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The Current Ethical Considerations of Using GenAI in Engineering Education and Practice: A Systematic Literature Review

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ABSTRACT

CONTEXT

The rapid advancement and integration of Generative Artificial Intelligence (GenAI) into engineering education and practice have brought to light many ethical considerations. The potential of GenAI to change engineering processes and higher educational approaches requires an understanding of its ethical implications to ensure its responsible use.

PURPOSE

This systematic literature review aims to identify and analyse the current ethical considerations associated with the use of GenAI in engineering education and practice. The review seeks to address the following research question: What are the current ethical considerations of utilising GenAI in engineering higher education and professional practice?

APPROACH

This review employs the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to systematically identify, select, and analyse relevant literature. The search strategy encompasses Scopus and AAEE conference proceedings, focusing on findings related to the ethical use of GenAI in engineering education and practice. The included studies are assessed for their methodological rigour and relevance to the research questions.

OUTCOMES

The review identifies ten key ethical considerations associated with GenAI in engineering, including bias, error, learning, sustainable practice, equity, intellectual ownership, competitive advantage and automation, misuse (academic misconduct), GenAI awareness, and transparency. The analysis reveals that these considerations span across individual, institutional, and societal levels, highlighting the multifaceted nature of ethical challenges posed by GenAI. The review also discusses the limitations of the current EA Code of Ethics in addressing GenAI-specific concerns and suggests potential revisions to ensure responsible GenAI integration.

CONCLUSIONS

The findings underscore the critical need for ongoing adaptation of ethical frameworks to navigate the ethical considerations of GenAI in engineering. The review emphasises the importance of further research to explore the implications of GenAI. Further work includes reviewing the current practice of implementation by the engineering industry, continuing empirical research and understanding if GenAI and current policies align regarding equity and diversity in engineering.

KEYWORDS

Ethics, GenAI, Systematic Review

Introduction

Generative Artificial Intelligence (GenAI) is an AI technology capable of generating new content, such as text, images, audio, and video, that has been identified as both a threat and an opportunity within Engineering Education (Nikolic et al., 2024). Opportunities include personalised feedback and learning enhancements, while risks include accuracy, reliability, academic integrity, and cognitive and social development (Ansari et al., 2023). With this comes many questions about the ethical application, use and development of AI which has been approached in a chaotic way with no quick fix in sight (Morley et al., 2023). While many ethical implications of GenAI integration have been raised (Daniel & Nikolic, 2023), there does not appear to be any comprehensive approaches or guidelines on what or how students and academics should engage with ethics when utilising GenAI in engineering education.

Learning and demonstrating ethical competencies is already integrated into engineering programs due to explicit requirements through accreditation (Australia, 2008). However, even before GenAI found itself in the spotlight, there has been many appeals to give ethics greater emphasis in the curriculum (Gwynne-Evans et al., 2021). Therefore, as future engineers are poised to work increasingly with AI technologies, it becomes imperative to embed a robust ethical framework within engineering curricula. The integration of GenAI into various aspects of engineering practice brings forth unique ethical challenges and considerations that must be addressed to ensure that these technologies are developed and deployed responsibly. To accomplish this, it is imperative that we first understand the current state of the field. Therefore, this systematic literature review will consider the below research question.

Research Question

1. What are the current ethical considerations for utilising GenAI in engineering education and professional practice?

Methodology

A systematic literature review was conducted using the PRISMA framework (Page et al., 2021).

Inclusion and Exclusion Criteria

Papers were included that met each of the following criteria:

1. Reported empirical findings related to the ethical use of GenAI that is focused on engineering education at a tertiary level (associate diploma (Australian qualification framework level 6) or above) or engineering practice.
2. For engineering education, the research had to be defined as ‘engineering’. For this review, if the paper listed computer systems engineering or computer engineering it was included however, if was listed as computer science it was excluded.
3. The research needed to include original contributions where ethics or ethical considerations of using GenAI were a focus and not tangential or incidental.
4. All publications that were found by a search on SCOPUS and the AAEE conference proceedings were included. This includes review papers, conference papers, book chapters and research articles.
5. Published from 2022 due to the technology only reaching the masses in late 2022 (Teubner et al., 2023).
6. Articles needed to be in the English language.

At each level of screening, these criteria were checked to ensure that they were still meeting the criteria. There were three levels of screening as per the PRISMA guidelines which will be explained in detail below.

