WIP: Exploring the Impact of Generative AI in Engineering Education: A Scoping Review of Applications and Innovations

Animesh Paul, University of Georgia

Animesh (he/they) is a Ph.D. Candidate at the Engineering Education Transformation Institute at the University of Georgia. Their research explores user experience and the transition of engineering students into the workforce.

VINCENT OLUWASETO FAKIYESI, University of Georgia

Vincent Oluwaseto Fakiyesi received the B.Tech. degree in chemical engineering from the Ladoke Akintola University of Technology, Ogbomosho, Oyo State, , Nigeria in 2015, and He is presently a Doctoral Students at Engineering Education Transformative Institute at the University of Georgia College of Engineering.

Md Ulfat Tahsin, The Ohio State University

Md Ulfat Tahsin is a Ph.D. student and a Graduate Fellow in the Department of Engineering Education at The Ohio State University. He is from Bangladesh. He has previously worked closely with engineering faculties and students in Bangladesh from where his love and interest for engineering education started to flourish.

Lexy Chiwete Arinze, Purdue University at West Lafayette (COE)

Lexy Arinze is a first-generation PhD student in the School of Engineering Education at Purdue University and a Graduate Research Assistant with the Global Learning Initiatives for the Development of Engineers (GLIDE) research group. Lexy's research interests include early career engineers, Artificial Intelligence, experiential learning, and global experiences. He earned his master's degree in Civil Engineering from Purdue University. Before that, he received an Erasmus scholarship for an exchange program at the University of Jaén, Spain. He completed his undergraduate degree in Civil Engineering at the University of Ibadan, Nigeria.

Dr. Sreyoshi Bhaduri, Private Entity

Dr. Sreyoshi Bhaduri is an AI scientist. Currently, she spearheads innovative research in applying generative AI to solve complex supply chain logistics and operations challenges. Her expertise spans applied statistics and natural language processing, with a PhD from Virginia Tech and specialized training in Responsible AI from MILA. Sreyoshi has been recognized as a Graduate Academy for Teaching Excellence (VTGrATE) Fellow, a Global Perspectives Program (GPP) Fellow, and was inducted in the Bouchet Honor Society in 2017. Sreyoshi is committed to demystifying and democratizing generative AI solutions and bridging the gap between theoretical research and practical applications using AWS technologies.

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1. Introduction

The emergence of generative artificial intelligence (GenAI) represents a paradigm shift in various sectors, including education. This transformation is particularly significant in engineering education, where the integration of advanced technologies has consistently reshaped pedagogical practices. Generative AI, characterized by its ability to produce content such as text, images, and multimedia through models like ChatGPT by openai, has garnered increasing attention due to its potential to enhance teaching and learning experiences. Studies highlight how these technologies personalize learning, adapt to diverse student needs, and create innovative educational tools that improve comprehension and engagement [1] in the context of engineering education, generative AI offers transformative opportunities, from fostering creativity in problem-solving to streamlining instructional design. However, these advancements also present challenges, including ethical considerations, reliability concerns, and the risk of over-reliance on AI systems. To address these complexities and maximize the potential of generative AI, it is essential to explore how these tools are being implemented, the challenges they pose, and their implications for students and educators.

This study conducts a scoping review to systematically examine the applications and innovations of generative AI in engineering education. By employing the five-step framework proposed by [2] this review seeks to provide critical insights into the current landscape, including the extent of generative AI adoption, its educational applications, and its associated challenges. Following [3], [4] this exploration, we aim to contribute to the evolving discourse on leveraging generative AI responsibly and effectively in engineering education. The findings of this scoping review will not only illuminate current practices but also guide future research and implementation strategies, ensuring that generative AI is utilized to foster innovation while upholding ethical standards. In this Work-in-Progress paper, we present a detailed account of the comprehensive methodology employed to conduct the scoping review, outlining each step of the process. The project's primary aim is to share key findings derived from these steps, offering critical insights into the outcomes of the scoping review. Through this publication, we also aim to present systematic steps that can serve as a guide for others conducting a scoping review.

