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Generative AI Tools in Teaching and Educational Research in Engineering

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Abstract

The use of generative Artificial Intelligence (genAI) in teaching and education has received attention and rapid growth in university engineering programs since OpenAI released ChatGPT in November 2022. In this paper, the authors explore the use of genAI in teaching and educational research in engineering disciplines and examine potential benefits and challenges while transitioning to genAI implemented in engineering education. This study A) Analyzes how educators and learners understand and identify the usage of genAI and ChatGPT in engineering education; B) Explores the potential benefits, challenges, and limitations of using these technologies; and C) Identifies educators' perceptions of using and understanding technologies like genAI, specifically ChatGPT. Student perspectives are analyzed using surveys including qualitative and quantitative questions. The authors explore educators' perspectives, whether they embrace genAI, how they use it, to what extent, and specific use cases, in teaching and educational research. Also, perspectives are included from educators opposed to the idea of using genAI or encouraging students to use it. Additionally, students' perspectives on the uses and misuse of genAI are discussed. Results of surveys from students are included in this paper.

Background and Literature Review

There is a growing need to train creative professionals by teaching them skills that will be important in the future to make them more competitive and better prepared to handle professional challenges [1]. Eliseeva et al. (2016) [1] indicated that advanced education promotes adaptability, innovation, and creativity, aligning specialists with future labor market demands. Integrating engineering design into technology teacher education can enhance curricula and instructional strategies. Hill (2006) [2] suggests that this integration can improve educational experiences by emphasizing analytical skills, problem-solving, and collaboration, but it requires significant curriculum and teacher preparation changes.

AI methodologies can support educational praxis, which means the practical application of teaching theories and methods, and teacher metacognition, which refers to the awareness and understanding of their own teaching processes [3]. AI, especially in knowledge representation and elicitation, can significantly aid teachers' metacognitive skills and professional development by enabling detailed, context-specific reflection and adaptive decision-making [3]. Researchers [4] investigate how generative AI, as an advanced innovative tool, can transform engineering

education by creating content, enhancing personalized learning, and updating curricula efficiently. Yelamathi et al. (2024) [4] collected data through literature reviews and analysis of AI tools from engineering fields. They found that generative AI can improve personalized learning and streamline curriculum updates, enhancing education quality. However, their study [4] suggests potential biases and ethical issues, indicating that future research should address these concerns and develop user-friendly AI tools for education.

From the learner's perspective, Sokhibov et al. (2024) [5] suggested that AI can improve teaching effectiveness, learning outcomes, and accessibility, but also raise concerns about data privacy, algorithmic bias, and the changing role of educators [5]. Their study [5] examines the transformative potential, challenges, and ethical implications of integrating AI into higher education, aiming to enhance teaching efficacy, personalized learning, and inclusivity. Researchers [5] suggested that future research should develop ethical frameworks and regulatory mechanisms to ensure transparency, accountability, and fairness in AI use in education. From the educator's perspective, Menekse (2023) [6] explores the opportunities and challenges of integrating generative AI in engineering education to enhance learning and teaching experiences. Generative AI can improve personalized learning, create innovative instructional materials, and reduce instructors' workloads, enhancing student engagement and understanding of complex concepts [6]. However, concerns include potential inaccuracies, privacy issues, and reduced cognitive engagement, suggesting future research should develop ethical guidelines and investigate longterm impacts [6].

There are also ethical dilemmas in Engineering Education 4.0, focusing on unintended negative consequences of technology, discrimination, and educator agency [7] and highlighted consistent ethical issues such as lack of contact time, compromised online assessment integrity, and privacy concerns [7]. Future research should develop context-specific ethics guidelines and establish a network of safety champions to enhance the quality of engineering education.

In this paper, the research highlights the rapid growth and increasing attention generative AI (genAI) has received in university engineering programs since the release of ChatGPT by OpenAI in November 2022 [8]. The authors aim to explore the integration of genAI in teaching and educational research within engineering disciplines. This exploration includes analyzing how both educators and learners understand and utilize genAI tools like ChatGPT, examining the potential benefits and challenges associated with their use, and identifying the perceptions of educators regarding these technologies in the perspective of both educators and learners.

Methodology

This study aims to gather insights from engineering students at a comprehensive university regarding their perspectives on the use of generative AI (genAI) in their education. Institutional Review Board (IRB) approval has been obtained to conduct the research (IRB-FY25-166). The primary objectives are to assess: (a) whether students are currently using genAI as part of their

academic experience, and (b) their openness to learning about genAI's applications for education and other professional purposes. As part of the consent form, students are informed about the nature and intent of the survey, general explanation of the procedure, risks and discomforts, benefits, and confidentiality. The data collected offers valuable insights for engineering educators, helping them identify potential gaps and design targeted training and resources to better prepare students for industry demands upon graduation. The survey begins with a consent form to ensure participants' informed participation. The following questions are asked in the survey.