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Search Terms, Database and Screening Protocol

Due to the recent uprise of GenAI since 2022 and the lag between conducting research and publishing journal articles, both journal papers and conference papers (that have a more immediate publication cycle) were assessed to identify the articles for review. Specific conferences such as SEFI, ASEE and AAEE were targeted as they represent the largest engineering education conferences across Europe, America and Asia Pacific. Scopus (https://www.scopus.com/) represents a large online repository of peer-reviewed literature and both SEFI and ASEE conferences are housed within (Borrego et al., 2014; Mazzurco et al., 2021). The AAEE conference proceedings were found manually through a web search, and as such, they were assessed outside of the Scopus review and were not undertaken using the PRISMA framework. While investigating the AAEE conference papers, there were zero papers that met the inclusion criteria. Due to the different methods to assess these papers, they were not included in the below PRISMA diagram. The Scopus search was undertaken on 7th of May 2024 and the AAEE search was undertaken on 28th of May 2024.

To develop a comprehensive and exhaustive literature basis the search string was developed to ensure it would capture all relevant articles for both engineering education and engineering practice. As such, engineering was included in the search string combined with education or industry or curriculum or practice or learning (including wildcards) to fully capture all required articles. The search required GenAI applications and ethical considerations, as such variations on common GenAI langue were used, as well as ethics. All of these terms were required to be found in either the title, abstract or keywords. Due to the search string not containing all variations of some of the key search words, there is a limitation of this study that not all articles were found however, it was consensus within the research team that if they were not found using the current terms, it would not have met the inclusion criteria. The search string that was used, can be seen below.

TITLE-ABS-KEY (engineer*) AND (TITLE-ABS-KEY (educat*) OR TITLE-ABS-KEY (curriculum) OR TITLE-ABS-KEY (practic*) OR TITLE-ABS-KEY (industr*) OR TITLE-ABS-KEY (assess*) OR TITLE-ABS-KEY (profession*) OR TITLE-ABS-KEY (learn*) OR TITLE-ABS-KEY (teach*)) AND TITLE-ABS-KEY (ethic*) AND (TITLE-ABS-KEY (gen*) OR TITLE-ABS-KEY (chatgpt) OR TITLE-ABS-KEY (chatgpt*) OR TITLE-ABS-KEY ("generative artificial intelligence") OR TITLE-ABS-KEY (genai)) AND LANGUAGE (english) AND PUBYEAR > 2021

The screening protocol had various steps to ensure the correct articles were assessed in the final review. The first step is to review the title for suitability. Each of the titles were reviewed by two researchers and where there was disagreement it was discussed with the research team until a consensus was determined. The next stage of screening was through an evaluation of the articles abstract. A three-step criteria was used to assess the articles that met the inclusion criteria. For a paper to move on to the next step of screening it must be focused on engineering education or practice, including ethics and the use of GenAI. Again, two reviewers read the abstract for consensus. When a disagreement occurred, it was discussed with the research team. The final stage of screening was the full article evaluation. Two reviewers were again used to screen at this step however, where there was disagreement, the lead author made the decision on whether to include it. All initial screening decisions were undertaken independently to remain objective to the inclusion criteria.

A total of 560 articles were included in the initial title screening from the search return from Scopus. As mentioned earlier in this section, there were no articles that met the inclusion criteria from the AAEE conference proceedings. There was a total of 64 articles that passed both the title and the abstract screening. Finally, 10 papers were included in the full article assessment, and 8 did not meet the eligibility criteria. As such, 2 manuscripts were included in the final analysis. Figure 1 details the PRISMA inclusion and exclusion process.

