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EXPLORING EDUCATION IN THE DIGITAL AGE: INNOVATIONS, INTERSECTIONS AND INSIGHTS

PREFACE

Dear esteemed readers and contributors,

It is with great pleasure and excitement that I extend a warm welcome to you all to this special edition of our journal, dedicated to exploring the diverse and dynamic themes shaping the landscape of education in the digital era. As we embark on this journey of discovery, each theme serves as a guiding beacon, illuminating the innovative intersections of technology and pedagogy.

Our first theme, Teaching based on Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT), sets the stage for our exploration by delving into the transformative potential of intelligent technologies in education. From personalized learning experiences to predictive analytics, AI, ML, and IoT hold the promise of revolutionizing traditional teaching methods and unlocking new pathways to knowledge acquisition.

Theme 2 invites us to immerse ourselves in the realm of 360 Learning, Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). Here, we witness the fusion of physical and digital worlds, as learners embark on immersive journeys that transcend the confines of the traditional classroom. Through experiential learning and interactive simulations, VR, AR, and MR technologies redefine the boundaries of education, offering unprecedented opportunities for engagement and exploration.

In Theme 3, we explore the power of Collaborative Teaching, Global Learning, and innovative practices such as Gamification, Maker-Space, and Maker Lab initiatives. This theme underscores the importance of collaboration, cultural exchange, and hands-on experimentation in fostering creativity, critical thinking, and problem-solving skills among learners worldwide.

Theme 4 sheds light on the paradigm shift towards Open and Distance Learning (ODL), Self-Instructional Materials (SIM), and the utilization of Big Data Analytics in Learning. Here, we witness the democratization of education, as learners gain access to high-quality resources and personalized learning experiences irrespective of geographical constraints. Big Data analytics further enhance the educational landscape by providing insights into learner behavior and preferences, enabling educators to tailor instruction to individual needs.

In Theme 5, we explore the evolving role of Social Media Learning as a catalyst for knowledge dissemination, collaboration, and community building. From online forums to multimedia platforms, social media offers a dynamic space for peer-to-peer learning, digital literacy development, and the cultivation of virtual learning communities.

Theme 6 invites us to embrace Design Thinking for new Learning Delivery, emphasizing the importance of user- centered design principles in creating innovative and inclusive learning experiences. Through empathetic design, educators can reimagine learning environments that foster creativity, adaptability, and lifelong learning skills.

In Theme 7, we delve into Andragogy in technology-based learning, Instructional Design, and Best Practices in e-learning. This theme highlights the importance of learner-centered approaches, effective instructional design strategies, and the dissemination of evidence-based practices to optimize learning outcomes in the digital age.

Finally, Theme 8 explores the Development of e-learning systems, materials, and mobile technologies, including the emergence of MOOC-based mobile learning materials. Here, we witness the evolution of educational technologies, as mobile devices and online platforms redefine the boundaries of access and engagement in education.

As we navigate through these diverse themes, let us embrace the spirit of inquiry, collaboration, and innovation that defines our scholarly community. I extend my deepest gratitude to all the contributors who have enriched this journal with their insights and expertise. May this edition inspire new ideas, spark fruitful discussions, and contribute to the ongoing dialogue surrounding the future of education.

Thank you for your dedication and commitment to advancing the frontiers of knowledge in the field of education.

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Theme 7: Andragogy in technology-based learning/Technology in learning/Instructional design in learning/Best practices in e-learning

1. Challenges and Innovations: Adapting Practical Culinary and Foodservice Subjects for Distance Learning during COVID-19
2. Exploring Tertiary Education ESL Learners' Dependency on the Internet, Internet Sources, and Internet Source Reliability

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ABSTRACT
Chemical engineering education, traditionally grounded in rigorous theoretical instruction and hands-on laboratory experiences, stands on the edge of a transformative shift with the advent of Generative Artificial Intelligence (AI). This manuscript explores the potential of generative AI as a dynamic tool capable of producing innovative content tailored to enhance the learning experience in chemical engineering. This manuscript explores the integration of AI in education and its preliminary applications in creating complex simulations, diverse problem sets, and virtual experiments for chemical engineering students. Generative AI holds immense potential to reshape chemical engineering education, paving the way for a future that not only delivers education, but also dynamically crafts it to suit the unique needs of each learner. This work serves as a roadmap for educators, researchers, and policymakers eager to harness the power of AI to shape the next generation of chemical engineers.