1. Consent Form [Read]
2. Do you wish to participate in this survey? [Yes / No]
3. What is your age: [Open Ended]
4. What is your major: [Open Ended]
5. What is your year in college: [Open Ended]
6. Have you used generative AI tools for your studies or projects?
   - Yes
   - No

   [If No, skip to Q7]

7. Which platform(s) do you use? [ChatGPT, Perplexity, GEMINI, CLAUDE, MS Co-Pilot, Others]
8. How frequently do you use these tools?
   - Daily
   - Weekly
   - Monthly
   - Rarely
   -
9. On a scale of 1 to 5, how easy is it for you to use generative AI tools?
   [1 = Very Easy, 5 = Not easy at all]
10. On a scale of 1 to 5, how would you rate the overall improvement in your learning experience due to generative AI tools?
    [1 = No improvement, 5 = Significant improvement]
11. How do you perceive the role of generative AI tools (e.g., ChatGPT) in your education?
    - Very positive
    - Positive
    - Neutral
    - Negative
    - Very negative
12. What specific tasks do you use generative AI tools for? [Multiple choice, select all that apply]

- Completing assignments
- Conducting research
- Learning new concepts
- Brainstorming
- Other [With text entry option]

Ethical Considerations

13. What ethical concerns do you have regarding the use of generative AI tools in your education? [Multiple choice, select all that apply]
    - Academic integrity
    - Data privacy
    - Bias in AI-generated content
    - Other [With text entry option]
14. Do you have any additional comments or suggestions regarding the use of generative AI tools in your education? [Open-ended]

The results obtained from this survey and their analyses are discussed in the following section.

Preliminary Results and Initial Conclusions

In this section, we present a detailed analysis of our preliminary findings, including drawing implications for each survey question regarding engineering students' use and perceptions of generative AI (genAI) in education. Each question is analyzed individually to assess students' engagement, perceived benefits, ethical concerns, and recommendations for educational practice. Question analysis begins with Q3 because the first two survey questions dealt only with consent, not data.

Q3: Age Distribution

Results indicate that the majority (93%) of respondents are aged 18-24, suggesting a predominantly undergraduate audience, likely adapting to college-level studies. This age group's openness to new technologies aligns with their reported engagement with genAI tools, positioning them as early adopters in educational technology use. Younger students may demonstrate a greater willingness to explore genAI in academic contexts, potentially using it as a supportive tool in their initial university years. This could set a precedent for ongoing AI integration in their educational and professional trajectories.

Q4: Major

Results show that 51% of respondents are Mechanical Engineering majors, followed by 32% in Electrical and Computer Engineering. Other fields like Civil and Environmental Engineering and Industrial Engineering represent smaller percentages. This is representative of the overall distribution of student population across various majors in the college. This distribution also emphasizes the predominance of genAI use within fields that involve complex calculations, simulations, and technical tasks. The overrepresentation of certain engineering majors suggests that specific technical demands in these fields may lend themselves well to AI tools for tasks such as problem-solving, design, and computational analysis. This trend underscores the value of genAI in disciplines requiring precision and efficiency.

Q5: Year of Study

Results reveal that most respondents are first-year students (60%), with seniors representing 26.5%, and minimal representation from sophomores and juniors. No postgraduate students participated in the survey. The concentration of first-year students could indicate that these students see genAI as a tool to facilitate their transition to higher education. Meanwhile, the lack of postgraduate responses may suggest lower engagement or skepticism about genAI's relevance at advanced academic levels, possibly due to established study habits or less need for supplementary study aids.

Q6: Use of Generative AI

Results indicate that 60.7% of students have used genAI in their studies, signifying substantial adoption across the sample. This high adoption rate underscores the relevance of genAI as an educational tool among engineering students. The substantial engagement suggests that students recognize genAI’s practical applications in academics, possibly for enhancing learning efficiency and improving academic performance.

Q7: Generative AI Platforms Used

Results show that ChatGPT is the most popular genAI platform (65%), followed by Gemini and Co-Pilot, each at 15%. The preference for ChatGPT highlights its reputation, accessibility, and versatility. It may also indicate a need for introducing students to more specialized AI platforms that cater to specific academic needs or disciplines.