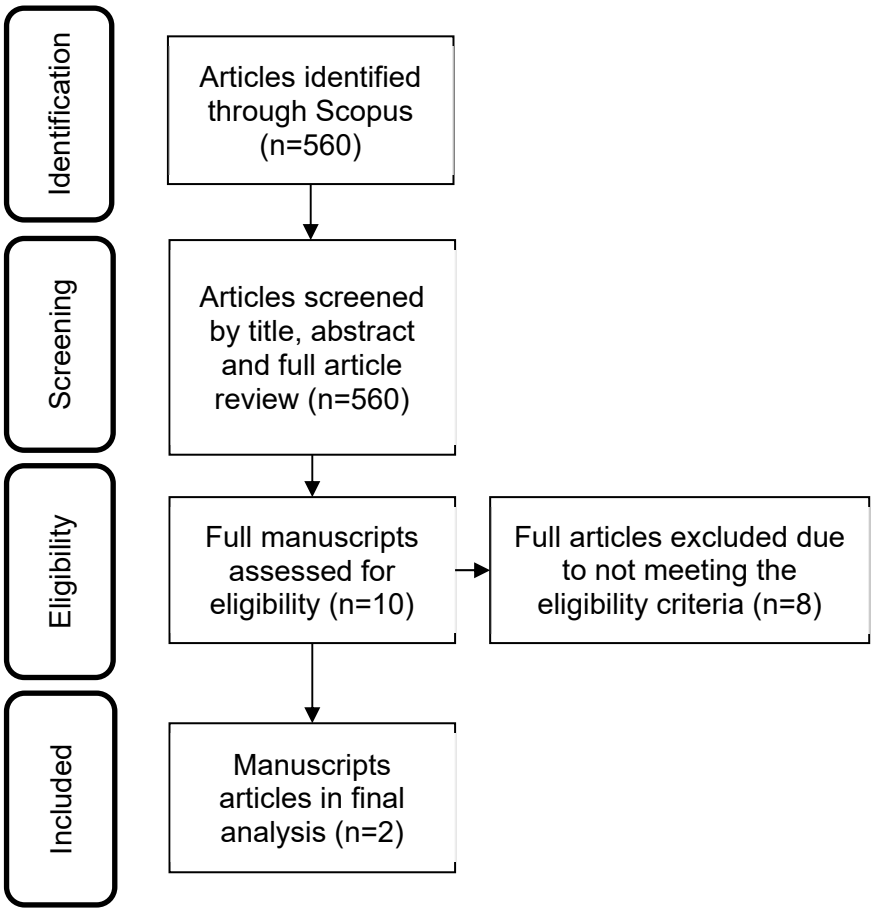

Figure 1: PRISMA inclusion and exclusion diagram.

Synthesis and Analysis

The ethical considerations of using GenAI in engineering education and practice were analysed in four separate ways. The first was an in-depth review of the final included articles. The topics found within the two articles were mapped to the EA code of ethics. Each of these considerations would then be assessed for the macro, meso and micro considerations. Other implications were then audited from a further literature search. Finally, the ethical considerations were then assessed to determine if they reside in the engineering domain or if they are a more general consideration.

The analysis of the final articles was assessed in multiple ways. The first was an in-depth review of the article's methodologies, discussion and meta-details (publication year, location, etc). This analysis allowed for the ethical considerations that were discussed in the articles to be derived. The paper was then assessed for how the research was conducted. This included a breakdown of if it was a review, included qualitative and/or qualitative methods and if there was any stakeholder data. The articles ethical considerations noted were mapped to the EA code of ethics (Engieers Australia, 2022) which are categorised below:

1. Demonstrate integrity
    1. Act on the basis of a well-informed conscience
    2. Be honest and trustworthy
    3. Respect the dignity of all persons
2. Practise competently
    1. Maintain and develop knowledge and skills
    2. Represent areas of competence objectively
    3. Act on the basis of adequate knowledge
3. Exercise leadership
    1. Uphold the reputation and trustworthiness of the practice of engineering

2. Support and encourage diversity
3. Make reasonable efforts to communicate honestly and effectively to all stakeholders, taking into account the reliance of others on engineering expertise

4. Promote sustainability
    1. Engage responsibly with the community and other stakeholders
    2. Practise engineering to foster the health, safety and wellbeing of the community and the environment
    3. Balance the needs of the present with the needs of future generations

This approach allowed the ethical considerations to be compared against our current consensus of ethical considerations in professional engineering practice and gave rise to a discussion of whether the code of ethics encompasses enough detail to not require any revisions with the rise of GenAI. The papers were then assessed for the different categorisations of the ethical considerations. To undertake this analysis the considerations were broken down into three different categories. These categories are derived from the work by (Herkert, 2005) that investigated the micro and macro ethics in engineering. Micro ethics is situated in the personal decisions about ethical situations that impact lives and careers, whereas macro ethics is centred around the social responsibilities of the engineering profession. This work was extended by (Davis, 2010) who further broke down the micro and macro ethics into micro, meso and macro. Where micro ethics was redefined to include only one's ethics. Meso is the ethics concern of the institution. Macro was redefined to be concerned about the societal implications of engineering ethics. Davis's introduction of the intermediate 'meso' level addressed the ambiguity inherent in Herkert's model regarding how institutional ethical considerations should be categorised.

