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Generative Artificial Intelligence in Engineering Education: Opportunities, Challenges, Ethical Concerns, and Future Directions – A Systematic Literature Review

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***Abstract*— Generative Artificial Intelligence (GenAI) has revolutionized engineering education, enabling intelligent tutoring, automated content creation, AI assistance for programming, assessment support, and personalized learning experiences. This systematic literature review presents the findings of a synthesis of recent research published in the years 2023-2026 on the educational advantages, obstacles, ethical considerations, and future research prospects related to GenAI in engineering education. The review also shows growth in student engagement, efficiency of teaching and learning, creativity and problem-solving, as well as potential issues of academic honesty, bias, hallucinations, privacy, and relying too heavily on AI. The results indicate that implementing successful integration of GenAI involves a shift in institutional policy, enhancing AI literacy, enhancing faculty development, and redesigning the assessment. The paper suggests that GenAI should be used to complement, not supplant, human teaching, and that responsible governance is critical to sustainable use.**

***Keywords*— Generative Artificial Intelligence, Engineering Education, ChatGPT, Higher Education, AI Ethics, Systematic Literature Review.**

I. Introduction

Artificial Intelligence (AI) has marked a radical change in many industries such as healthcare, manufacturing, finance, transportation, and education. Generative Artificial Intelligence (GenAI) is one of the most disruptive innovations in recent times because of its capacity to produce human-like text, images, computer programs and multimedia content based on natural language prompts. Unlike predictive AI models that mainly make predictions and classify data, generative AI models are tailored to generate novel content from large volumes of data, learning complex patterns. As large language models like ChatGPT become a public release, the use of AI in education is gaining momentum, allowing millions of learners and teachers to access high-quality learning support easily and quickly.

These attributes of engineering education—problem-solving, programming, mathematical reasoning, technical communication and design thinking—make it a field where generative AI has had a profound effect. AI tools are increasingly leveraged to provide students with deep understanding of complex concepts, to generate computer programming code, to solve numerical problems, to summarize research articles, to prepare laboratory reports and to provide personalized academic support. The technologies can also be used by faculty to design instructional materials, generate assessment tools, design interactive learning activities, and enhance student feedback processes. In turn, generative AI is changing the way traditional teaching and learning approaches are implemented, leading to more personalized, adaptive and learner-centric education.

Incorporating generative AI into engineering learning comes with many educational benefits. Learning assistants supported by artificial intelligence can give students instant answers to their questions, helping to solve conceptual problems before the teacher is ready. Adaptive feedback, intelligent programming support, multilingual learning aids, automated content generation, and personalized tutoring can enhance student confidence, efficiency, and engagement in learning. In addition, AI tools can help institutions cater to a wider audience of students by minimizing language barriers and enabling inclusive learning by providing personalized learning materials.

The potential for generative AI in education is great, but it has also created new challenges. While this offers great promise for education, it also presents numerous educational, ethical, and institutional challenges. A major worry is the potential danger of students relying on AI-generated answers, thereby diminishing their critical thinking, analysis, creativity, and problem-solving abilities when not used correctly. Large Language Models also sometimes give erroneous or fabricated information, which is often called “hallucination,” and can lead students to believe that this information is accurate when fact checking is not performed. Other worries encompass academic honesty, plagiarism and copyright ownership, data privacy, algorithmic bias, transparency and accountability. The challenges have led to reevaluations of assessment methods, academic honesty policies, and ethical guidelines for AI governance in educational institutions globally.

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One of the major challenges is the readiness of higher education institutions to incorporate generative AI into their current curricula. Some universities have actively embraced its use for learning, while some others have passed restrictions, due to issues of misuse and correctness of AI-generated content. While some of these factors have been discussed, the successful use of generative AI in engineering education remains heavily shaped by faculty readiness, digital literacy, how institutions develop policies addressing the use of generative AI, the presence of necessary infrastructure, and ethical awareness. With the rapid changes in education technologies, it has become crucial to balance the innovation of these with responsible academic use.