Keywords: artificial intelligence; chemical engineering; engineering education; generative AI; learning experience

INTRODUCTION

Higher education's landscape has undergone significant changes in recent years. The introduction of digital technologies has expanded the boundaries of traditional classrooms, providing educators with various tools and approaches to improve the learning process. Artificial Intelligence (AI) emerges as a significant innovation that holds great potential for transforming teaching practices and enhancing educational outcomes.

Chemical engineering, a discipline that intricately blends principles from chemistry, physics, mathematics, and biology, often presents unique challenges for educators and learners alike. Complex theoretical concepts, laboratory experiments, modelling and simulations, and the rapidly changing nature of the field require innovative teaching methods that can adapt to individual student needs while ensuring comprehensive coverage of the curriculum. The ability of AI to process and analyse huge amounts of data and simulate the real world holds the promise of addressing these challenges aggressively.

This work aims to explore the various ways to integrate AI into the undergraduate chemical engineering programme, offering insights into its potential benefits, challenges, and future prospects. This manuscript aims to provide a holistic overview of the current state of AI applications in chemical engineering education and chart a path forward for educators, institutions, and policymakers.

ARTIFICIAL INTELLIGENCE (AI)

Historical Context of AI in Education

For educators, integrating technology into education has long been a priority. Throughout the years, there have been numerous improvements in this area, ranging from computer-based learning to interactive online platforms. The emergence of AI and its generative capabilities marks the latest breakthrough in education. Initial uses of AI in education are primarily centred on adaptive learning systems, data analytics for predicting student performance, and personalised content recommendations (Ouyang et al., 2023; Klašnja-Milićević & Ivanović, 2021; Hwang et al., 2022). These AI applications act as the groundwork for current advancements made in AI technology that have permeated various fields, including chemical engineering education.

Many researchers have conducted review studies on various domains of AI-supported education, such as medical education (Han et al., 2019), engineering education (Shukla et al., 2019), higher education (Zawacki-Richter et al., 2019), and e-learning research (Tang et al., 2021). However, the integration of AI in chemical engineering education remains relatively unexplored. In recent years, there has been increasing recognition of the potential benefits that AI can offer to the field of chemical engineering education. While researchers have emphasised the importance of incorporating AI into engineering curricula due to the emergence of the Industry 4.0 phenomenon, a specific gap exists in investigating the prevalence of AI in engineering design education within Malaysian institutes of higher learning.

Generative AI: A Paradigm Shift

Generative AI represents a significant departure from traditional AI applications. While conventional AI systems are designed to process data and make predictions, generative models are trained to produce new content. Generative AI models like GPT have demonstrated impressive abilities in generating various types of content, including texts, images, and simulations. This advanced technology holds great potential for revolutionising education by allowing the creation of personalised, adaptable, and diverse learning experiences through dynamic content generation.

Several academic studies have highlighted the potential benefits of generative AI in shaping personalised learning and generating assessment materials. This technology has shown promise in addressing challenging issues such as plagiarism, by ensuring a diverse evaluation landscape. Moreover, it offers opportunities for simulating complex real-world problems in fields like medicine, architecture, and environmental science. For example, Pena et al. (2021) reported how a generative AI model could create unique architectural design challenges for students with individualised constraints and hurdles to overcome. These findings suggest that generative AI has the potential to improve the field of education by providing tailored learning experiences, feedback, and assessments that cater to the individual needs and capabilities of students.