Results and Discussion

Manuscript Analysis

Both articles focused on the ethical considerations of using GenAI in engineering education and practice. Table 1 describes the article's details.

Table 1: Categorisation of articles included in this study including publication mode, domain, discipline and synthesis method.

Citation	Year	Publication mode	Practice or education	Discipline	Synthesis method
(Yu & Gong, 2024)	2023	Journal article	Practice	Management	Review
(Kirova et al., 2024)	2024	Conference	Education	Software	Review

Article 1

This article focused on the potential and current uses of GenAI or as they termed AI-generated content (AIGC) in the engineering management lifecycle. The paper was opinion-based, and was grounded in the current engineering management lifecycle literature. There was no quantitative analysis or survey mechanisms contained within. They did not focus on a particular model but GenAI as a whole technology. The article was submitted in June 2023, and published 2024 in Frontiers in Engineering Management, a Q2 journal. There was no country of focus for this paper.

The article listed several ethical considerations that engineering management and project lifecycle would have to consider that are more broadly categorised under engineering practice. They spoke on the risk of inadvertent biases or errors in the training data. This consideration should be broken into two as there is a distinct difference between 'bias' and 'error' in the training data. **Bias** is the limitation of the model that will only use specific information such as demographic or historical. **Error** is when the model uses information that is factually incorrect or faulty when training. They then spoke on the potential that the technology could be mishandled if not trained correctly. This leads to an ethical consideration around the **learning** of the use of GenAI. The article then dived into the sustainability and social responsibilities of engineering and mentioned resource consumption, waste generation and community involvement if using AIGC.

Both resource consumption and waste generation fall under a general category of **sustainable practice.** Community involvement is a more difficult consideration as it would fall under two categories the bias the data is trained on and **equity** to ensure that all voices are heard. Finally, the last ethical consideration that the article discussed was the **intellectual ownership** of the outputs from GenAI**.** The article's main focus was on the ability of GenAI to be incorporated into engineering management, this directly brings forth an ethical situation of **competitive advantage and automation.**

Article 2

The second article investigated the implications of GenAI on software engineering curricula. Whilst it was focused on software engineering, the discussion focused on several topics that were broad to engineering education and the use of GenAI. The paper was opinion-based and contained literature focusing on the use of GenAI in the education of software engineers. There was no qualitative or survey mechanism. The article was published in a 2024 conference proceedings. There was no country of focus for this paper.

There was a good range of ethical considerations that were discussed in this paper. The first mentioned, and most commonly discussed in the article was **bias.** In this article, bias was consistently referenced with GenAI's tendency to produce non-factual information which is categorised under **error.** As with most investigations of the use of GenAI in engineering education **academic misconduct** was raised, as students have the potential to use GenAI to complete assessment items. **GenAI awareness** was another point raised by this article. The fact that GenAI models do not contain consciousness and are not free thinking. This was inferred to mean the safety, privacy and reality concerns that humans have, GenAI would not be able to understand these. The discussion around the model's lack of awareness resulted in comments regarding **transparency**. It was noted that if the models were transparent and outputs were able to be understood then it would allow for human interactions to be inserted at critical decision points, drastically altering the output. Finally, **equity** was discussed from the viewpoint of students with disabilities or those that whom English is not their first language.

For both of the articles, there were 10 unique ethical considerations that were discussed. Table 2 shows each of the considerations, with a brief description, as well as which paper it was cited in.

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Table 2: Ethical Considerations Topics

