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Artificial Intelligence's Opportunities and Challenges in Engineering Curricular Design: A Combined Review and Focus Group Study

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Abstract: This study explores the opportunities and challenges of integrating artificial intelligence (AI) into engineering education. Through a review of the literature and a qualitative focus group study, an assessment was made for the role of AI in personalizing learning, enhancing simulation engagement, providing real-time feedback, and preparing students for AI-integrated workplaces. The study emphasizes how AI may significantly improve educational experiences by making them more dynamic, interactive, and successful. It also draws attention to important issues, such as moral questions, algorithmic biases in AI, infrastructure constraints, the need for AI literacy training for educators, and a range of student perspectives on AI engineering education. The results support a systematic approach to AI integration, highlighting the necessity of cooperative efforts by educators, legislators, curriculum designers, and technologists in order to overcome these obstacles. The study makes the case that AI can transform engineering education by negotiating these challenges and providing students with the information and skills needed for the digital future, all the while assuring fair and moral access to technology-enhanced learning.

Keywords: artificial intelligence; curricular design; engineering; education; technology

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1. Introduction

We are becoming more and more technologically interconnected, and artificial intelligence (AI) and related technologies are playing a significant role in the digital economy [1]. They are critical to the digital economy and have the power to fundamentally change a number of facets of our lives, including education, as our technological connections make us more interconnected than ever. AI has the power to drastically alter our lives and the way we work, learn, travel, and communicate in the future [1]. As we explore more about AI, it becomes evident that this continuous development in AI will change the way engineering is taught in a significant manner. Digitalization will influence every aspect of society as the use of new technologies, such AI and the Internet of Things, is predicted to rise [2]. It will also have an impact on engineering disciplines [2]. AI encompasses a broad spectrum of digital technologies that can effectively process information to help humans with various tasks [3]. Over the past few decades, there has been a major evolution in the integration of AI into education, moving from simple automated systems to complex tools that can improve a variety of educational processes. AI-powered engineering applications can tackle complicated engineering challenges and work with unclear design parameters, which are not achievable with conventional design techniques [4]. In other words, AI continuously learns and develops on its own, whereas traditional software never changes unless humans update it [3]. Transitioning from the general impact of AI, we see its intense influence in the educational sector. AI tools have revolutionized education, bringing about a significant change in the way that learning environments are improved, innovation is generated, and students are prepared for the challenges of the digital age [5]. The potential of AI-driven platforms, such as ChatGPT chatbots, to revolutionize educational methods

and results has garnered a lot of attention [5]. Moreover, research and education are just two of the fields that AI has completely transformed [6]. Large language models like GPT-4 and BARD, along with natural language processing techniques, have greatly improved our understanding and use of AI in these domains [6]. This brings us to a critical turning point: this development emphasizes how much change educational systems must undergo in order to integrate AI and provide more personalized, inventive, and interactive learning environments [5]. However, the integration of AI is not without its challenges. The gradual incorporation of AI into curricula raises a number of ethical concerns, calls for a thorough redesign of the curriculum, and requires the adoption of continuous learning techniques to guarantee compliance with changing industry standards [5]. Thus, AI offers both unique chances and significant challenges for designing curricula. In the context of educational institutions, when AI is used in educational institutions, it makes learning more personalized, keeps students more interested, and makes it easier to efficiently grade students. However, in order to reach this goal, we need to carefully handle a wide range of issues related to ethics, resource sharing, and changes in the manner in which we teach. Acknowledging the complexity of this integration, the rapid growth of AI integration in engineering education signals a paradigm-shifting period. According to Memarian and Doleck (2023), the application of AI is surging in education. AI is becoming more and more prevalent in areas that may need some automation and (induced) logic, such as student admissions and recruitment, adaptive learning, and assessment [7].

This paper aims to navigate through this evolving landscape by examining the growing amount of research on AI's role in engineering curriculum creation. It examines a number of studies in an attempt to provide a sense of the complicated effects AI has on education. Focusing specifically on engineering education, by looking at how AI is currently used in engineering education and listing the opportunities and challenges that come with it, we find promising applications. Using AI in civil engineering courses, for example, has shown promise in greatly improving students' actual skills by giving them a deeper understanding of project construction and the use of professional mechanical equipment in the classroom [8]. Additionally, engineering students' attitudes concerning their final year projects and the prerequisite courses were strongly linked to how successfully they performed in school [9]. This suggests that having positive thoughts about AI-enabled lessons can lead to better results in education.