In recent years, an increasing volume of studies has explored different facets of generative AI in education, such as student acceptance, teaching effectiveness, academic performance, assessment redesign, AI literacy, ethical issues, and institutional readiness. While there are a number of studies available, the literature is disjointed with some focusing on particular applications and some on specific educational settings. Few comparative review studies exist that have brought together recent evidence from the perspective of engineering education and that have also looked at educational opportunities, the implementation of the new system, ethical issues, and future research directions. With technology evolving at such a rate, it is always necessary to pull together what is known and to look for new areas of research that can inform teachers, researchers and policy makers.

This systematic literature review is intended to fill this gap by critically reviewing recent scholarly literature concerning the use of generative artificial intelligence in engineering education. The review collates the most recent research on the educational benefits, uses of generative AI in teaching or learning, ethical issues raised by using generative AI in education, institutional issues and future possibilities of generative AI in education. The paper brings together the results of recent studies to offer a comprehensive understanding of the advent of generative AI in engineering education and the strategies needed for its responsible and sustainable implementation. The results will help those involved in education to make well-informed decisions about the successful use of generative AI in higher education, from teachers to institutional leaders, curriculum developers, and researchers.

II. Review Methodology

2.1 Evolution of Generative Artificial Intelligence in Engineering Education

The applications of AI in education have been gradually being introduced over the last 30 years, starting with the use of intelligent tutoring systems, adaptive learning systems, and eventually, complex deep learning models that can produce human-like content. The major use cases of early education AI applications were automation of grade assignment, personalized feedback, adaptive learning, and student performance prediction via educational data mining and learning analytics. These systems were successful in boosting the efficiency of instruction, but were largely predictive and rule-based. Generative Artificial Intelligence (GenAI) is a paradigm shift from analytical AI to a paradigm of content-creating systems capable of generating text, computer programs, images, simulations and educational resources using natural language interaction. The shift has significantly enhanced the way AI is integrated into engineering education, offering students a more engaging and interactive learning experience compared to traditional educational technologies.

In November 2022, OpenAI's Chat GPT was launched to the public, ushering in a new era for higher education. In a matter of months, universities around the globe started using generative AI in teaching and learning, assessment, curriculum development, and academic assistance. Unlike conventional search engines, large language models (LLMs) will be able to produce contextualized responses, drawing upon knowledge acquired in their massive pre-training. With this ability, students can pose further questions, get step-by-step explanations, write source code, break down technical concepts, and get help for learning customized to their needs on the spot. Due to its heavy reliance on programming, mathematics, problem-solving, technical writing, and design thinking, engineering education is one of the first fields to experience such a broad proliferation of generative AI adoption.

Lo [1] has done one of the first systematic reviews that focused on analyzing fifty publications that were published within the first few months of the model's release and investigated educational implications. The study findings revealed that ChatGPT can help teachers to create teaching materials, develop questions for assessment, and aid in curriculum design, and it can also serve as a virtual tutor to answer students' questions and help them learn collaboratively.

The review also revealed a number of key shortcomings, such as inaccurate answers, fabricated references, hallucinations, and the fact that traditional plagiarism detection tools are not very effective at detecting AI-generated content. The author made a case for a change in the assessment paradigm within the educational system, for the updating of institutional policies, and for the enhancement of the knowledge and understanding of artificial intelligence for students and teachers.

Similar trends were noted in general educational studies. The ability of LLMs to deliver personalized, scalable support and to alleviate repetitive teaching tasks has been suggested by Kasneci et al. [2] as the potential for LLM systems to revolutionize teaching and learning. They found that rather than being just a tool for automation, AI should be seen as an educational partner that could improve student engagement, personalization, and formative assessment. The authors, however, reiterated that responsible governance, ongoing human oversight, and transparent institutional policies must be in place for the effective implementation as current language models still have factual inaccuracies, biases, and limited reasoning abilities.