Ethical Consideration	Macro, micro or meso	Brief Explanation	Cited
Bias	Micro	The bias caused by Large Language Model (LLM) is that if the data that trains the model only uses specific information or historical it may produce a bias in the output. Furthermore, if models use historical data, it can lead to certain stakeholders being mis, or underrepresented.	Article 1 & 2
Error	Meso	The error relates to bias, as both revolve around the training data. Errors are caused when the model is trained on non-factual data and can lead to incorrect or non-factual outputs. Error also contains the model's ability to 'hallucinate' and produce statements that are a combination of information it believes is correct.	Article 1 & 2
Learning	Micro	Learning has two facets, the ability for GenAI to be used as a tool for lifelong learning and that GenAI requires training to ensure the correct usage that does not lead to low-quality outputs.	Article 1
Sustainable practice	Macro	Sustainability is now becoming a crucial part of society, and as such GenAI should be held to the same expectation. This includes power generation, waste generation, and environmental concerns over the use of GenAI.	Article 1
Equity	Macro	Equity is broken into several considerations, but all focus on the fact that GenAI should cater to all people, regardless of circumstance. This includes that the training data accurately represents a global presence and that GenAI can be used by all regardless of the situation.	Article 1 & 2
Intellectual ownership	Meso	Crucially, there is still much dialogue surrounding who owns the intellectual property of the output of GenAI. This is particularly important when it comes to using GenAI for financial gain	Article 1
Competitive advantage and automation	Meso	Gen-AI tools can add the competitive advantage of rapid digital transformation in practice. This can be as simple as sending an email, to being sophisticated as running correspondence, feedback and marking for an academic. There is a range of considerations that has to be considered regarding when human oversight is required.	Article 1
Misuse - Academic misconduct	Micro	The misuse of GenAI outputs is vast and requires contextualisation for the purpose of higher education specifically, where there is the temptation for students to use GenAI to undertake assessment items.	Article 2
GenAI awareness	Micro	GenAI awareness considers that the tool is not sentient. It can not 'think as a human' therefore there should be limitations and human oversight in some applications.	Article 2
Transparency	Micro	Within the GenAI model, there is currently limited visibility of how it determines the output, being equated as a 'black box' This can cause issues when errors in the output are not able to be fixed or tracked.	Article 2

Macro, Meso or Micro Considerations

Although engineering ethics has sometimes been criticised as focusing too much on micro-ethics (rather than macro), these two papers discussed ethical considerations encompassing sustainable methods, ownership and equity consideration which can be classified as macro. Whilst there is still a focus on the micro or meso considerations as they will only impact the individual using the software, pending the application of the use of GenAI all could impact society and then be reclassified as macro. This framework may be more impactful within specific contexts and applications of GenAI.

EA Code of Ethics

To understand if the current EA code of ethics is currently sufficient with the rise of GenAI, the 10 topics listed in Table 2 were mapped against the current code of ethics. Table 3 shows the topics as mapped to the EA code of ethics.

Table 3: Ethical Considerations Topics Compared to the EA Code of Ethics

	Code of Ethics Values											
Ethical Considerations	**1.1**	**1.2**	**1.3**	**2.1**	**2.2**	**2.3**	**3.1**	**3.2**	**3.3**	**4.1**	**4.2**	**4.3**
Bias	X		X			X				X	X	
Error	X					X					X	
Learning				X		X						
Sustainable practice											X	X
Equity			X		X				X	X		
Intellectual ownership												
Competitive advantage and automation												
Misuse - Academic misconduct		X					X					
GenAI awareness												
Transparency	X					X						

Across the 10 topics found in the articles, seven were mapped to at least one of the four broad categories of the EA code of ethics. The three that did not map were ‘Intellectual ownership’, ‘Competitive advantage and automation’ and ‘GenAI awareness’. Intellectual ownership has implications that are currently not able to be seen within the code of ethics. As such, this should be included in the EA code of ethics document as GenAI content is a specific consideration. Competitive advantage falls within the same space as intellectual ownership, that there is currently no limitation on the use of GenAI for automating processes. Finally, GenAI awareness also requires a specific statement regarding what GenAI output requires human oversights. Given the current code of ethics, it is recommended that in section 2 of the document, a sub-section about the use of GenAI should be considered. This would give specific limitations on the use of GenAI and should be monitored closely for changes as this is a rapidly changing technology.

Conclusions

The integration of GenAI into engineering education and practice presents a complex landscape of ethical considerations that require careful attention. While the existing EA Code of Ethics provides a foundation for ethical conduct, it may require revision to explicitly address the unique challenges posed by GenAI. The rapid evolution of GenAI technologies necessitates ongoing dialogue and adaptation of ethical frameworks between both academia and practice. The limitations of this review, including the limited number of included studies and the potential for publication bias, show that there is a need for further research in this area. Future studies should explore the implications of GenAI in engineering using empirical methods, investigate if the current diversity and inclusion practices are mimicked by GenAI in the engineering profession and examine the current practice by industry engineers.

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