Generative AI in Chemical Engineering Education

The integration of generative AI has great potential in chemical engineering education due to its complex and diverse nature. Initial research and applications have primarily focused on simulating chemical reactions that are not easily feasible within traditional laboratory settings. Additionally, generative AI can be utilised to create problem sets that require students to apply theoretical knowledge in unique contexts. Furthermore, virtual experiments can be developed where students can observe the impact of various chemical principles, thereby enhancing their understanding and practical skills. For instance, researchers have employed generative AI techniques to simulate the behaviour of catalysts and predict their effectiveness in chemical reactions (Huang & Ling, 2019). By using generative AI, chemical engineering students can explore and experiment with different catalyst designs and parameters, leading to a deeper understanding of the underlying principles and potential optimisations. Pietikäinen et al. (2021) developed a virtual reality powered by AI that simulates chemical reactions in real time. This tool allowed students to conduct experiments in a risk-free environment, fostering exploration and deepening understanding.

APPLICATIONS OF AI IN CHEMICAL ENGINEERING EDUCATION

Generative AI for Curriculum Enhancement

One of generative AI's primary applications in chemical engineering education is its ability to dynamically generate curriculum content. Marquez et al. (2023) conducted a recent study exploring the integration of text-generation AI into Materials in chemical engineering education as a means to incorporate new computational tools and enhance students' professional skills and aptitudes. Meanwhile, Caccavale et al. (2023) investigated the incorporation of a hands-on series of Python courses (sPyCE) for chemical engineering students, covering topics such as chemical reaction engineering and machine learning. This innovative approach not only aims to create a more engaging and effective learning environment, but also seeks to empower students with valuable knowledge and expertise in their field. Using generative AI, educators can automate the creation of educational materials such as lectures, quizzes, and assignments. This allows for a more efficient and personalised learning experience, as the content can be tailored to meet the specific needs and interests of individual students.

Furthermore, the use of generative AI in curriculum enhancement can keep pace with the rapidly evolving field of chemical engineering by incorporating the latest research findings and advancements in real time. Using AI algorithms, educational platforms can analyse huge amounts of data on student performance, learning styles, and knowledge gaps to generate personalised learning pathways. These pathways can adapt to individual student needs, providing customised lessons, practice problems, and resources tailored to enhance their understanding and address specific areas of difficulty. This approach ensures that each student receives personalised support and guidance, enabling them to reach their full potential. The integration of generative AI in curriculum enhancement also fosters critical thinking and problem-solving skills. Through the use of AI algorithms, students can be presented with complex and real-world scenarios, requiring them to apply their knowledge and skills to solve problems.

Virtual Labs and Simulations

Traditional chemical engineering labs often have constraints related to safety, equipment availability, and cost. Generative AI offers a solution by simulating complex chemical reactions and processes. These simulations can provide a virtual lab environment where students can explore and experiment with different scenarios without the limitations of a physical lab. Ciolacu et al. (2023) illustrated Education 4.0 skill initiatives in Germany, Romania, and Italy, which include the Lab for Digital Innovation, a remote lab, and experimental-based interactions with the learning environment. The Lab for Digital Innovation provides a foundation for collaborative learning and sustainable development of knowledge in situational contexts.

Moreover, AI is currently employed in generating virtual and augmented reality settings aimed at fostering educational outcomes. Generating virtual and augmented reality settings through AI allows for immersive and interactive learning experiences. This not only enhances student engagement, but also provides a safer and more cost-effective alternative to traditional lab experiments. Through virtual reality simulations, students can engage in realistic and hands-on experiments without the need for physical lab equipment. In addition to simulating chemical reactions and processes, generative AI can also contribute to the development of intelligent virtual reality environments. These environments can be designed to emulate real-world industrial settings, providing students with a realistic context to practice problem-solving and decision-making. AI-powered virtual labs provide a risk-free environment for students to explore and experiment (Gasparello et al., 2022), enhancing their understanding of chemical reactions and processes.

Additionally, generative AI can facilitate collaborative learning and peer engagement. For example, AI algorithms can create virtual simulations or experiments where students can work together to analyse data, make predictions, and develop solutions. This collaborative learning approach promotes active engagement and critical thinking, as students are encouraged to work together, exchange ideas, and learn from each other's perspectives.