Engineering and computer science education are groundbreaking examples of the widespread adoption of generative AI. Large language models are well-suited for programming courses, software engineering labs, and algorithm design classes, where their ability to generate code, provide programming concepts, point out syntax mistakes, and offer ideas for optimization would prove valuable. To explore the educational implications of ChatGPT in university-level computer science education, Malinka et al. [3] investigated several scenarios in which ChatGPT was able to successfully complete technical reports, programming tasks, and exams. While the study draws attention to the dangers of AI in academic dishonesty, it also found that using generative AI as an intelligent learning assistant, instead of a replacement for independent problem solving, has the potential to greatly enhance understanding of concepts.

In a similar vein, engineering educators have also seen the potential of generative AI to support active learning and problem solving with peers. According to Gill et al. [4,5] ChatGPT is a revolutionary technology for education that can create teaching material, facilitate virtual tutoring, assist with collaborative learning and enhance student engagement in engineering fields. They also found that AI-generated explanations can help to mitigate cognitive load when dealing with complex technical concepts by providing simplified explanations tailored to the specific needs of each learner.

The authors noted, however, that there are significant challenges in engineering education, especially for students who report hallucinated responses or factually incorrect answers: "Precision and correctness are key goals in engineering education, however, and remain major obstacles. Thus, they suggested the need to modify institutional policies, evaluation systems and faculty development initiatives prior to a large-scale adoption.

New educational studies also have been highlighting the disparity between generative AI and other tools used in the past to help with education, as generative AI is fundamentally about conversational learning as opposed to the retrieval of information. Large language models can adapt their explanations based on learner questions, previous interactions, and context, rather than just providing content that has been pre-defined. Furthermore, this conversational capability allows for personalized instruction, ongoing formative feedback, automated assessment support and intelligent academic support, to name a few, going beyond the scope of conventional intelligent tutoring systems as observed by Tzirides et al. [5]. Further, their work indicated that the future of education could be increasingly multimodal and generative AI that can process text, images, code, audio, and engineering diagrams, can now generate richer learning experiences.

Another major change is the role shifts of the teacher. Traditionally, teachers were seen as the main holders of knowledge to share while today's AI-enhanced learning environments place teachers as facilitators who help students discern information generated by AI. The literature of today places greater emphasis on the transition from delivery to mentoring, ethical supervision, guidance on projects, and the development of higher order cognitive skills in the role of the engineering faculty. Generative AI is seen more as an assistive technology that augments teachers' classwork, rather than a technology that can replace them, by freeing them up to focus more on conceptual conversations and hands-on learning.

The development of generative AI has also contributed to the advancement of interdisciplinary research in education. Recent studies move beyond the performance of the chatbot to investigate pedagogical effectiveness, students' acceptance, AI literacy, curriculum integration, ethical governance, assessment redesign, and institutional readiness, among other things, while initial investigations prioritized the performance of the chatbot. The sequence reflects a shift from technology-based research to learner-centered, policy-based research.

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In recent years, researchers have recognized that the success of generative AI in education is not just about the technology; it is also about responsible governance, teacher readiness, curriculum transformation, and cultivating students' critical thinking.

Our review of the literature shows that the use of generative AI has advanced beyond being just a conversational tool and is now a complete education system that can be used to assist teaching, learning, assessment, programming education, technical communication, and academic administration. While the transformative impact is well recognised, there is also strong evidence that schools need to be mindful of the implementation of innovation. The development of generative AI is therefore not only a technological advancement, but a pedagogical shift that needs to be coordinated across all stakeholders: researchers, educators, policy makers, and software developers, to ensure its sustainable use in engineering education.

This section focuses on the opportunities of the Generative Artificial Intelligence in engineering education. The accelerating advancement of Generative Artificial Intelligence (GenAI) has greatly broadened the potential of educational technologies, especially in engineering education. While the first-generation intelligent tutoring systems were mainly used to present ready-made educational material, current large language models (LLMs) can provide explanations, answer engineering questions, generate computer programs, summarize scientific research and have interactive dialogues with students. Such capacities have opened up new learning opportunities that are not in the traditional e-learning context. The recent publications consistently show how generative AI can increase the efficiency of learning, help focus learning on the individual, assist in programming education, aid engineering design tasks, alleviate teaching burden, and make education more accessible. But these opportunities come when AI is not used as a substitute for independent thinking or work, but as a learning assistant.