Q8: Frequency of genAI Use

Results reveal that 48% of students use genAI weekly, with 18% using it daily. Weekly use suggests that genAI is becoming an integrated part of students' study routines rather than an occasional resource. This regular engagement implies that students find consistent value in AI, possibly to support ongoing projects or recurring academic tasks.

Q9: Ease of Use

Results indicate a moderate mean ease-of-use rating of 3.06 (on a 1-5 scale), showing general comfort with genAI but also some challenges. The moderate ease of use highlights potential areas

for improvement in AI interfaces or additional training. Institutions may consider workshops to increase students' technical proficiency with AI tools, enhancing both comfort and productivity.

Q10: Overall Learning Improvement due to GenAI Tools

Results for Q10 indicate a generally positive perception of the impact of generative AI tools on learning experiences. On a scale of 1 to 5, where 1 represents "No Improvement" and 5 represents "Significant Improvement," most students rated their learning experience as moderately to significantly improved, with 33.96% selecting a rating of 3, 30.19% selecting 4, and 20.75% selecting 5. A smaller portion (15.10%) indicated little to no perceived improvement (ratings of 1 or 2). The mean score of 3.49 suggests that overall, students believe generative AI tools have positively contributed to their learning, though there is some variation in the level of perceived benefit. The responses show a general trend towards acknowledging positive impacts of genAI tools on learning experiences, with most respondents rating it between moderate to significant improvement. However, a notable minority feels that genAI tools haven't brought significant benefits to their learning.

Q11: Perceptions of genAI in Education

Results show that 54% of students hold a positive view of genAI's role in education, while 36% remain neutral, and 10% express negative sentiments. The favorable outlook suggests that most students recognize the potential benefits of genAI for enhancing learning. However, the neutral responses imply that some students may not fully trust or rely on genAI, potentially due to concerns about accuracy or ethical considerations. The small percentage of negative perceptions reflects skepticism that could stem from concerns about dependency or the risk of diminishing academic integrity.

Q12: Applications in Academic Tasks

Results indicate that students primarily use genAI for brainstorming (36%) and learning new concepts (26%). This usage pattern shows that students treat genAI as a supplementary aid rather than a primary source for task completion. By leveraging AI for brainstorming and conceptual understanding, students may use genAI to deepen learning rather than merely complete assignments, indicating a thoughtful approach to AI use.

Q13: Ethical Concerns

Results identify the top concerns as academic integrity (45%), data privacy (26.6%), and bias in AI content (25.9%). These ethical concerns highlight a strong awareness of AI's potential to impact educational standards and personal data security. Concerns about bias also demonstrate students' understanding of AI's limitations in delivering fair and inclusive content. Addressing these ethical issues through educational policies and training could alleviate concerns, promoting more confident and ethical AI usage.

Q14: Additional Comments on genAI

Sentiment Analysis reveals a balance between positive, neutral, and negative sentiments. Positive feedback praises genAI's utility in brainstorming and learning, while neutral feedback emphasizes responsible use. Negative feedback reflects concerns over dependency, accuracy, and AI's appropriateness in creative fields. The varied feedback indicates a nuanced perception of genAI, with students recognizing its benefits while also cautioning against over-reliance and ethical pitfalls. This awareness suggests that students are actively assessing genAI's role, leading to a balanced view where AI serves as an aid but not a replacement for human effort and creativity.

Qualitative Analysis and Sentiment Summary for Generative AI in Education

This section provides a comprehensive analysis of the qualitative data from the survey, specifically focusing on open-ended responses. Responses were grouped by thematic categories based on sentiment (positive, neutral, negative) and key topics that students addressed in their comments, offering a detailed view of students' nuanced perceptions, concerns, and suggestions regarding generative AI (genAI) in their education.

Q14: Additional Comments on genAI in Education – Sentiment and Thematic Analysis The open-ended responses for Q14 reveal a spectrum of sentiments, which are broadly categorized as positive, neutral, and negative. In these categories, themes include genAI as a learning tool, ethical and practical concerns, and advice on responsible usage.

Positive Sentiments (Approx. 40% of Comments)

1. Support for AI as a Learning Aid: Many students highlighted the value of genAI as a tool for brainstorming, rephrasing, and learning new concepts. For instance, comments like "AI is a great tool for learning" and "I believe AI is the future" reflect enthusiasm about AI's potential to enhance academic work and understanding.

2. Enhancement of Study Practices: Students noted that genAI tools aid in problem-solving and study material organization, with statements like "AI tools help me tremendously" and "I've incorporated AI into my learning workflow" showing appreciation for genAI's impact on their study routines.