2. Motivation

The motivation for this study stems from the rapid rise and integration of generative AI technologies across various sectors, particularly their transformative potential in education. Recognizing the power of these technologies to empower individuals and redefine learning environments, our research team sought to explore their application within engineering education. Generative AI systems, capable of creating text, images, and other media, are revolutionizing classroom practices by offering personalized and adaptive learning experiences. These systems not only enhance comprehension and retention but also streamline the creation of educational tools, making learning more efficient and engaging. Our team began conceptualizing this study in September 2024, driven by a collective belief that generative AI is not a fleeting trend but a technology that is here to stay. We aim to understand how these tools are being implemented in classrooms, what ethical considerations are being addressed, and what research questions scholars are posing as these technologies evolve. As researchers, we are committed to helping educators and students embrace these advancements ethically and effectively, ensuring that the integration of generative AI fosters innovation while upholding the principles of responsible technology use. In this paper, we outline the comprehensive methodology employed to conduct the scoping review, detailing each step taken throughout the process. Additionally, we present key findings derived from these steps, providing critical insights into the outcomes of the scoping review.

3. Methodology

This scoping review applies to the five-step framework from [2] illustrated in Figure 1, which involves 1) defining the research question, 2) identifying relevant studies, 3) selecting eligible studies, 4) charting the data, and 5) synthesizing the findings. The study systematically examines the use of generative models in engineering education by deconstructing the research question into key components. Aligned with Joanna Briggs Institute (JBI) guidelines [3], this approach ensures a thorough and structured exploration of literature. The following section outlines each step of the framework, emphasizing the processes implemented to uphold rigor and transparency [5].

Figure 1: Scoping Review Methodology Framework for use of Generative Models in Engineering Education

3.1. Defining the research question

Following our meeting on September 24th, 2024, we refined our broader research question: "What is the extent of generative models' utilization in engineering education?" This question builds upon previous work by [6], "Path *to Personalization: A Systematic Review of GenAI in Engineering Education."* To structure our investigation, we further deconstructed the question using the Population, Concept, and Context (PCC) framework, a widely used approach in systematic literature reviews [7]. The PCC guidelines for this review are Population – engineering educators and students; Concept – utilization of generative models (e.g., Generative AI, ChatGPT, GPT); Context – formal and informal engineering education settings.

3.2. Identifying Relevant Studies

The search strategy is structured into concept lines, following the approach outlined in [8] for scoping reviews, which is designed to identify and include articles, conference papers, and gray literature relevant to the research question. For the scope of our project, we define this as an "Aspect": An aspect is an element or dimension of the research focus that breaks down the key components of a study. In this context, it refers to a specific part of the research framework (e.g., concept, population, or context) that informs the formulation of search terms and justifies their inclusion in a systematic or scoping review. **Appendix A** summarizes the structured search strategy, categorizing key terms based on Concept, Population, and Context. We utilized four databases for data collection: EI Village, WOB, IEEE Xplore, and ERIC. The search was conducted over a timeframe from 2014 to 2024. In databases that allowed precise date inputs, we specified a range from January 1, 2014, to October 31, 2024. For those that only permitted input by year, we selected the range 2014 to 2024. The searches were carried out in November 2024. Following the search, all retrieved articles were exported in .bib file format and subsequently imported into Rayyan [9], the scoping review workspace used for this study. For the comprehensive search, we combined these Aspect lines using Boolean operators such as "AND" & executed the search across multiple databases. The total results retrieved from each database were as follows:

Table 1: Databases Used for Literature Search and Retrieved Results

Database	*Interface*	*Result*

EI Village	Engineering Village	648
WOB	Web of Science	139
IEEE Xplore	IEEE Xplore	127
ERIC	ProQuest	17

3.3. Selecting eligible studies

To ensure a rigorous and systematic approach, we established detailed inclusion and exclusion criteria to guide the study selection process. These criteria were formulated as specific questions to maintain clarity and consistency during the screening phases. The studies were initially screened at the title level, followed by the abstract level recommended by [10]. Only those meeting all inclusion criteria and none of the exclusion criteria were advanced to the next phase of review. The detailed inclusion and exclusion criteria are presented in the **Appendix B:** This section emphasizes the title and abstract review phase, applying consistent processes throughout this stage of the review. When the inclusion and exclusion criteria do not provide enough clarity to determine whether a study should be included or excluded, it is marked as "Maybe" in the Rayyan workspace, which allows for flexible categorization. To uphold rigor, the team underwent comprehensive training on the methodology and participated in regular virtual meetings to maintain alignment and collaboration. Individual support was also provided to team members as needed to ensure consistency in the review process. Once this step is completed, a preliminary PRISMA like flow diagram [11] as shown in Figure 2, using [12] is created to detail the progression from the number of articles retrieved to those included for full-text analysis.