2.2 Opportunities of Generative Artificial Intelligence in Engineering Education

Personalized learning experiences is one of the most well-known benefits of generative AI. Students in engineering classrooms have varying backgrounds of knowledge, learning speeds, and academic styles. Typical teaching styles offer the same content to all learners, with little opportunity for personalised support. Generative AI can overcome this by generating specific explanations based on students' queries, past interactions, and understanding.

By engaging in a dialogue with ChatGPT, students can get immediate feedback on concepts they can't master, which can help them learn at their own pace and avoid relying too heavily on attendance at class. The interaction between students and ChatGPT can facilitate self-paced learning by providing immediate information on challenging concepts; this can reduce students' reliance on the availability of the teacher. Likewise, Tilili et al. [8] proposed that LLMs could serve as virtual tutors that can provide personalized explanations based on student needs, but still keep them engaged with the learning process. The research indicated that AI-driven educational assistants could play a crucial role in addressing educational disparities by providing students with access to high-quality academic assistance, even in resource-poor settings.

2.2.1 Personalized Learning and Adaptive Instruction

One of the most widely recognized advantages of generative AI is its ability to provide personalized learning experiences. Engineering classrooms often include students with diverse academic backgrounds, learning speeds, and prior knowledge. Traditional teaching methods generally provide identical instructional material to all learners, limiting opportunities for individualized support. Generative AI addresses this limitation by producing customized explanations according to students' questions, previous interactions, and knowledge levels.

Generative AI's adaptability is especially useful in engineering, where students often need multiple explanations to understand mathematical calculations, algorithms, circuit analysis, or coding logic. Instead of using the textbook definitions, the AI system generates similar examples, analogies and simplified explanations, which is beneficial for conceptual understanding and learner confidence

2.2.2 Intelligent Tutoring and Immediate Feedback

It has long been known that immediate feedback, or feedback that is immediate to the learning, is one of the most powerful ways to enhance student learning. Numerical problems, writing of computer programs and understanding of laboratory procedure is a common problem among engineering students. Too long a delay in feedback from instructors can disrupt learning and decrease student motivation.

Generative AI resolves this issue by offering immediate responses to learners' questions. Rather than having to wait to attend class or the instructor's office hours, students get advice right away about what they have misunderstood, about the mistakes they made in coding, about engineering calculations, and about how to prepare the report.

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Large language models can engage in conversation, enabling students to have multiple exchanges until they grasp the concept.

New research shows that AI tutors can boost student participation as students are more likely to seek repetition from AI than from humans, who may consider such questions "basic". Recent research suggests that AI tutors have the ability to drive higher student engagement by enabling students to ask repetitive or "basic" questions to the AI tutor that they would not ask a human tutor. This lessening of social anxiety enables active learning and ongoing knowledge building. In addition, AI-driven formative feedback helps students overcome errors before formal assessment, which enhances learning outcomes and minimizes academic frustration.

2.2.3 Programming Education and Software Development

One of the most widely studied application areas of generative AI is programming education. Programming concepts are explained, source code is generated, syntax errors are debugged, algorithms are optimized, and software documentation is understood using ChatGPT, GitHub Copilot, and other code generation systems, which are gaining popularity among computer science and engineering students.

Bringula [9] explored the potential of ChatGPT in programming education and found that the students were satisfied with the system as a programming assistant that could enhance their understanding of programming concepts and make debugging easier. While students valued AI's ability to quickly produce code, the research highlighted the value of encouraging students to reflect on AI's outputs instead of simply copying them.

Sun et al. [10] also showed that the use of ChatGPT in programming positively affected students' programming behaviour, learning performance, and confidence in learning programming in the introductory programming course. They conducted an empirical study that showed that the students who got the support of AI for programming guidance were more engaged and understood the code better than those who did not receive any such support. The authors noted that while AI can aid in programming education, it is important not to use it to replace algorithmic thinking or problem-solving exercises.

