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Systematic Literature Review of GenAI Integration in Higher Education and Analysis of Opportunities for Engineering Education

Marina Belkina[a], Peter Neal[b], Sarah Grundy[b], Ghulam Hassan[c], Rezwanul Haque[d], Scott Daniel[e], Sasha Nikolic[f] and Sarah Lyden[g].

Western Sydney University[a], University of New South Wales[b], University of Western Australia[c], University of the Sunshine Coast[d], University of Technology Sydney[e], University of Wollongong[f], University of Tasmania[g]

Corresponding Author Email: m.belkina@westernsydney.edu.au

ABSTRACT

CONTEXT

New Generative Artificial Intelligence (GenAI) tools have gained significant attention in higher education, with studies across disciplines evaluating their performance against university assessments. Findings suggest that GenAI can generate acceptable responses with minimal input modification. This suggests the necessity to recalibrate current educational practices, particularly with the ongoing evolution and improvement of new GenAI tools. Integrating these tools into the classroom could enhance productivity, and their increasing use in industry professional practice.

PURPOSE OR GOAL

This study aims to systematically review case studies and practical examples of GenAI integration in university teaching and learning. The goal is to identify the factors that facilitate or hinder the effective use of GenAI in educational contexts and to provide insights for its application in engineering education.

APPROACH OR METHODOLOGY/METHODS

A systematic scoping review was conducted. A Scopus database search conducted in February 2024 identifies 487 publications, the titles and abstracts of which were screened by eight academics from seven Australian universities. Of these, 21 appeared to meet the inclusion criteria – thus, the data from these publications were extracted and analysed.

ACTUAL OR ANTICIPATED OUTCOMES

Results demonstrate that the number of publications in relation to GenAI in higher education has increased dramatically, confirming the importance of the topic. However, relatively few publications present research designs that demonstrate case studies and evaluation of the integration of GenAI in the classroom. The identified case studies can be applied in engineering education to enhance problem-solving, interactive learning, project-based learning, written communication, coding skills, and professional competencies, as well as to promote creative and critical thinking.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The identified case studies provide practical, evidence-based insights for engineering academics to integrate Generative AI into their teaching practice.

KEYWORDS

Generative AI, GenAI, ChatGPT, AI Classroom Integration

Introduction

Generative Artificial Intelligence (GenAI) is transforming higher education in Australia and globally by enhancing traditional teaching methods, refining student support systems, and reshaping the educational landscape. Defined as technology that utilises deep learning models to create content that mimics human responses to various prompts, GenAI, including models like ChatGPT, has garnered significant attention for its ability to perform at the highest academic levels (Lim et al., 2023; OpenAI et al., 2023). This technology is sparking crucial discussions about academic integrity and transforming teaching practices.

Research across various fields—from engineering to economics—has started assessing GenAI's suitability and effectiveness in university assessments (Currie, 2023; Geerling et al., 2023; Nikolic et al., 2023; Nikolic et al., 2024). These studies indicate that GenAI can effectively produce academic work with minimal tweaks, highlighting the need for Aussie educational practices to evolve in response to advancing AI technologies.

Recent literature reviews, such as those by Bozkurt (2023) and Park et al. (2024), have explored the vast potential of GenAI, identifying key themes and applications in blended learning environments and asynchronous online learning components. Additionally, Sohail et al. (2023) and Castillo-Segura (2023) have emphasised the practical applications and challenges of GenAI, advocating for ongoing research to enhance its reliability and ethical deployment in educational settings. However, a recent systematic literature review conducted by Alateyyat et al. (2024) noted a significant focus on general overviews but a shortage of research on specific applications such as integration with teaching practices,, AI in assessment, and support of administrative processes in higher education. This gap underscores the need for deeper exploration and practical application of GenAI technologies to fully realise their potential in educational settings.

This paper aims to provide an overview of the integration of GenAI in higher education by systematically reviewing empirical research and case studies and identify opportunities for integrating GenAI in engineering education, ensuring they enhance productivity and professional practice readiness.

Methods

Research Design

This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement approach (Page et al., 2021) and was conducted in three phases: (i) article selection, (ii) article screening and inclusion, and (iii) data extraction and analysis.

To the best of the authors' knowledge, this is the first review of its kind, confirmed by searches across academic databases. The scope of this review was restricted to articles from the Scopus database due to its extensive coverage of high-quality journals that meet the study's aims. The novelty of the topic allowed for inclusion (Table 1) of sources beyond peer-reviewed journals, including conference papers and book chapters.

Table 1. Inclusion and exclusion criteria for article selection.