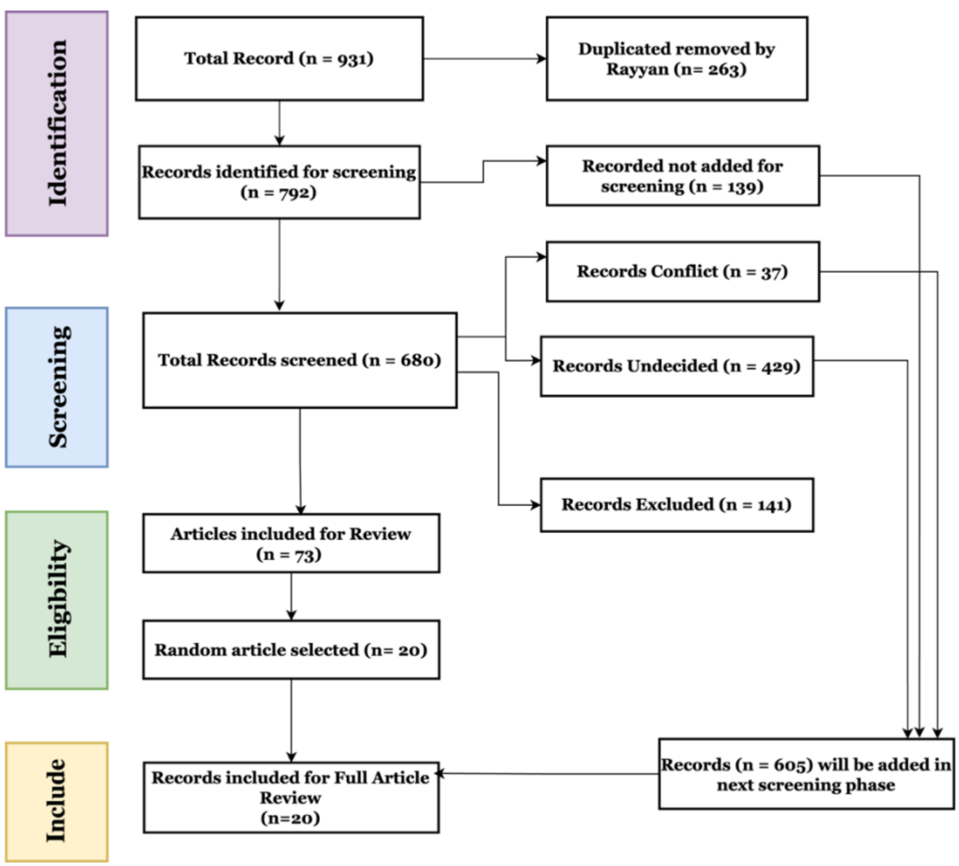

Figure 2: Preliminary PRISMA like flow diagram for scoping review

3.4. Charting the data

Step 4 focuses on charting the data, systematically extracting and organizing key information from the included studies to address the research question: "What is the extent of generative models' utilization in engineering education?" A standardized data-charting form was developed to capture details such as study authors, publication year, population, methodology, key findings, and context, including ethical considerations and applications. For the scope of this work-in-progress paper, 20 studies were randomly selected for inclusion in this and the subsequent step. The process was iterative, starting with these studies to refine the form and ensure it aligned with the study objectives.

3.5. Synthesizing the findings

Step 5 involved collating, summarizing, and reporting the results, synthesizing the data to provide a comprehensive overview of the literature addressing the research question: "What is the extent of generative models' utilization in engineering education?" Descriptive numerical analyses were conducted to summarize key study characteristics such as publication trends, methodologies, and geographic distribution, while thematic analysis identified patterns, gaps, and emerging issues, focusing on ethical considerations, applications, and challenges. The findings were presented through tables, charts, and narrative summaries, linking themes back to the research question and discussing broader implications, particularly regarding the integration and ethical use of generative AI in education. Feedback from team members and stakeholders validated the findings, ensuring they were accurate, relevant, and aligned with the study's objectives, ultimately providing actionable insights for future research and practice.

4. Preliminary Results

We coded 20 articles to examine the applications, methodologies, findings, and theoretical foundations of generative AI in engineering education. The findings provide insights into the impact of AI-driven educational tools across diverse learning environments. Engineering students, faculty, and administrators were involved, with most studies focusing on AI-assisted learning. Research methodologies included mixed methods, quantitative analysis, and qualitative case studies. Key themes explored were AI tutoring, ethics, AI-driven assessments, and AI-enhanced problem-solving. While AI adoption is growing, concerns persist around misinformation, bias, and over-reliance on AI tools. Some studies referenced theoretical frameworks such as Technology Acceptance Model (TAM), Bloom's Taxonomy, and Cognitive Load Theory, though many lacked a structured theoretical foundation. Geographically, research was concentrated in Finland, the Netherlands, Brazil, Austria, and India. While AI-driven learning presents potential, refining ethical guidelines and best practices remains crucial. Future research should explore long-term AI impacts and responsible integration strategies. The research question guided the study using the PCC framework, emphasizing targeted research in technical disciplines to investigate AI's role in engagement and learning. As summarized in Figure 3 below, the initial findings on Generative AI in Engineering Education highlight these themes and findings.