The pathway to integrating AI into the engineering curriculum is not simple and includes several obstacles and gaps to cover. Concerns about bias and the digital gap, along with other social issues related to AI, make it challenging to know how to employ AI fairly in schools [10]. Other problems that need to be addressed are the need for an array of tools and for teachers to get more training on how to use AI tools effectively in educational settings [11]. In light of these challenges, this paper contributes to the growing discussions about how AI is changing education, especially in engineering, where employers need graduates who are not only technically skilled but also competent to work with AI systems that are becoming more intelligent constantly. This study aims to investigate AI's transformational potential in engineering education. The engineering field's nature requires the ability to think critically and solve complicated problems. AI can improve these educational experiences by offering individualized learning settings, enabling real-time feedback, and equipping students for the AI-integrated workplaces of the future, the incorporation of AI can improve these educational experiences. AI-driven personalized learning platforms, as well as the use of AI for formative assessment and real-time feedback, are examples of current trends in AI integration in education. In order to equip students for the appropriate use of AI technology, there is an increasing emphasis on incorporating AI ethics into curricula. The final objective is to provide an outline of current opportunities, challenges, and recommendations for effective integration so that it gives educators, lawmakers, and curriculum creators useful information about how to implement AI effectively in engineering classes.

2. Methodology

In order to obtain a wide range of viewpoints on AI in engineering education, this study combined a thorough literature review with a qualitative focus group study. This mixed-methods approach allowed researchers to investigate the integration of AI into engineering education. Figure 1 illustrates the methodological process of this study.

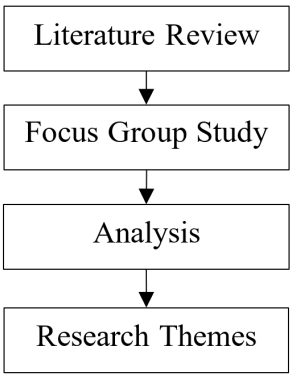

Figure 1. The methodological research process.

2.1. Literature Review

The initial phase involved a systematic review of the literature. Several electronic databases, such as the Saudi Digital Library and Google Scholar, were used for this study to find research material that was directly connected to the topic of the paper. AI, education, curriculum design, engineering, students, and "challenges and opportunities" were some of the keywords that were used. The studies were considered if they met the following criteria: (1) they were published in peer-reviewed journals or conference proceedings; (2) they looked at how AI could be used to improve engineering curriculum design; (3) they discussed the opportunities and challenges of using AI in education; and (4) they were written in English. Articles that were not peer-reviewed, studies that were not directly linked to AI's role in designing engineering curricula, and articles that were not available in full text were all ruled out. A significant number of records came up in the initial search—about 90 references. They were sorted by title and abstracts to determine how relevant they were to the study questions. Then, the full texts of studies that might have been useful were found and read carefully. The assessment of the quality of the studies included the research goals' clarity, the data analysis method's usefulness, and the results' usefulness. The final number of papers used in this research was 41 references.

2.2. Focus Group Study

In order to obtain comprehensive insights into the complex and diverse experiences, opinions, and attitudes of stakeholders concerning the incorporation of AI in engineering education, a qualitative focus group was chosen as a method of data collection for this study. Open-ended discussions during qualitative focus groups can reveal rich, comprehensive information that may not be revealed by quantitative approaches alone, making them perfect for exploratory studies. Focus groups facilitate dialogue, fostering consensus and understanding among participants, thereby aiding in the research of stakeholder perceptions and experiences. It was carried out after the literature analysis to obtain qualitative insights from a wide range of stakeholders who are directly involved in engineering education. This stage sought to investigate in-depth opinions regarding the possible advantages, difficulties, and moral implications of integrating AI into the curriculum.

2.3. Participant Selection

To reflect a wide range of viewpoints and experiences on the subject of engineering education, eight individuals were chosen. Professional experience in engineering education or curriculum design, familiarity with AI technology, and a readiness to participate in

in-depth conversations regarding the incorporation of AI into teaching practices were among the selection criteria. Table 1 illustrates the demographics of the eight participants.

Table 1. Participant demographics.