Similarly, Ahmed et al. [11] developed an intelligence assistant that utilizes ChatGPT to assist students in introductory programming courses and found that students and instructors agreed that AI was useful for explaining programming concepts, creating examples, and offering prompt help during lab sessions. However, issues with wrong code generation and too much dependency on the learner were still relevant.

2.2.4 Engineering Design and Technical Communication

Programming is not the only aspect of engineering education, it also encompasses design thinking, innovation, technical communication, and documentation. In these areas, Generative AI can offer a lot of support for students, such as brainstorming engineering solutions, creating project proposals, generating design alternatives, summarizing engineering standards, and drafting technical reports.

The literature indicates that with the use of AI generated brainstorming, the conceptual design phase is more creative since it presents several solution alternatives in a short time. Students can then analyse these options with engineering principles to make better decisions and limit the amount of time spent exploring options in the initial design phase. Professors also get assistance from AI in creating teaching tools, lab manuals, project descriptions, quizzes and case studies. The digitization of repetitive documentation tasks allows for instructors to focus more time on mentoring, innovation in the curriculum, and research. This change helps to enhance the quality of education as well as reducing administrative workload.

2.2.5 Accessibility, Multilingual Learning, and Inclusive Education

One of the most significant impacts of generative AI is enhancing access to education. As the number of students from various cultural, language, and socioeconomic backgrounds has continued to rise, engineering institutions are seeing an increasing diversity of their students. There is a lack of understanding of complex engineering concepts because of language barriers, especially for first generation university students and international learners.

Generative AI can solve these problems by translating technical jargon, breaking down academic jargon, providing explanations in multiple languages, and customizing teaching material based on the level of the learner. Thus, students can learn the same engineering concepts in different ways, depending on their language proficiency. UNESCO highlighted that generative AI has great potential for inclusive education, both in terms of addressing educational inequalities and supporting learners with varying educational needs. Together, these technologies support lifelong learning and equitable learning environments, thanks to AI-assisted translation, speech generation and personalized tutoring. At the same time, UNESCO emphasizes the importance of responsible governance, transparency, and ethical protection in implementing inclusive AI.

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2.2.6 Faculty Productivity and Curriculum Development

Academic practice from the instructor's side has also changed with the advent of generative AI. AI systems have become a tool for faculty members to create lecture notes, develop learning goals, craft assessment questions, design laboratory exercises, summarize research articles, and generate teaching presentations.AI systems are being used to prepare lecture notes, develop learning goals, craft assessment questions, design laboratory exercises, summarize research articles, and generate teaching presentations.

New research indicates that AI can significantly save educators time with repetitive tasks in the classroom, allowing them to dedicate more time to research supervision, curriculum development, mentorship, and student engagement. Moreover, AI-driven curriculum development can enable the quick adaptation of new technologies into engineering curricula, enhancing the relevance of the curriculum in the fast-changing industrial landscape.

But some scholars believe that education value is dependent on human supervision. AI-generated instructional materials must be carefully validated for technical correctness, pedagogical appropriateness and alignment with course learning outcomes. In light of these advancements, faculty knowledge will continue to be invaluable even with the rise of AI powers.

Critical Analysis

The literature and experiences clearly show that the use of generative AI in engineering education provides significant potential for delivering personalized learning, intelligent tutoring, engineering design assistance, enhanced faculty productivity, programming assistance, and multilingual learning. The vast majority of empirical research findings indicate positve student perceptions, enhanced engagement and higher learning efficiency. However, the research reviewed also highlights the importance of the responsible application, the students' AI literacy, the supervision of the application of artificial intelligence in education, and the design of the assessment. It can be concluded from the current evidence that generative AI is not an educational replacement, but rather an intelligent learning assistant that can be used in a human-in-the-loop educational model. Future research should shift from the perception-based studies to longitudinal research that tracks real-world improvements in engineering skills, critical thinking, creativity, and career readiness of graduates.