3. Future-Forward Perspective: Some comments reflect optimism about genAI's long-term role in education, indicating that students see it as an essential part of modern academic life. Such feedback includes "AI will lead us ahead if used properly," underscoring a forward-thinking outlook on genAI's benefits.

Neutral Sentiments (Approx. 30% of Comments)

1. Balanced Views on AI Utility: Some students appreciated AI's role but advised caution. Comments like "AI should be used to enhance what's already learned" and "Use AI for

correction, not creation" reflect a moderate stance where students acknowledge the benefits but see genAI as supplementary rather than primary.

2. Acknowledgment of AI's Role with Caveats: Many students support AI's use but emphasize responsibility and moderation. For example, statements like "AI is helpful for brainstorming but shouldn't make students lazy" illustrate a cautious approach that values AI's assistance without dependency.

Negative Sentiments (Approx. 30% of Comments)

1. Concerns Over Dependency and Accuracy: Some students voiced concerns that genAI could encourage academic laziness or dependency. Comments such as "AI shouldn't enhance laziness" and "AI often gives inaccurate answers, especially in formulas" reflect students' worry about relying on AI without critical engagement.

2. Skepticism in Creative Fields: Students in creative disciplines expressed discomfort with genAI in arts and writing fields, suggesting that AI lacks suitability for creative expression. Statements like "AI should NEVER be used in arts or writing" highlight students' perception of genAI's limitations in creativity-driven tasks.

3. Distrust of AI Reliability: Certain students noted that genAI can produce inaccurate information, especially in technical subjects. Comments like "AI often gives bogus solutions" and "I'm concerned about my classmates' reliance on AI for answers" point to doubts about AI's dependability for accurate academic work.

Thematic Implications and Summary of Sentiment Analysis

The sentiment analysis across qualitative responses reflects a mix of positive engagement, cautious pragmatism, and skepticism:

1. Positive Feedback (40%): Enthusiasm centers on genAI's potential for brainstorming, rephrasing, and understanding complex topics, which students view as constructive additions to their learning process.

2. Neutral Feedback (30%): Comments underscore a balanced outlook, acknowledging AI's benefits but stressing the need for ethical and responsible use. This perspective highlights the value students place on using AI as an educational support rather than a replacement for independent thought.

3. Negative Feedback (30%): Concerns primarily revolve around dependency, accuracy, and genAI's role in subjective fields like creative arts. This skepticism reflects a desire for

clarity on genAI's limitations and risks, especially in terms of accuracy and academic integrity.

Implications for Educational Practice

1. Encourage Responsible Use of genAI: Educators could integrate discussions on ethical AI usage into curricula, emphasizing AI as a tool for enhancement rather than substitution. This guidance can address student concerns about over-reliance and promote a balanced approach.

2. Tailored AI Guidelines for Specific Disciplines: Given the diverse attitudes towards genAI in technical versus creative fields, discipline-specific guidelines could clarify appropriate AI use cases and ethical considerations.

3. AI Literacy and Critical Thinking Training: Training students to evaluate AI-generated information critically, especially for research and technical work, could help mitigate concerns about accuracy and dependency, encouraging students to use AI discerningly.

Preliminary Takeaways and Initial Recommendations

The survey reveals a high engagement rate with genAI among undergraduate engineering students, particularly first-year students in technical disciplines. While most students recognize genAI's potential benefits, significant concerns remain regarding academic integrity, privacy, and bias. The qualitative data underscores that while students appreciate genAI's benefits, they are also acutely aware of its potential pitfalls. The mixed sentiments suggest that students are eager to leverage genAI's advantages but remain cautious about its impact on academic integrity and learning quality. Addressing these concerns through guidance, policies, and AI literacy training can help students navigate genAI's potential responsibly, aligning its use with both academic integrity and effective learning practices.

To foster responsible AI usage, institutions could implement the following recommendations:

1. Provide genAI Training and Ethical Guidelines: Workshops could familiarize students with genAI's capabilities, ethical considerations, and best practices for responsible usage.

2. Establish Clear Policies on Academic Integrity: Defining acceptable uses of AI in coursework could alleviate concerns about academic integrity and prevent misuse.

3. Tailor genAI Usage to Disciplines: Certain engineering fields benefit more from genAI, so providing field-specific guidance could help optimize utility and relevance.

4. Encourage Critical Evaluation of AI Content: Training students to critically assess AIgenerated information could mitigate bias and inaccuracies.

These steps would support students in using genAI as an academic tool while safeguarding educational standards and fostering a thoughtful approach to AI technology in academia.

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