Participant Code	Educational Qualification	Specialty	Years of Experience	Administrative Roles
1	PhD	Mechanical Engineering	16	Member of various committees
2	Undergraduate student	Civil Engineering	None	None
3	Undergraduate student	Civil Engineering	None	None
4	PhD	Industrial Engineering	23	Member of various committees
5	PhD	Civil Engineering	27	Member of various committees
6	PhD	Industrial Engineering	14	Vice-dean
7	PhD	Architecture	15	Head of department
8	PhD	Civil Engineering	32	Member of various committees

2.4. Data Collection

Ensuring accessibility for all participants, the focus group was held using a virtual meeting platform during March 2024, which included all participants. Questions aimed at collecting in-depth responses on experiences with AI in education, perceived advantages and difficulties of AI integration, ethical considerations, and recommendations for efficiently utilizing AI technologies in engineering curricula were used to guide a semi-structured interview format.

2.5. Data Analysis

The focus group data were analyzed using thematic analysis, which included transcriptions of the discussions, response coding, and theme identification. With an emphasis on transformative potential, personalization and engagement, obstacles and barriers, ethical considerations, and recommendations for successful integration, this qualitative investigation sought to identify significant trends surrounding the integration of AI in engineering education.

2.6. Integration of Findings

The results of the focus group study and the literature analysis were combined to create a thorough picture of the state, difficulties, and potential future directions of AI in engineering education. By fusing in-depth, qualitative viewpoints from practitioners in the area with evidence-based ideas from published research, this mixed-methods approach enhanced the study's conclusions.

2.7. Study Validity and Reliability

The study used a systematic literature review and a focus group study to establish a theoretical foundation for AI in engineering education. The review used electronic databases and clear inclusion and exclusion criteria to select studies. The focus group used a semi-structured interview format with open-ended questions to elicit in-depth responses. Ethical considerations were addressed through transparency and participant consent. The study acknowledged limitations due to sample size, demographic characteristics, and its context-specific nature, but aimed to maximize the validity and reliability of its findings.

3. Opportunities Presented by AI in Curricular Design

AI can be used to improve many areas of education, especially in engineering fields, by being built into curricula. At the forefront of educational innovation is AI, which can perform previously unattainable tasks like customizing lessons to each student's needs, analyzing data in real time, and offering perceptive viewpoints on current market trends and sustainability issues [5]. The integration of AI into curriculum design not

only improves the educational programs' efficacy and relevance, but also guarantees that students possess the necessary knowledge and abilities to tackle the complex sustainability challenges prevalent in the industry 4.0 terrain [5]. One practical way to incorporate AI into engineering education is to introduce a small part of the technology into already-existing courses [12]. AI can be included into already-taught courses to educate students about a variety of numerical techniques, such as statistical or numerical methods [12]. The teaching of AI components should be led by faculty members with experience in programming and applications, taking into account their expertise [12]. This section discusses the main research opportunities and provides evidence in the form of findings from more recent studies. Table 2 at the end of this section presents the major findings about opportunities presented by AI in curricular design.

3.1. Personalized Learning Environments

Personalized learning is an instructional strategy that adapts to each student's particular requirements, interests, and ability level. AI's ability to analyze massive quantities of data makes it possible to create personalized educational environments that change based on each student's needs [1,7]. Educators can improve learning outcomes and student engagement by identifying areas of struggle for their students and providing targeted interventions by utilizing AI's data-driven insights [6,7]. For example, AI can change the level of difficulty of tasks based on how well students do on them, which lets them learn at their own pace [8]. This personalization includes finding out where students are falling short in their learning and giving them the right resources to help them improve [13]. Furthermore, AI performance prediction models are frequently used to create student-centered learning pathways, pinpoint high-risk students who have a history of failing, and enhance instructional design and development [14]. Since each student is different, AI helps teachers by pointing out crucial elements of effective learning that might not be seen otherwise. A personalized learning environment can change content and learning variables and give individualized feedback by looking at real-time student performance data [15]. Immersion case studies, similar to those used in engineering ethics guidance, greatly improve the capacity to customize individualized learning experiences [16]. Teachers support a shift from theoretical to immersive case studies based on factual or current data and set in real or realistic contexts [16]. In addition to increasing student engagement, these immersive experiences encourage in-depth thought on the ethical issues that are prevalent in modern engineering practices [16]. Inspired by the findings of Martin et al. (2021), this method argues that incorporating AI-powered, interactive case studies into engineering courses increases student engagement and fosters a deep comprehension of complex engineering problems. This approach emphasizes the transformative potential of personalized learning environments in engineering education by preparing students for a range of complex challenges they may encounter in their professional careers. This type of education not only democratizes learning but also ties in with the dynamic needs of the engineering industry, where flexibility and lifelong learning are critical [7]. AI tools that personalize content delivery are an example of this kind of cooperation; they reduce learning time and discourage studying for exams at the last minute [17]. AI agents also enable question-answering services, offering prompt support even outside of regular school hours [17].