Criterion	Inclusion
Topic	Focusing on the use GenAI in education or technologies with GenAI characteristics - technology that generates human-like content in response to complex and varied prompts
Study type	Empirical studies that demonstrate an authentic example of GenAI integration into the university teaching
Source	Journals, Conference papers, Book chapters
Period	January 1, 2023 to February 15, 2024
Language	English

Article selection

Given the massive increase in publications related to GenAI, the keyword structure was specifically designed to capture papers addressing the scope of the study and to ensure the inclusion of the most recent and relevant insights, particularly following the significant advancements in GenAI marked by the launch of GPT-3 in late 2022, the article selection was limited to publications from 2023 onwards. Articles not published in English and review papers were excluded. The following Boolean search string we used was:

TITLE-ABS-KEY("artificial intelligence" OR "ChatGPT" OR "AI" OR "GenAI") AND TITLE-ABS-KEY ("integration" OR "case study" OR "application" OR "implementation" OR "example")AND TITLE-ABS-KEY ("teaching" OR "education" OR "classroom") AND TITLE-ABS-KEY ("college" OR "faculty" OR "post-graduate" OR "postgraduate" OR "tertiary" OR "under-graduate" OR "undergraduate" OR "university" OR "HE") AND TITLE-ABS-KEY(student) AND PUBYEAR > 2022 AND PUBYEAR < 2026 AND (LIMIT-TO (LANGUAGE,"English")) AND (EXCLUDE(DOCTYPE, “re”) OR EXCLUDE (DOCTYPE, “cr”)).

Article screening and inclusion

The article search conducted in February 2024 identified 489 publications. No ineligible records were identified by the authors, and all articles were included for screening. Titles and abstracts of the publications were screened by eight authors to identify articles focused on findings from examples or case studies of the integration of GenAI in university teaching and learning. Each article was screened by two authors independently. Differences of opinion were resolved through group discussion. The exclusion criteria (EC) established for this review were as follows:

- EC1: Publications not relevant to the scope of the study, for example, research focusing on school students instead of university students.
- EC2: Publications lacking a case study with empirical data on GenAI implementation in tertiary education, such as for example, studies focusing solely on perceptions (rather than observations) of how GenAI can be used or misused in tertiary education.
- EC3: Publication not accessible.

A total of 400 records were excluded during the abstract screening. The full-text screening of the remaining 89 reports led to the exclusion of 68 papers, leaving 21 studies for the final analysis. The detailed article screening, selection and exclusion process is comprehensively described in our publication (Belkina et al., 2024).

Results and discussion

Characteristics of selected studies

Study characteristics are important to be able to understand the breadth of implementation (and any under-studied areas). As shown in Table 2, first-year students are represented in 4 studies, second and third-year students are also featured in 4 studies, postgraduate students are involved in 2 studies, mixed undergraduate and postgraduate groups appear in 1 study, unspecified undergraduate students are included in 7 studies, unspecified students are represented in 2 studies, and academics are the focus of 1 study.

Discipline distribution (Figure 1) shows that language courses, of all disciplines, have the highest number of related articles at 33% (n=7). This focus is largely due to the significant impact GenAI tools like ChatGPT have on language-related academic tasks, particularly in writing.

Following Languages, the fields of Information & Communication Technologies (29%; n=6) and Engineering & Science (19%; n=4), demonstrate the applicability of GenAI in more technical academic tasks, especially coding. Education disciplines (9%; n=2), complemented by contributions from the Humanities and Social Sciences (5%; n=1) and Multidisciplinary case studies (5%; n=1), reflect the widespread impact of GenAI across the entire education system. This variety suggests that as more tailored applications of GenAI are developed, its influence could extend further, enhancing various fields of study.

