknowledged a substantial revolution with the application of GAI tools like ChatGPT. This could have a massive influence on PhD research. They highlighted the necessity for adjusting supervision practices instead of limiting PhD students' access to these tools.

4. USE OF AI IN ENGINEERING INDUSTRY

The use of AI in the engineering industry is revolutionising the conventional way projects are designed, executed, and maintained. AI-driven technologies are enhancing efficiency, precision, and innovation across various engineering disciplines. From predictive maintenance, quality control and automated design to intelligent robotics and data analytics, AI is enabling engineers to tackle complex challenges with greater accuracy and speed. This integration is not only optimising traditional processes but also paving the way for new methodologies and solutions, making the engineering industry more agile and forward-looking in an increasingly competitive global market. For example, Rane (2023) mentioned that GAI models such as ChatGPT are becoming a popular platform across diverse industries, marking the advent of Industry 4.0, Industry 5.0, and Society 5.0. These AI tools are being widely adopted for improved conversation with multi-dimensional resolutions, advancing abilities, and enhancing productivity in various fields ranging from customer service to healthcare and education. In industries, ChatGPT or similar GAI systems can facilitate automated and rationalised data processing, simplify manufacturing processes, and improve supply chain management. A vast array of technical opportunities is accelerating inclusivity to enable coexistence of people and AI based tools.

Koroteev and Tekic (2021) presented a comprehensive investigation on AI applications. They stated that AI development had a great impact on reducing risks in energy sector such as oil and gas industries. Moreover, they identified the key non-technical challenges that could negatively impact adoption of AI in the oil and gas industries. They elaborated existing challenges associated with data, human elements, and emerging collaborations. In another study, Naqbi et al. (2024) conducted a comprehensive review (using 159 research publications) on the impacts of GAI on work productivity across various professional sectors. The study focused on how GAI could enhance institutional performance in areas such as academia, technology, communication, agriculture, government, and business. It also highlighted key trends, gaps, and the popularity of tools like Chatbots and Conversational Agents, particularly ChatGPT.

Wong (2024), emphasised that educators had mixed reactions, grappling with its potential disruptions. In the global labor market, GAI could significantly reduce white-collar jobs once issues like bias, security, and misinformation are addressed. Despite its portrayal as a sudden disruptive force, this study clarified that GAI had been in development for nearly eight decades and is still evolving, particularly with advancements in pattern recognition, problem-solving, and quantum computing. The study also cautioned that this powerful technology must not be in the capture of few major

corporations, rather it should be made available to all sorts of people in society.

5. ETHICAL ISSUE

The application of AI presents significant ethical issues, particularly regarding privacy, bias, and accountability. As AI systems are increasingly influencing decision-making, there is a heightened risk of unintended outcomes, such as discrimination and diminished human oversight. This demands creation of strong ethical framework to ensure that AI is implemented responsibly and fairly across multiple sectors. In this regard, Ouchchy et al. (2020) stated that since AI technologies had become more integrated into our day-to-day activities, media coverage had gradually focused on the ethical implications of these advancements. Since media plays a significant role in shaping public discourse on new technologies, understanding how AI's ethical issues are portrayed in the media can offer insights into the potential impact of AI's development. To address the social, ethical, and policy challenges of AI, a comprehensive approach is necessary. This includes ensuring accurate information is accessible to the public through trusted sources, involving ethics and AI professionals in both research and public discussions, and establishing effective government regulations on AI use.

Stahl and Eke (2024) examined the ethical concerns surrounding generative conversational AI methods, such as ChatGPT. By applying established frameworks for analysing the ethics of emerging technologies, they presented a systematic review on the potential benefits and challenges of ChatGPT. While this study highlighted the significant societal and ethical advantages of ChatGPT, it also identified substantial ethical concerns in relation to “social justice, individual autonomy, cultural identity, and environmental impact”.

Prem (2023) mentioned that cconsidering the ethical issues associated with AI, numerous proposals were published on how to address these ethical concerns. But many of these proposals are too conceptual to be easily translated into concrete AI system models. These ethical frameworks resemble principlism in medical ethics, where ethics are general and lack specific guidance on effective application in many cases. Consequently, they proposed several approaches to deal with the ethical aspects of the use of AI systems to maximise its benefits. In another study, Kirova et al. (2023) mentioned that in the early 2020’s a massive progression was observed in the application of GAI such as ChatGPT and Bard across various industries, including art, healthcare, and finance. They studied the historical context of these developments, highlighted ethical challenges in engineering and cyber-physical systems, and emphasised the importance of ethical aspects to address the ongoing challenges posed by GAI.