3.2. Enhanced Engagement through Simulation

Simulations that are powered by AI have been shown to get students much more interested and motivated. ChatGPT and other AI technologies have the potential to revolutionize a range of tasks, including ideation, business model creation, plan writing, and customer interviews [3]. Furthermore, simulations powered by AI can create realistic, interactive situations where students can use what they have learned in a virtual setting, connecting theory and practice [18]. Over 20,000 students took part in a study that looked into the design of AI-driven interfaces for Intelligent Tutoring Systems (ITSs). The results showed that the AI-enhanced interfaces made students much more interested in learning,

with improvements of up to 25.13% [19]. This finding emphasizes how important AI is for improving student engagement and motivation in educational environments [19]. AI's ability to get students more interested in learning through interactive simulations and game-based learning makes a strong case for including it in the design of curricula [18]. These technologies can make learning more fun and interesting by making difficult engineering topics easier to understand [20]. Furthermore, one feature of AI courses meant for non-specialists is that they are frequently organized into brief, manageable sections [21].

3.3. Real-Time Feedback and Assessment

AI makes it possible to give and receive feedback in real time, which gives students a quick glance into the way they are learning. This immediate feedback can help reinforce ideas and clear up confusion very quickly, which is especially helpful in difficult subjects like engineering, through formative assessment and hands-on learning [22]. The potential of ChatGPT to raise student involvement and enhance the entire student experience is one of its main advantages in engineering education [23]. Students can engage in conversational interactions with ChatGPT, asking questions in real time and receiving individualized feedback [23]. Additionally, AI can help grade student work, giving teachers more time to work on more complex educational tasks [24]. Parambil et al. (2022) talk about an AI-powered system that can track students' emotions and attention in real time in the classroom. This system gives teachers instant graphical feedback, which helps them accurately measure and respond to the level of student engagement [25]. This kind of technology makes teaching more effective, meeting the needs of a wide range of students and possibly leading to better academic results [25]. AI can also be used to forecast student performance. Researchers were able to develop an AI-enabled prediction model for student academic performance in online engineering courses [26]. The results show that knowledge acquisition, class participation, and summative performance are the dominant variables in academic performance, with prerequisite knowledge not playing a key role [26].

3.4. Preparing Students for AI-Integrated Workplaces

The engineering fields have seen a rise in the use of AI tools in recent years [27]. Given that designing products and services is the primary responsibility of engineers, investigating the use of AI in design software packages is crucial [27]. As AI systems become more common in the workplace, courses that include AI elements can better prepare students for their future jobs. Students who engage in AI learning programs will be more equipped to interact with AI, come up with original AI concepts, and recognize the benefits and societal implications of AI. Aligning students' abilities and competencies with their ethical development is a significant program realization [7]. Including AI in education is not solely about using technology to assist students in learning; it is also about getting them ready for the future of work, where AI will be a crucial component of every aspect [28]. In addition to technical knowledge, this preparation involves helping people understand how AI will affect society and how to make ethical decisions [29]. Educational institutions can give students the skills they need to do well in a job market that uses AI by teaching them how to use AI instruments and techniques [30]. This training is very important for engineering students because they are likely to interact with AI in different ways [31]. For example, Bühler et al. (2022) say that engineering education needs to change to meet the needs of the Fourth Industrial Revolution, which is mainly driven by AI. Their study suggests an engineering curriculum that combines traditional teaching methods with new AI-focused components [32]. Active e-learning, case studies, and immersive technologies like visualization and gamification are all parts of this [32]. Not only does the curriculum teach technical skills, but it also focuses on developing people's skills like empathy and creativity [32]. The goal is to give engineering students the skills they need to work well in the AI-driven professional world, which is known for being complex and involving numerous stakeholders [32]. AI has the potential to greatly improve engineering education by offering cutting-edge research and curricula that adapt

to the demands of businesses and students simultaneously. A study on AI's application in geotechnics and engineering education emphasizes the need for a partnership between educational institutions and engineering businesses to develop innovative research and educational programs, addressing employer requests for increased specialized education in AI applications, thereby achieving strategic objectives [33].

Table 2. Major findings about opportunities presented by AI in curricular design.