AI-Driven Assessment and Feedback

AI has proven to be an invaluable tool for assessment, as it possesses the capability to analyse huge amounts of data in real-time. This enables efficient grading and also allows for immediate and personalised feedback that provides individual strengths and areas requiring improvement. Through its advanced algorithms, AI is adept at pinpointing specific areas where students excel while identifying potential growth opportunities, thus enhancing the learning experience overall. AI-guided assessment systems can analyse student performance data to identify patterns and trends, providing valuable insights for both students and educators (Yi et al., 2018). Traditional assessments do not rigorously evaluate students' understanding of a topic. AI-generated problem sets can offer students a diverse range of challenges, ensuring comprehensive understanding and skill development. AI-based assessment provides constant feedback to teachers, students, and parents about how the students learn, the support they need, and the progress they are making towards their learning goals (Luckin, 2017).

The integration of AI technology can greatly enhance this pedagogical approach by serving as a facilitator. Through real-time analytics and insights, AI can provide invaluable support to educators by helping them identify the strengths, weaknesses, and specific learning patterns of individual students (Cao et al., 2020). This enables educators to design their teaching strategies accordingly for maximum effectiveness. Additionally, AI's ability to conduct in-situ assessments and deliver instant feedback empowers educators with the capability to make timely adjustments during class sessions. AI systems have the capability to not only evaluate assignments in chemical engineering education, but also provide personalised recommendations for supplementary resources or additional practice based on individual performance. Moreover, by employing neural network algorithms, AI can analyse students' academic progress and enable educators to conduct more comprehensive assessments that accurately reflect their understanding of the course material. By applying AI in assessment, educators can evaluate students' knowledge and skills more holistically and accurately, surpassing the limitations of traditional methods that may have limited scope and not offer meaningful feedback. The integration of AI in chemical engineering education also encompasses adaptive pedagogical frameworks, early warning systems, and learning management systems. These AI-driven systems have the capacity to monitor and track student progress, alerting teachers and administrators of any potential areas of concern or students who may be at risk of falling behind (Bertolini et al., 2023).

Collaborative Learning with AI

Collaborative learning, which involves students working together to solve problems or engage in projects, is a fundamental aspect of chemical engineering education. However, it can sometimes be challenging for educators to effectively manage and facilitate collaborative learning activities, especially in large classes. The collaboration between teachers and students can be facilitated by AI, enhancing the overall learning experience. By providing real-time analytics and insights, AI can help educators identify students' strengths, weaknesses, and learning patterns, allowing them to adjust their teaching strategies accordingly.

Moreover, AI can foster effective collaboration among students, especially in a virtual learning environment (Lee et al., 2021; Kuleto et al., 2021). By leveraging AI technology, students can collaborate online, share resources, and engage in group discussions with ease. An example of collaborative activity among students in group projects is the use of AI-powered virtual labs, where students can simulate chemical engineering experiments and work together to analyse data and draw conclusions. The integration of AI into collaborative learning not only improves students' ability to work together effectively, but also provides opportunities for peer learning and knowledge sharing.

EDUCATORS' PERCEPTION OF AI IN CHEMICAL ENGINEERING EDUCATION

A survey was conducted with chemical engineering educators from Universiti Teknologi MARA (UiTM), Universiti Teknologi Malaysia (UTM), Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA), and Universiti Putra Malaysia (UPM) to capture their perspectives on the potential of AI in education. The results provide an intriguing glimpse into educators' thoughts and concerns. Overall, the sentiment towards integrating AI into the curriculum was optimistic.