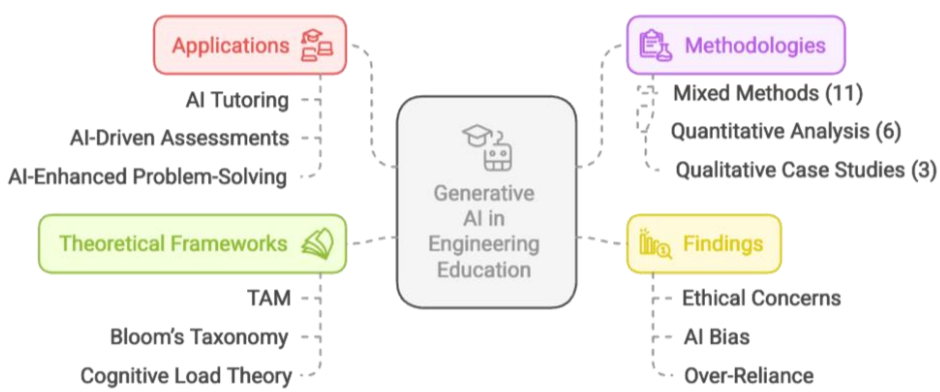

Figure 3: Summary of Initial Findings on Generative AI in Engineering Education

The initial search retrieved 931 articles, with a notable rise in publications post-2021, aligning with advancements in generative AI. Engineering-focused AI studies remain scarce, highlighting an emerging field. AI tutoring, assessments, and adaptive learning were the most common themes. For preliminary analysis a total of 73 studies met the inclusion criteria and we were able to code just 20 random articles for the scope of this work in progress study, with most focusing on undergraduate engineering education. AI-driven problem-solving and assessment tools dominated, with academic integrity and data privacy emerging as key ethical concerns. Only 25% of studies referenced theoretical frameworks, indicating a need for structured research approaches. Data extraction revealed key methodological trends, with mixed methods comprising 55% (11 studies), quantitative approaches 30% (6 studies), and qualitative methods 15% (3 studies). The majority of studies originated from the US, Europe, Brazil, and India. Notable research gaps included a lack of longitudinal studies examining AI's long-term impact. The adoption of generative AI is increasing, primarily driven by faculty-led initiatives. However, equity concerns persist, particularly regarding disparities in access to AI tools. Additionally, AI reliability issues—such as misinformation and bias—remain significant challenges. Furthermore, excessive reliance on AI poses risks to students' problem-solving abilities and independent critical thinking skills.

5. Conclusions and Future Work

We see the potential of integrating GenAI tools, as educators can provide personalized learning experiences, reduce administrative burdens, and create more engaging curricula while preparing future engineers to tackle global challenges through interdisciplinary approaches. However, critical challenges accompany AI adoption, including ethical concerns related to fairness in algorithms, data privacy, and the risk of over-reliance, which may undermine students' problem-solving and critical thinking skills. Addressing these challenges requires clear guidelines, educator training, and stakeholder collaboration to develop robust policies for AI integration. Future research will focus on completing full-text screening, conducting a thematic analysis to identify emerging trends and gaps, and exploring the long-term impact of GenAI on student performance and engagement. As generative AI continues to evolve, its integration must be guided by ethical considerations and a commitment to equitable learning experiences, ensuring that it enhances rather than detracts from the quality of engineering education.

6. Limitations

The limitations of this scoping review include its subjective nature, shaped by researcher judgment. Resource constraints, including time and database access, restricted the search criteria and study selection. While keywords were collaboratively refined, they may not have been comprehensive, risking the exclusion of relevant studies. Additionally, omitting certain terms to avoid redundancy or irrelevant results may have inadvertently filtered out valuable literature.

Reference

[1] Q. Xia, X. Weng, F. Ouyang, T. J. Lin, and T. K. F. Chiu, "A scoping review on how generative artificial intelligence transforms assessment in higher education," Dec. 01, 2024, *Springer Science and Business Media Deutschland GmbH*. doi: 10.1186/s41239-024-00468-z.