Figure 1 illustrates major issues on the use of GAI in engineering education. It shows that ethical issues, institutional barriers, and course curriculum updating are few major challenges that need attention to make GAI an effective educational tool to enhance technological education.

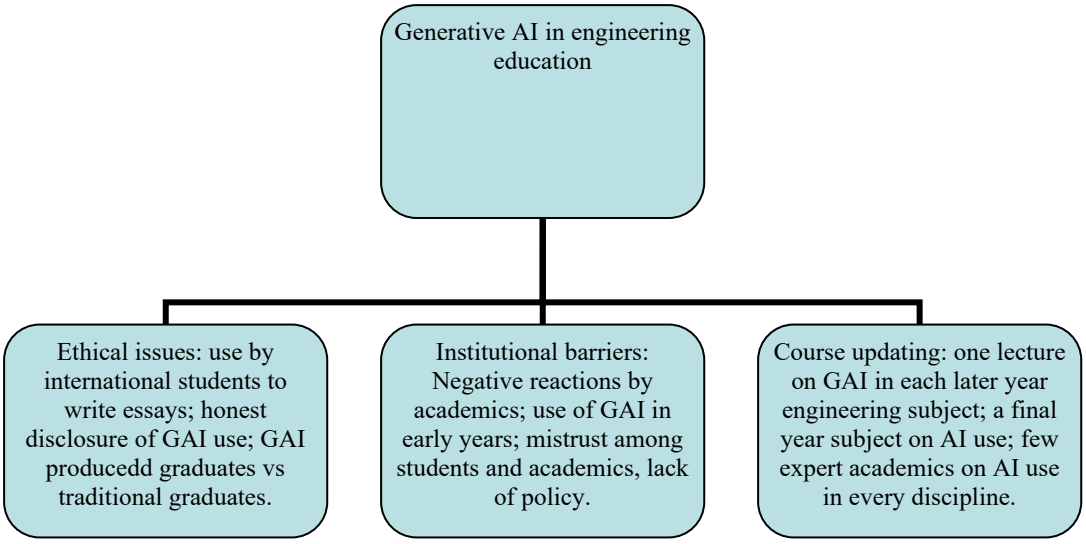

Figure 1. Major issues with the use of generative AI (GAI) in engineering education.

6. SCOPE OF FUTURE RESEARCH

The impact of GAI on engineering education is an emerging field with significant potentials for further research and development. Future research should focus on several key areas:

(i) Long-Term Learning Outcomes: While initial studies suggest that AI-enhanced education can improve engagement and understanding, there is a need for longitudinal research to evaluate its long-term impacts on students' skills, knowledge retention, and career success.

(ii) Ethical Implications: As AI becomes more integrated into educational settings, research should investigate the ethical concerns regarding data privacy, bias in AI algorithms, and the implications of AI-driven decision-making in educational assessments and student support systems.

(iii) AI in Curriculum Development: Further studies should explore how AI can assist in dynamic creation and updating of engineering curricula, ensuring that it remains aligned with industry needs and technological advancements.

(iv) Student-Teacher Interaction: Research should examine the evolving role of educators in an AI-driven educational world, focusing on how AI tools can be designed to support, rather than replace, the human aspects of teaching, such as mentorship, critical thinking, and ethical guidance.

(v) Impact on Creativity and Innovation: Future research should assess how GAI influences students' creative and innovative capacities, exploring whether AI tools enhance or hinder the development of original ideas and solutions in engineering disciplines.

(vi) Institutional Adoption and Resistance: Understanding the factors that influence the adoption of AI in educational institutions, including faculty resistance, financial constraints, and the need for professional development, could provide valuable insights for policymakers and administrators in educational sectors.

(vii) AI and Interdisciplinary Learning: As engineering is increasingly intersecting with other fields, research could explore how AI can facilitate interdisciplinary learning and collaboration to prepare students in meeting the multifaceted challenges of the modern technology-driven world.

7. CONCLUSION

Generative AI (GAI) is rapidly transforming the landscape of engineering education. This paper has

explored the diverse applications of GAI in fluid mechanics education. By automating repetitive tasks, enhancing personalised learning, and fostering creativity, AI is enabling educators to focus more on mentoring and complex problem-solving. However, the integration of AI also presents challenges, including ethical considerations, the need for robust data infrastructure, and the potential for over-reliance on technology in education. As AI continues to evolve, it is crucial for educational institutions to strike a balance between leveraging its benefits and maintaining the core human sides of teaching and learning. The future of engineering education will likely be a synergistic blend of traditional methodologies and AI-driven innovations to produce engineers who are not only technically proficient but also adaptive, ethical, and creative problem solvers.

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