Opportunity	Major Findings
Personalized Learning Environments	-Creates personalized educational environments tailored to each student's needs.
	-Identifies student struggles and provides targeted interventions.
	-Adjusts task difficulty based on performance.
	-Offers real-time performance data and feedback.
Enhanced Engagement through Simulation	-AI-powered simulations increase student engagement and motivation.
	-Provides realistic, interactive scenarios connecting theory and practice.
	-Demonstrated a 25.13% increase in student engagement in a study involving over 20,000 students.
Real-time Feedback and Assessment	-Provides instant feedback, reinforcing ideas and clearing up confusion.
	-Assists in grading, freeing up teachers for complex tasks.
	-AI systems track student emotions and attention, providing real-time feedback for better engagement.
Preparing Students for AI-integrated Workplaces	-Courses with AI elements prepare students for AI-integrated workplaces.
	-AI learning programs equip students with the skills to interact with AI, develop original concepts, and understand its benefits and societal implications.
	-Combines traditional teaching with AI-focused components like active e-learning and gamification.

4. Challenges Presented by AI in Curricular Design

Even though AI holds great promise for changing educational paradigms, a careful review of the literature reveals significant discrepancies, especially in the ethical area of using AI in educational settings [5]. This discrepancy highlights a crucial oversight because the moral implications of incorporating AI into curriculum have not received sufficient consideration [5]. Other drawbacks to using AI and IT systems in sustainable education include possible biases in algorithms and machine learning models, privacy and data security concerns, and other issues [34]. To get the most out of AI in education, these challenges need to be fixed. The literature brings up a number of important issues that require consideration. Table 3 at the end of this section presents the major findings about challenges presented by AI in curricular design.

Table 3. Major findings about challenges presented by AI in curricular design.

Challenge	Major Findings
Ethical Considerations and Prejudice	-AI systems can be biased, leading to unfair decisions.
	-Ethical implications of AI in education need thorough research.
	-Training data preparation is crucial to avoid biases.
	-An ethical framework to guide AI application in education is required.
Infrastructure and Resource Requirements	-AI requires significant infrastructure, such as hardware, software, subscriptions, and reliable internet access.
	-High costs can limit access to AI-enhanced education.
	-Progress in AI and related technologies is necessary to overcome these challenges.

Table 3. *Cont.*

Challenge	Major Findings
Teacher Training and AI Literacy	-Teachers must receive training on AI technologies.
	-Lack of AI knowledge among teachers can hinder effective AI use in classrooms.
	-Ongoing support and professional development are essential.
	-Teachers' roles shift to facilitators of ethical reasoning and critical thinking.
Student Attitudes and Acceptance	-Students' acceptance of AI-driven learning methods is crucial for successful integration.
	-Some students may prefer traditional methods.
	-Overcoming skepticism and gaining student buy-in is important.
	-AI can enhance critical thinking and engagement in students.

4.1. Ethical Considerations and Prejudice

One of the greatest challenges is that AI systems can be biased and need to be considered from an ethical point of view. There is concern with the lack of thorough research into the ethical implications of AI in education, which calls for a thorough and nuanced approach to identify and reduce any potential risks [5]. AI algorithms often rely on training datasets, which can be biased, leading to biased decisions [27]. Even the handling of sensitive data like age, sex, and race can be influenced by these biases [27]. Therefore, careful preparation of training data is crucial to avoid such biases [27]. For instance, Amazon's AI-based screening system was scrapped due to gender bias, because it favored men over women [27]. Therefore, careful goal definition is essential to avoid undesired results in AI algorithms [27]. Other examples include Microsoft's AI chatbot, which "learned" racist slurs within a day by reading Twitter feeds, and Facebook's chatbot, which could only reply appropriately to 30% of its Messenger services [35]. This is an extremely sensitive topic in learning environments, where fairness and equality are very important. Significant ethical issues are raised when AI is included in engineering curricula, especially in light of possible biases in AI systems [7]. The fairness of the data used to train AI algorithms is a fundamental requirement for their integrity [7]. Because of this, these systems may unintentionally reinforce preexisting biases, which emphasizes the need for ethical consideration when implementing them [7]. Moreover, it emphasizes the significance of an ethical framework that directs the application of AI in education, guaranteeing that these tools improve learning outcomes without fostering societal biases [7]. The integration of AI into engineering education presents ethical challenges, especially when focusing on technical aspects and ignoring human-centered aspects [35]. The black-box nature of AI systems can lead to physical and mental harm [35]. A holistic approach incorporating human-centered design principles is needed to ensure the effective and ethical use of AI technology. A major challenge for curriculum designers is making sure that AI tools are used effectively and do not harm any group of students [36]. Maintaining the values of justice and equity in educational settings requires constant observation and improvement of AI applications, protecting against the unanticipated effects of bias in AI-driven educational tools [7]. Furthermore, using AI for evaluations should be limited, and people should be aware of their limits. The fact that AI might not understand what students are conveying or might not record all of their learning makes it even more important for humans to be involved in the assessment process [37].