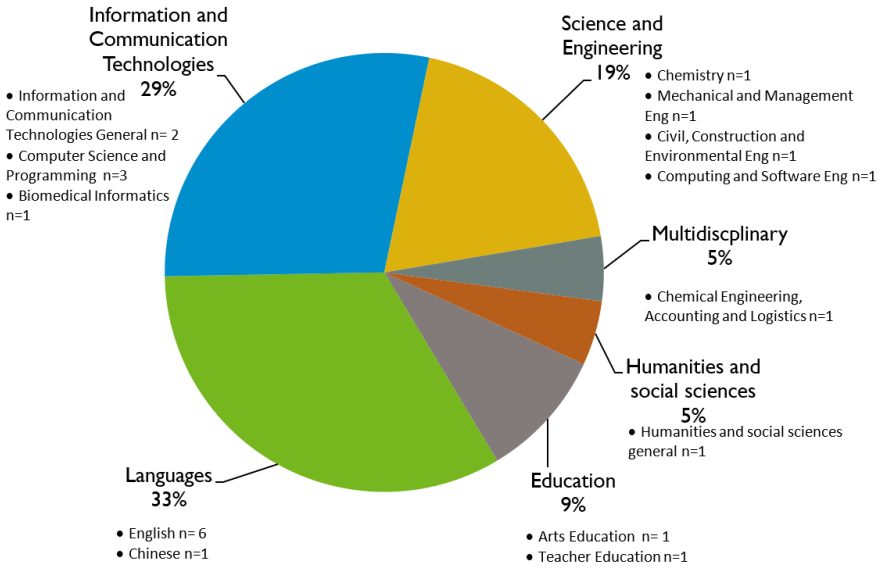

Figure 1: Discipline distribution of selected papers. (n = 21)

The aims of the selected research papers are diverse, reflecting the wide-ranging potential of GenAI in transforming higher education practice across various disciplines. These studies collectively focus on leveraging GenAI to enhance learning experiences, develop specific skills, and assess the impact of this technology on both students and educators.

Table 2: Characteristics of Included Studies Classified by Educational Level (n=21)

Reference	Disciplines	GenAI used	№ of participants	Aim(s)
First-year students				
Exintaris et al. (2023)	Science (chemistry)	ChatGPT 3.5	213	Develop problem-solving skills and critical thinking using ChatGPT-generated prompts.
Kirwan (2023)	Humanities and social sciences	ChatGPT 3.5	Not reported	Understand GenAI technologies and encourage critical thinking about their use.
Wang, Wang, et al. (2024)	Information Technology	ChatGPT 3.5	26	Evaluate the impact of prompt engineering on information retrieval skills.
Khang et al. (2023)	English	My virtual Dream Friend and John English Bot	36	Determine how AI chatbots can help in learning English as a foreign language.
Second and Third-Year Students				
Wang and Feng (2024)	English	ChatGPT	83	Investigate ChatGPT's effectiveness in assisting with reading comprehension and language analysis.
Kuramitsu et al. (2023)	Information Technology	ChatGPT 3.5	127	Evaluate AI-based assistance for addressing unresolved errors and clarifying terms.
Belda-Medina et al. (2023)	Teacher Education (EFL)	Chatbots: Mondly, Andy, John Bot and Buddy.ai	237	Compare linguistic and technological aspects of App-Integrated Chatbots and investigate perceptions of EFL teacher candidates.
Uddin et	Civil and	ChatGPT	42	Explore if ChatGPT can aid hazard recognition

Reference	Disciplines	GenAI used	№ of participants	Aim(s)
al. (2023)	Environmental Engineering			in construction industry curriculum.
Postgraduate students				
Murillo-Ligorred et al. (2023)	Education (Arts)	Technology generating 'deepfake images'	100	Assess ability to recognise deepfakes and knowledge about the technology.
Bernabei et al. (2023)	Mechanical and management engineering	ChatGPT 3.5	31	Examine effectiveness of ChatGPT in generating essays and exploring perceptions of LLMs.
Mixed undergraduate and postgraduate				
Elkhodr et al. (2023)	Information Technology	ChatGPT 3.5	52	Explore outcomes of using GenAI as an assistive tool in tutorials.
Unspecified undergraduate students				
Lu et al. (2024)	Chinese writing	ChatGPT 3.5	46	Compare teacher and ChatGPT feedback on student writing.
Speth et al. (2023)	Information Technology	ChatGPT 3.5	9	Evaluate effectiveness of using GenAI teaching materials in coding education.
French et al. (2023)	Software Engineering	ChatGPT 3.5 or Dall-E-2	Not reported	Describe and evaluate students' experiences using AI tools.
Pitso (2023)	Chemical Engineering, Accounting, Logistics	ChatGPT 3.5	15	Examine the use of ChatGPT in assignments and problem-solving processes.
Qureshi (2023)	Information Technology	ChatGPT 3.5	24	Investigate effectiveness of ChatGPT in improving learning outcomes in initial programming courses.
Guo et al. (2023)	English	Argumate chatbot	44	Examine impact of chatbots on argumentation skills and motivation.
Han et al. (2023)	English	RECIPE that uses ChatGPT	231	Evaluate RECIPE platform for EFL learners.
Unspecified students				
Zhao et al. (2023)	Biomedical informatics	ChatGPT 3.5 and available AI tools	6	Explore potential and limitations of AI in the classroom; investigate perceptions and experiences.
Silitonga et al. (2023)	English	ChatGPT 3.5	109	Investigate impact of AI chatbots on motivation to learn English.
Academics				
Widiati et al. (2023)	English	Jenni AI, Quillbot, WordTune, ChatGPT, Copy.ai Paperpal, Essay Writer	4	Investigate AI writing tools used by EFL teachers and their impact on students' writing quality and organization.