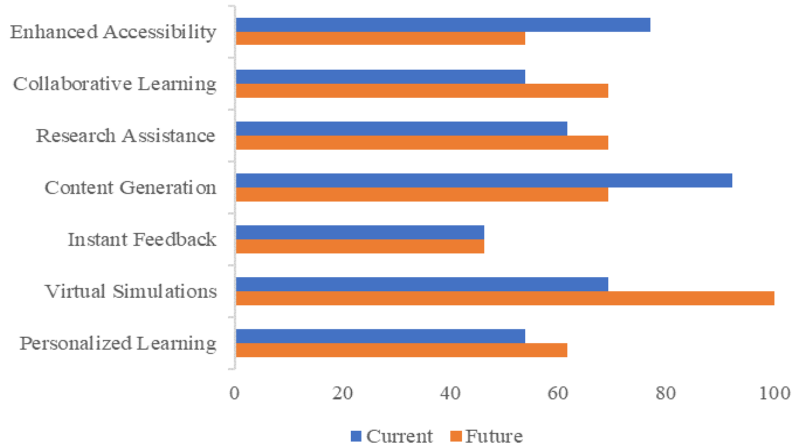

Figure 1. Educators' perception of the current and future application of AI in chemical engineering education

A significant portion of the respondents expressed enthusiasm about AI's capacity to transform curriculum adaptability, tailoring learning to individual students' needs. The average sentiment on a 5-point Likert scale encapsulated within a 95% confidence interval oscillated between 3.93 and 4.69. This indicates moderate to strong agreement regarding AI's potential to enable personalised curriculum.

Moreover, there was a consensus that AI could connect theoretical knowledge with practical application. The majority of opinions on this dimension were clustered between 4.02 and 4.60 on the scale, underscoring confidence in AI's ability to bridge pedagogical gaps through advanced simulations. The promise of AI in developing virtual laboratories also garnered attention, though at lower levels, with opinions varying between 3.45 and 4.55. With the acceleration of AI, educators expressed urgency in modernising the chemical engineering curriculum. The sentiment towards updating the curriculum with AI methods fell within a confidence band of 3.46 to 4.38, with a strong preference for integration. This highlights a perceived need to infuse AI-driven techniques into coursework. However, amidst the general optimism, genuine concerns emerged. Data privacy intertwined with AI integration emerged as a salient issue, with opinions ranging from 2.79 to 3.82 on the scale. Additionally, most perspectives consolidated between 2.67 and 3.79, emphasising the ethical challenges of potential misinformation or biases from AI systems.

While the modest sample size of 26 educators limits generalizability, the survey provides a nuanced snapshot of the exciting potential and risks of fusing AI with chemical engineering education. Harnessing the promise while addressing the challenges will require responsible AI development and rigorous pedagogical research. Overall, the results highlight educators' openness to an AI-enabled future in chemical engineering education, if thoughtfully implemented.

CHALLENGES AND ETHICAL CONSIDERATIONS

The integration of generative AI into chemical engineering education presents both promising opportunities and significant challenges. It is crucial to ensure the accuracy, reliability, and prevention of misinformation in generated content, as well as address concerns about data privacy. Furthermore, it is important to carefully consider the ethical implications of relying heavily on AI-generated content in order to avoid undermining human expertise. Despite these challenges, the integration of AI offers numerous benefits within chemical engineering education. Educators need to navigate various issues, such as data privacy concerns, addressing potential biases in AI algorithms, and mitigating the risk associated with technology dependency. However, it is important to acknowledge that the benefits of AI integration outweigh these challenges significantly. AI-powered platforms can provide students with instant feedback, tailored learning resources, and interactive learning experiences that were previously unimaginable. Moreover, AI can bridge the gap between theoretical knowledge and practical application, simulating real-world chemical processes and reactions with high reliability.

CONCLUSIONS

The integration of AI-based tools in chemical engineering education has the potential to significantly change how students and teachers interact. Virtual assistants that provide personalised, real-time feedback can greatly enhance students' understanding and engagement. However, it is crucial to approach this technology with consideration of both the advantages and ethical aspects. It is important to ensure that these tools support human educators rather than replace them while maintaining educational objectives and upholding ethical standards. Educators in chemical engineering can harness AI's potential to improve learning outcomes in this field while also addressing concerns and engaging students' interests. In conclusion, the integration of AI has the potential to transform the teaching and learning practices in chemical engineering education.

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