4.2. Infrastructure and Resource Requirements

AI often needs a lot of infrastructure, such as hardware, software, and a reliable internet connection, which may not be easy to find in every educational institution [38]. Also, these technologies can be very expensive, which makes it hard for everyone to get access to AI-enhanced education [38]. Furthermore, paid submissions for AI services should be considered as part of the infrastructure and resource requirements. There are problems with incorporating AI into education, like not having enough infrastructure and

resources. However, progress in AI and related technologies is necessary for moving ahead of these challenges to ensure the new educational policies perform properly [39].

4.3. Teacher Training and AI Literacy

The use of cutting-edge AI tools in education, like ChatGPT, highlights the vital role teachers play in helping students navigate the always-changing digital landscape [5]. For AI to be employed effectively in the classroom, teachers must receive training on how to use these technologies. Teachers are not familiar with sufficient information regarding AI at the present time, which could make it harder for them to effectively employ AI tools in the classroom [40]. To solve this issue, it is very important to give teachers ongoing support and professional development [5,40]. It is clear that faculty members need to be knowledgeable about these technologies because their proficiency affects their ability to use AI to enhance learning experiences while addressing the pedagogical, ethical, and technological challenges that come with such integration [5]. In order to achieve this, we need to fully understand and use AI, as well as evaluate its use and think about the ethical issues it raises. Developing this kind of literacy requires a wide range of training programs with different lessons and useful tools. In this manner, teachers will be able to employ AI effectively in their classes, which will lead to long-term professional growth [40]. The role of the teacher in the era of digital transformation changes from that of a traditional knowledge disseminator to that of a facilitator of ethical reasoning and critical thinking [5].

4.4. Student Attitudes and Acceptance

Human factors have a major effect on how AI is used in education, and how well AI is integrated depends on how students feel about it and how willing they are to use it. Some students might not like AI-driven learning methods and would rather use old-fashioned ones [41]. To successfully use AI in curriculum design, it is important to get past skepticism and get students on board. Research indicates that students view ChatGPT as an effective instrument for honing important elements of their business model canvas, particularly Channels, Key Resources, and Key Activities [3]. These components are usually rigorous in terms of research and conceptual depth, suggesting that students can benefit greatly from AI's capacity to process and analyze enormous volumes of data in these areas [3]. Additionally, this method can create a more active and participatory learning environment in the classroom by pushing students to think critically and creatively about the issues at hand and encouraging deeper engagement with the material.

5. Focus Group

After examining the various opportunities and challenges that AI offers for improving the design of engineering curricula, it is critical to place these challenges and opportunities in the context of educators' and students' real-world experiences. In order to collect different perspectives on the incorporation of AI technology into engineering curricula, a focus group was organized. The goal of this qualitative technique was to uncover the complex feelings, perceptions, and expectations of those who will be directly influenced by the use of AI in educational settings. The focus group discussed a variety of subjects, including the first impressions and individual experiences with AI tools, as well as anticipated difficulties, ethical issues, and the possibility that AI will change engineering education. The purpose of the insights from these discussions is to supplement the literature research by offering a practical perspective that allows for a deeper analysis of the opportunities, difficulties, and potential directions of AI in engineering education. With the potential to completely transform the way engineering concepts are taught and learned, the incorporation of AI into engineering education marks a significant shift in pedagogical approaches. The opinions of eight participants, each of whom provided distinct insights on the possible advantages, difficulties, and ethical issues surrounding AI in this context, are synthesized in this study. Their combined viewpoints offer an in-depth understanding of AI's contribution to improving educational results and getting students ready for the challenges of the contemporary engineering environment.

5.1. AI's Potential in Engineering Education

All participants agree that AI has the power to revolutionize engineering education. Participant 1 emphasizes how AI has the potential to "drastically alter our lives and the way we work," highlighting the wide-ranging effects of the technology. The hope expressed by Participant 2 that AI will make "learning more personalized" illustrates a common optimism about AI's ability to customize educational experiences to meet the needs of each individual. This view is further echoed by Participant 4's excitement about AI "revolutionizing learning processes" and Participant 3's reference to AI regarding "personalized learning environments". The focus placed by Participant 5 on AI "offering tailored suggestions" and the idea put forth by Participant 6 that AI is "completely transforming the learning process" demonstrate the broad support that AI-enhanced education has. Viewing AI as a dynamic tool for "interactive learning" and "real-world applications," Participants 7 and 8 demonstrate the technical capabilities of AI.