[2] H. Arksey and L. O'Malley, "Scoping studies: Towards a methodological framework," *International Journal of Social Research Methodology: Theory and Practice*, vol. 8, no. 1, pp. 19–32, Feb. 2005, doi: 10.1080/1364557032000119616.

[3] Peters, M. D. J., Marnie, C., Colquhoun, H., Garritty, C. M., Hempel, S., Horsley, T., Langlois, E. v., Lillie, E., O'Brien, K. K., Tunçalp, Özge, Wilson, M. G., Zarin, W., & Tricco, A. C. (2021). Scoping reviews: reinforcing and advancing the methodology and application. In Systematic Reviews (Vol. 10, Issue 1). BioMed Central Ltd. https://doi.org/10.1186/s13643-021-01821-3

[4] M. J. Grant and A. Booth, "A typology of reviews: An analysis of 14 review types and associated methodologies," Jun. 2009. doi: 10.1111/j.1471-1842.2009.00848.x.

[5] D. Levac, H. Colquhoun, and K. K. O'brien, "Scoping studies: advancing the methodology," 2010. [Online]. Available: http://www.cihr-irsc.ca

[6] R. Khan *et al.*, "Path to Personalization: A Systematic Review of GenAI in Engineering Education Path to Personalization: A Systematic Review of GenAI in Engineering Education," 2024. [Online]. Available: https://hal.science/hal-04673700v1

[7] Peters, M. D. J., Marnie, C., Tricco, A. C., Pollock, D., Munn, Z., Alexander, L., McInerney, P., Godfrey, C. M., & Khalil, H. (2020). Updated methodological guidance for the conduct of scoping reviews. JBI Evidence Synthesis, 18(10), 2119–2126. https://doi.org/10.11124/JBIES-20-00167

[8] A. Paul and R. S. Lewis, "Understanding the Workplace Transition Experiences of Undergraduate Queer Engineering Students," in *ASEE Annual Conference & Exposition*, American Society for Engineering Education, 2024. doi: 10.18260/1-2--48200.

[9] M. Ouzzani, H. Hammady, Z. Fedorowicz, and A. Elmagarmid, "Rayyan-a web and mobile app for systematic reviews," *Syst Rev*, vol. 5, no. 1, Dec. 2016, doi: 10.1186/s13643-016-0384-4.

[10] S. J. Bork, A. Tuladhar, and J.-L. Mondisa, "Board 134: Methods for Conducting a Scoping Literature Review on Engi-neering Graduate Student Mental Health (Work in Progress) Methods for Conducting a Scoping Literature Review on Engineering Graduate Student Mental Health (Work in Progress)," in *American Society for Engineering Education*, 2019.

[11] "PRISMA Flow Diagram," https://www.prisma-statement.org/.

[12] "Draw.io," https://www.drawio.com/.

Appendix A: Structured Search Strategy and search term: Categorization by Concept, Population, and Context

Aspect	**Search term**	**Rational**
Concept: *Explores tools and technologies related to generative AI, such as ChatGPT, GPT models, or generative AI systems, and their relevance in education.*	("generative artificial intelligence" OR "ChatGPT" OR "generative AI" OR Generative* OR GPT*)	Focused on identifying studies or articles that discuss generative AI technologies, including ChatGPT and other GPT-based models, in line with search strategies used in [6]

Population: *Focuses on individuals, groups, or systems involved in the field of engineering education, including students, educators, and institutions.*	"Engineering Education"	Ensures relevance to the field of engineering education
Context: *Examines the application, adoption, integration, or use of generative AI within the specific educational practices and learning environments in engineering.*	(utilization OR implementation OR application OR use OR adoption OR integration)	Highlights studies that explore how generative AI is being used, integrated, or adopted within engineering education settings, ensuring a focus on practical and theoretical implementation.

Appendix B: Inclusion and Exclusion Criteria for study Selection

Criteria	*Question*	*Action*
Inclusion	Does the study focus on the implementation or integration of generative models in engineering education?	Include if "Yes"
	Does the study fall within the review timeframe (2014–2024)?	Include if "Yes"
	Is the study specifically rooted in engineering education?	Include if "Yes"
	Is the study written in English?	Include if "Yes"
	Is the study a peer-reviewed article?	Include if "Yes"
Exclusion	Does the study focus on STEM literature rather than engineering education?	Exclude if "Yes"
	Is the study written in a language other than English?	Exclude if "Yes"
	Is the study a book chapter/report instead of a peer-reviewed article?	Exclude if "Yes"