2.3 Challenges and Limitations of Generative Artificial Intelligence in Engineering Education

While generative artificial intelligence (GenAI) shows great promise for the future of engineering education, it has also raised a number of pedagogical, technological, ethical and institutional challenges. As we addressed in the previous issue, these obstacles are not limited to the technical capabilities of large language models (LLMs) but are also broader concerns about academic integrity, cognitive growth, assessment, algorithmic bias, privacy, faculty readiness, and institutional governance. The adoption of generative AI in engineering education is not just about technology; it relies on the availability of holistic tools for education policy and implementation frameworks that guide the responsible use of this powerful technology.

2.3.1 Reliability and Hallucination of AI-Generated Content

AI hallucination is one of the most talked-about challenges with generative AI, where LLMs generate false, made-up, or misleading information with a high degree of confidence. LLMs also create answers by making predictions based on statistical patterns of probable word sequences instead of building on accurate knowledge bases, which means they can sometimes make up references, mathematical equations, programming syntax, engineering equations, and scientific explanations. In engineering education, this kind of inaccuracies has serious implications as technical fields involve a great degree of precision and correctness.

While ChatGPT is a powerful tool for providing explanations of engineering concepts and programming problems, as noted by Sallam [12] students may not have the necessary domain expertise to identify the correct answers from erroneous ones. As such, false information provided by AI-generated explanations can further the false understanding rather than aiding in learning. Baidoo-Anu et al. [13] also noted that the use of generative AI is not a substitute for a definitive source of technical knowledge but rather a support tool for the cognitive process that needs constant verification by humans. They also pointed out that the use of hallucinated outputs becomes more of an issue in engineering fields such as structural analysis, control systems, electronics, software engineering, and others, where small errors can have a significant impact on the engineering solutions.

Another restriction is related to the non-simultaneity of AI responses. Several studies have shown that the same cues can yield varying responses in subsequent interactions or software versions.

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This variability decreases re-producibility and makes it challenging to create AI-assisted learning activities across different courses. Possibility of inconsistent AI responses, a problem that needs further research due to the focus of engineering education on repeatability, reproducibility, and evidence-based problem solving.

2.3.2 Academic Integrity and Assessment Challenges

The rise of generative AI has changed the way academic assessment is done. AI systems are becoming widespread for engineering students creating programming tasks, lab reports, design documents, literature reviews, and technical papers. AI-powered learning is an effective tool for conceptual understanding when applied responsibly, but it is also a potential for plagiarism, authorship, originality issues and academic dishonesty.

However, recent research suggests that traditional plagiarism detection tools are not very good at catching AI-generated content because AI models produce original, not copied, texts. As a result, worldwide, Universities are revisiting their assessment methods that are predominantly based on unsupervised take home assignments.

Deng & Joshi [14] also proposed that the educational institutions should shift from ban to reimagining assessment responsibly with AI. Instead of trying to ban the use of AI, universities should develop transparent disclosure policies to support responsible and ethical use of AI in academic settings, maintaining the integrity of educational practices. This is a new definition that captures a growing consensus that instead of censorship, it is possible to foster AI literacy and ethical understanding.

2.3.3 Overdependence and Reduced Critical Thinking

A related issue highlighted in the literature is the reliance on AI-generated solutions by students. Engineering education is about the ability to think in a way that is analytical, computational, mathematical modelling, creative and systematic in solving problems. As students can get answers instantly from generative AI, they may be less inclined to try to solve problems on their own. When answers are provided instantly, students may be less likely to attempt solving problems independently.

While several empirical studies indicate that AI can enhance short-term productivity, there is a potential downside to knowledge retention and critical thinking in the long term. Often, students will take an AI-provided explanation without engaging in self-verification of correctness, which reduces the chances for conceptual understanding and reflective learning. This behavior will eventually undermine the engineering judgment, which is an important engineering skill.

It's important to remember that generative AI is not about replacing cognition; it's about supplementing it," Williams said [15]. The author contended that students need to learn how to critically assess AI-generated content rather than accepting it blindly as part of engineering education. Likewise, Tang and Su [16] proposed incorporating AI literacy and ethical considerations into engineering curricula to equip graduates with the skills to recognize inaccuracies, bias, and unsupported conclusions produced by AI systems.