5.2. Challenges and Ethical Considerations

Participants expressed concerns about incorporating AI into the curriculum despite their excitement. Participant 2 raises concerns about AI technologies "limiting student exposure to diverse approaches," while Participant 1 warns of "significant challenges" in curriculum integration. The ethical conundrums involved are highlighted by Participant 3's anxiety about "ethical concerns" and Participant 4's worry about "data privacy and security" difficulties. The possibility of "algorithmic bias" and the "necessity for strong data governance," respectively, are discussed by Participants 5 and 6. The concerns expressed by Participant 7 over "bias affecting learning outcomes" and Participant 8's criticism of the "challenges in ensuring data privacy" highlight the difficulties involved in using AI ethically in education.

5.3. Thematic Analysis of Participants' Perspectives on AI in Engineering Education

Theme 1: Transformative Potential of AI

All participants agree that AI has the ability to significantly improve engineering education. They emphasize how AI can transform education by enabling personalized support, dynamic tools, and interactive learning. AI has the potential to "drastically alter our lives," for example, according to Participant 1, yet Participant 8 highlights AI's contribution to "real-world applications to improve student engagement." This theme highlights a common optimism about AI's potential to improve engineering education.

Theme 2: Personalization and Engagement

The promise of AI to enhance student engagement and personalize learning experiences is a recurring subject in the comments. Participants highlight AI's capacity to generate realistic simulations, adjust to each learner's unique learning style, and offer real-time feedback. Two participants highlight the importance of "personalized learning," while Participant 7 talks about AI's capacity to "provide real-time feedback for each individual student." This theme highlights a general understanding of how critical it is to use AI to customize instructional materials and delivery strategies to fit the wide range of student needs.

Theme 3: Challenges and Barriers to Integration

While participants are optimistic about AI's potential, they are also worried about the difficulties and obstacles that stand in the way of integrating AI into the engineering curriculum. These include reluctance to adapt, constraints in the infrastructure, students' reliance on AI, and worries about data security and privacy. The "challenge of ensuring data privacy" is mentioned by Participant 4, and "opposition to change" is mentioned by Participant 6 as major barriers. The practical concerns and worries that must be addressed for an AI integration to be successful are encapsulated in this theme.

Theme 4: Ethical Considerations and Bias Mitigation

Critical factors to take into account include the possibility of bias in AI tools and ethical problems. The significance of tackling algorithmic bias, data privacy, and the

moral use of AI in education is emphasized by the participants. Concerning "algorithmic prejudice", Participant 3 suggests "transparency and strong data governance" as remedies. Participant 5 also has similar concerns. This subject emphasizes how important it is to create moral standards and methods for reducing bias in order to guarantee the ethical application of AI in engineering education.

Theme 5: Recommendations for Effective Integration

Several recommendations have been brought forward by participants to tackle these difficulties. Participant 1 makes the suggestion to "implement AI with caution," highlighting the necessity of cautious integration. In order to promote the efficient use of AI, Participant 2 is an advocate for "training programs for educators". "Ethical guidelines" are demanded by Participants 3 and 4 to control the use of AI in education. In order to facilitate AI integration, Participant 5 emphasizes the significance of "bias mitigation strategies", whereas Participant 6 emphasizes the necessity of "infrastructure improvements". To avoid prejudice, Participant 7 suggests "continuous monitoring" of AI tools; Participant 8 offers "partnering with industry" to obtain knowledge about useful AI applications.

5.4. Focus Group Overview

A generally positive assessment of AI's potential to transform engineering education is highlighted by the thematic analysis of the participants' input; however, this optimism is constrained by realistic worries about obstacles, moral dilemmas, and the possibility of bias. A balanced approach to integrating AI into engineering courses is crucial, with a focus on tailored learning experiences, engagement augmentation, careful navigation of barriers, and adherence to ethical norms. This varied set of participants' perspectives highlights this point. This sophisticated comprehension of AI's possibilities and drawbacks offers a useful starting point for formulating plans to make the most of AI technologies in educating the upcoming generation of engineers for the problems of the future.