Analysis of GenAI Integration in Engineering Education

This section describes the opportunities that GenAI presents for engineering education (Table 3), examining how it can be leveraged to benefit both students and teachers. The analysis categorizes the applications into two primary types: student-centric and teacher-centric (Woods et al., 2024).

- Student-centric applications refer to the use of GenAI that directly impacts students' learning experiences. These include tools and systems designed to enhance their engagement, understanding, and skills development.
- Teacher-centric applications focus on how GenAI can support teachers in their roles. This includes improving their efficiency in administrative tasks, curriculum design, and the assessment process.

As shown in Table 2, for students, GenAI tools facilitate problem-solving by providing AI-generated evaluations of engineering problems, which enriches their understanding and application of technical concepts (Kuramitsu et al., 2023; Qureshi, 2023). GenAI supports project-based learning by aiding in the brainstorming and efficient gathering of relevant information (French et al., 2023; Pitso, 2023; Zhao et al., 2023). Moreover, GenAI contributes to the development of language skills (Lu et al., 2024; Widiati et al., 2023) critical thinking (Bernabei et al., 2023; Exintaris et al., 2023), and enhancing engagement through interactive learning environment (Belda-Medina & Kokošková, 2023; Guo et al., 2023; Silitonga et al., 2023).

For educators, the capacity of GenAI to generate diverse problem sets and assessments significantly enhances educational content and reduces the teaching workload (Exintaris et al., 2023; Speth et al., 2023). This capability not only enhances the educational content but also lightens the workload for teachers, allowing them to dedicate more time to teaching and other educational activities. GenAI's integration into the curriculum has been reported to improve student performance and engagement (French et al., 2023; Uddin et al., 2023).

Furthermore, teachers can utilise GenAI to deliver personalised and instant responses, thus enhancing the feedback mechanism (Lu et al., 2024). They can also experience a reduced number of basic enquiries, allowing them to focus on more complex queries and educational enhancement (Kuramitsu et al., 2023).

Table 3: Opportunities for GenAI Integration in Engineering Education

Implementation Category	Student-Centric Applications	Teacher-Centric Applications	Reference(s)
Technical Assistance and Problem-Solving	Evaluation of AI-generated solutions to engineering problems and assessments.	Assistance in generating diverse problem sets for coding, STEM subjects, and scenario-based assessments; Evaluation of student performance using generative AI.	Exintaris et al. (2023); Han et al. (2023); Kuramitsu et al. (2023); Qureshi (2023); Speth et al. (2023); Wang, Wang, et al. (2024); Zhao et al. (2023)
Project-Based Learning and Research	Use of generative AI to assist in information gathering for project-based learning.	Facilitation of project-based learning and research through AI; Overseeing student projects and research integration of AI tools.	French et al. (2023); Pitso (2023); Uddin et al. (2023); Wang et al. (2023)
Language Support	Language improvement initiatives through AI-assisted feedback and training.	Integration of generative AI to support understanding of technical language in lecture notes and textbooks; Oversight of language training programs.	Han et al. (2023); Lu et al. (2024); Wang and Feng (2024); Widiati et al. (2023)
Interactive Learning and Engagement	Development of conversational and professional skills in global engineering competencies.	Designing interactive sessions and personalized learning environments; Supporting staff in managing engaging learning activities.	Belda-Medina and Kokošková (2023); Elkhodr et al. (2023); Zhao et al. (2023)
Reflective and Critical Thinking Development	Critical thinking exercises, ethical discussions, and media literacy activities.	Implementation and guidance in exercises for developing critical and reflective thinking; Application in design and ethics education.	Bernabei et al. (2023); Exintaris et al. (2023); Guo et al. (2023); Murillo-Ligorred et al. (2023)
Assessment and Evaluation	Feedback on writing drafts, enhancing the quality and timeliness of feedback on student reports.	Supporting the assessment process, ensuring academic integrity and appropriate use of AI in assessments.	Lu et al. (2024); Silitonga et al. (2023)

Research limitations

The limitation of our study is that due to the dynamic nature of the field of GenAI, this systematic literature review captures papers published from January 2023 to February 2024, potentially overlooking more recent developments. Additionally, it includes only papers written in English, which may exclude relevant research published in other languages.

Conclusions

The finding from this systematic literature review reveals GenAI's potential to elevate educational pedagogy, boost student motivation, and enrich the overall learning experience. Despite encountering issues such as bias and reliability, this research argues that critical thinking can harness GenAI to tailor and enhance each student's learning journey. The integration of GenAI in engineering education offers significant opportunities to enhance both student and teacher experiences.

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