2.3.4 Faculty Readiness and Institutional Barriers

Faculty readiness and institutional readiness play a crucial role in the effectiveness of generative AI integration. While a number of teachers understand how teaching and learning can benefit from AI support, many instructors are unsure about prompt engineering, AI-supported pedagogy, assessment rethinking and ethical supervision. Many higher education institutions have not been able to keep up with the rapid advancement of AI, and have not established faculty training programs that can meet the pace.

Educator competence is not the only issue related to institutional challenges. Universities are tasked with related cybersecurity concerns, software licensing issues, availability of infrastructure, digital inequality, policy creation, protection of intellectual property and assurance of quality. McDonald et al. discovered that although many universities were supportive of productive uses of AI, institutional guidance on such uses was highly variable, especially within STEM fields. The policies often focus on academic honesty and transparency and offer little practical guidance in the engineering context, for example, in programming labs, design projects, and code generation.

2.3.5 Technical Limitations and Domain-Specific Constraints

While the remarkable advancements have been made, the present state of generative AI models still presents some technical issues that hinder the model's educational reliability. Large language models (LLMs) exhibit weaknesses in complex numerical reasoning, multi-step engineering calculations, higher-level symbolic mathematics, and domain expertise. Responses can be grammatically correct but have minor computational errors that can be missed by less experienced learners.

The engineering fields often demand adherence to standards, design specifications, safety requirements, and scientific facts. No current AI systems have built-in mechanisms for self-evaluation of generated engineering solutions against the professional standard.

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Researchers have repeatedly emphasized the need for human supervision in AI-assisted engineering, as this can help identify errors and provide a better grasp of the process. Human supervision is consistently called for in AI-assisted engineering processes because it can help identify errors and better understand the process. A second technical challenge is that of knowledge currency. Commercial language models typically use training data that have knowledge cut-off dates, meaning that the updated engineering standards, industrial regulations, software libraries, or research results may never be included in the model if it doesn't have access to external retrieval systems. This restriction is especially relevant in fast-changing areas of engineering like artificial intelligence, cybersecurity, renewable energy and semiconductor technologies.

Critical Analysis

This literature review highlights the pedagogical, ethical, and institutional challenges and constraints of generative AI. Responsible usage of AI in engineering education faces the main challenges including hallucinated information, lack of critical thinking, integrity of assessment, inconsistent outputs, and lack of institutional preparedness. However, the body of literature is increasingly unanimous that such restriction is not a valid argument to turn down generative AI. Rather, they highlight the need for the integration of AI that is people-focused, in which teachers continue to verify information produced by AI, modify genuine assessments, educate about AI literacy, and ensure ethical academic practices. Educational benefit and risk assessment to determine the most effective evidence-based instructional models should be a priority for future research..

III. Conclusion

Generative Artificial Intelligence (GenAI) has become a game-changer in the field of engineering education, changing the way engineering education is taught, learned, assessed, and developed. The purpose of this systematic literature review was to gain a comprehensive understanding of opportunities, challenges, ethical concerns and future prospects of the use of GenAI in engineering education in the last three years (2023–2026). The literature reviewed repeatedly shows that AI technologies like ChatGPT and other large language models have the potential to be a game-changer for personalized learning, intelligent tutoring, programming support, technical communication, assessment support, multilingual education, and faculty productivity.

One of the best things about GenAI is its capacity to offer students with diverse educational backgrounds immediate, context-aware and adaptive learning support. Personal explanations, problem solving, feedback, and intelligent programming support help individual students learn independently, and enhances engagement and learning efficiency. In a similar way, teachers can use AI tools to prepare teaching materials, create questions for assessments, design lab activities, and develop curriculum, thus freeing up more time for mentoring, research supervision, and innovating pedagogies.