6. Discussion

Incorporating knowledge from the focus group discussion with the literature analysis on AI in engineering education yields numerous important findings that deepen our understanding and provide future directions for practical solutions. This is a thorough analysis of the conclusions and recurring research themes.

6.1. Integration of Theory and Practice through AI

The literature and the results of the focus group both highlight AI's ability to close the gap between theoretical understanding and real-world applicability. Personalized learning environments and AI simulations let students apply theoretical knowledge in simulated real-world circumstances, while also improving student engagement. This combination points to a future trend in curriculum design that heavily leverages AI to make a smooth transition from studying theoretical foundations to using them in real-world, hands-on settings.

6.2. Ethical and Bias Considerations Require a Holistic Approach

The focus group talks strongly illustrate the ethical issues and potential biases raised by the literature review. These viewpoints' convergence highlights the need for an all-encompassing strategy for integrating AI that incorporates moral principles, techniques for reducing bias, and a structure for ongoing ethical evaluation. It emphasizes how critical it is to create AI tools and curricula in accordance with moral principles that give equality, openness, and diversity the top priority.

6.3. The Critical Role of Infrastructure and Accessibility

A major obstacle noted in both the literature review and focus group is the availability of resources and infrastructure. According to the conversation, in order to democratize access to AI-enhanced education, major investments in technology infrastructure are required. This covers not only actual technology and software but also dependable internet

connectivity and initiatives for digital literacy. Achieving fair access to these resources is essential to the effective incorporation of AI into engineering education.

6.4. Teacher Empowerment through Professional Development

The focus group's emphasis on the value of AI literacy and teacher preparation aligns with conclusions from the literature on the same topic. The necessity for thorough professional development programs that give teachers the know-how and abilities to successfully integrate AI into their lesson plans is highlighted by this convergence. In order to fully utilize AI tools to improve learning outcomes and navigate the digital transition of education, it is imperative that instructors are empowered.

6.5. Student-Centric AI Integration

The literature's discussion of personalized learning environments and the focus group feedback regarding students' attitudes towards AI-driven learning approaches indicate that a student-centric approach to AI integration is necessary. This includes actively integrating students in the creation and assessment of AI tools and approaches in addition to modifying instructional material and delivery to accommodate a variety of learning demands. Using this method would guarantee that AI improvements are in line with students' interests and learning styles in addition to being technically sound.

6.6. Collaborative Frameworks for Continuous Improvement

The findings from the focus group and the literature as a whole point to the significance of developing cooperative frameworks that include academics, students, technologists, and business experts in the ongoing development of AI in engineering education. These frameworks should make it easier for people to exchange ethical considerations, creative solutions, and best practices, guaranteeing that AI integration stays flexible, adaptable, and in line with the changing demands of the engineering community.

7. Conclusions

The integration of AI into engineering education presents both revolutionary possibilities and significant obstacles. It offers students real-time feedback, individualized learning experiences, and simulations to connect theory and practice. This shift towards a more personalized, effective, and engaged learning environment equips students for success in a digital and AI-integrated world. However, challenges include addressing ethical issues, thorough teacher preparation, infrastructural needs, and student acceptance and attitudes towards AI-enhanced learning. Collaboration between educators, legislators, curriculum designers, and technologists is essential for fully utilizing AI in engineering education. This involves a progressive, cooperative effort that values student-centered methods, ethical considerations, and seamless integration of theory and practice. This study uses real-world experiences and literary analysis to paint a picture of how AI's eventual transformation of education will become more than simply a theoretical concept. AI will serve as a catalyst for an educational revolution by embracing inclusion, exercising ethical care, and pursuing continuous improvement. This will equip students with the critical thinking and ethical discernment necessary to negotiate the complexity of today's world.

8. Study Limitations and Future Research

The study highlights the need for longitudinal studies to understand the long-term impacts of AI on engineering students' learning abilities. It explores the integration of AI in engineering education, but its limitations include its focus on a Saudi Arabian engineering college and potential biases in data collection. There is a need to highlight the importance of a broader scope, diverse samples, and methods to better understand the long-term effects and sustainability of AI integration in engineering education. Future research should explore AI applications in diverse educational settings and real-world methods while considering ethics and bias. A broader demographic range, including graduate

students and junior faculty, can provide valuable insights into AI integration. Gender diversity in focus groups can also help identify gender-specific challenges and biases. By considering these demographic factors, future studies can better understand the full spectrum of AI's impacts on engineering education, leading to more effective and inclusive integration strategies.

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