Notwithstanding all these exciting possibilities, there are also a number of key issues raised in the literature that must be addressed with great care before the widespread institutional adoption of these opportunities. Big challenges like hallucinated information, incorrect technical answers, academic integrity issues, plagiarism, algorithm bias, privacy, inconsistent outputs, and too much AI-generated content remain. Precision, analytical thinking, and decision making based on evidence are integral to the engineering education, and without the proper verification, the use of AI can have a negative impact on students' critical thinking and professional capabilities. The results indicate that traditional learning methods are unlikely to be superseded by generative AI, but rather serve as an intelligent learning assistant that should be continually monitored by humans.

Thus, this review confirms that the successful integration of GenAI requires technological progress but also institutional readiness. For sustainable implementation, the following are vital elements of faculty training, AI literacy of students, redesigning the curriculum, transparent academic policies, ethical governance, and responsible assessment strategies. It is important that universities create more comprehensive guidelines that foster responsible AI use, academic integrity and independent learning. Educational institutions should emphasize the critical evaluation and responsible use of AI-generated information in engineering practice, not ban the use of the technology.

Review suggests that carefully and ethically leveraging Generative Artificial Intelligence can be beneficial for modernizing engineering education. It will be most useful in complementing rather than supplanting human intelligence. With the appropriate governance framework, ongoing monitoring, and ethical educational practices, engineering institutions can harness the potential of AI while mitigating risks. However, the continual development and growth of GenAI technologies will necessitate the continued collaboration of educators, researchers, and in the future, policymakers, software developers, and industry to ensure that future engineering students hold not only strong technical competence in these technologies, but also responsible AI literacy.

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IV. Future Research Directions

The application of Generative Artificial Intelligence in engineering education has grown tremendously in the past few years, but there are several key areas of research that have not been addressed. Most of the existing research focuses on the students' perception, satisfaction, and immediate learning results of AI-supported learning, while there is still limited research on how AI-supported learning affects student engineering knowledge, critical thinking, creativity, innovation, and professional skills in the long term. Long-term studies are therefore required to determine the effect of the continued use of generative AI on students' problem-solving skills and job readiness.

Future research should also be directed towards developing engineering specific large language models based on domain knowledge, engineering standards, lab protocols, engineering design principles, and industrial engineering regulations. AI systems specifically designed to handle engineering-related tasks might offer greater precision and trustworthiness than more generic conversational AI, minimizing hallucinations and enhancing the reliability of educational content in the field.

The other promising path is the combination of generative AI with new and emerging education tools like Internet of Things (IoT) learning environments, simulated environments, robotics, virtual labs, and augmented reality. These multimodal learning systems could enable highly interactive and experiential learning that would be much like that of engineering practice. The combination of conversational AI with engineering simulations may significantly enhance laboratory education, design thinking, and collaborative project-based learning.

Research is also needed for assessment methodologies. Future research should focus on AI-friendly assessment tools that measure higher-order thinking skills, engineering design, team collaboration, creativity, ethical considerations, and real-world problem-solving, but not just factual knowledge. Project-based learning, oral exams, design challenges, reflective portfolios, and industry-relevant case studies are all forms of authentic assessment that might be increasingly vital in educational settings with AI.

Ethical governance will be a key topic of research. More research is required to develop comprehensive institutional policies to tackle issues of transparency, accountability, data privacy, intellectual property, algorithmic fairness, bias mitigation, and responsible use of AI in higher education. The study of the regulatory systems implemented in universities from various countries can offer useful insights to guide the design of a uniform governance model for engineering universities.

The ability of faculty to be ready and AI-literate should also be explored further. Going forward, it is advisable to identify effective ways to make AI tools a part of teaching without compromising academic integrity and pedagogical quality by designing professional development strategies for educators. Similarly, AI literacy courses should be structured to enable students to critically assess AI-generated information, identify misinformation, check technical correctness, and utilize AI responsibly in their learning and work lives.

Lastly, interdisciplinary collaboration will be crucial for meeting the educational potential of generative AI – in fact, it will be necessary. This is a type of collaborative research that could help to create a framework for education that is both evidence-based and ethical, as well as technologically innovative. Generative AI is still evolving and future research needs to focus on human-centered educational models, where AI enhances, not replaces, human knowledge and skills, and where AI will play an integral part in a more inclusive, effective, and sustainable engineering education ecosystem.

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