Artificial Intelligence Integration For Shaping Future Engineering Education At Higher Colleges of Technology, UAE

Article history
Received
22 June 2025
Received in revised form
25 June 2025
Accepted
25 June 2025
Published online
30 June 2025

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Abstract

Artificial intelligence (AI) continues to influence and reshape the field of higher education, offering new opportunities to enhance teaching and learning in engineering programs. This case study examines the integration and impact of AI tools, specifically ChatGPT and MATLAB Simulink, in supporting constructivist instructional approaches within typical undergraduate chemical engineering courses at the Higher Colleges of Technology in the United Arab Emirates (UAE). Grounded in Constructivist Learning Theory (CLT) and guided by the Technological Pedagogical Content Knowledge (TPCK) framework, the study explores how AI tools support student engagement, independence, and deep understanding of complex chemical engineering concepts. Data were collected through two focus group discussions with instructors and students, respectively, and complemented by document analysis of course materials and AI-generated student work. The findings indicate that AI integration contributes to personalized learning, improved academic performance, and increased student engagement. However, the study also identifies significant challenges, including academic integrity concerns, limited technical knowledge among educators and students, students' excessive reliance on AI, occasional inaccuracy of AI-generated content, restricted access to advanced AI tools, and the cost of implementation. These insights highlight both the promise and the challenges of integrating AI into engineering education.

Keywords: Artificial Intelligence, Engineering Education, Constructivist Learning Theory, and TPCK Framework.

Introduction

The Role of Technology in Engineering Education

For the last few decades, people's daily lives have been under constant change due to what is known as the digital age or information age. For instance, computer technology allowed not only the existence of vast amounts of information but also people's ability to access information at their fingertips. As well, engineering education has been greatly influenced by advanced technology (Komerath, 2021). Accordingly, most engineering educators have been acquiring and utilizing technology knowledge in the classrooms. However, the role of technology is more than its utilization in engineering education. Technology shapes engineering education.

Siemens argues that traditional learning theories, behaviorism, cognitivism, and constructivism, are unable to adapt to technological advancement since they were developed before the current waves of innovation and technology advancement (Siemens et. al., 2020). Siemens (2005) introduced the Connectivism Learning Theory, which is a theory that deals with learning in the Digital Age. Also, Downes (2006) expanded the connectivism theory; he introduced what is known as distributed (connective) knowledge, which is analogous to the other two well-known major types of knowledge, qualitative and quantitative knowledge. They wrote two articles: Connectivism- A Learning Theory for the Digital Age (Siemens et al., 2005) and An Introduction to Connective Knowledge (Downes, 2005). Connectivism confirms that knowledge and learning-knowledge are distributive. In other words, they are not bound by any given location but consist of networks of connections formed of experiences and interactions among individuals, societies, organizations, and the technologies that link them together. Also, Knowledge resides within networks, without any individual necessarily possessing it, and it can be stored in a variety of digital formats (Siemens, 2005; Downes, 2005, 2006 & 2019; Goldie, 2016).

The researchers (such as Fitria and Singh and coworkers) believe that the connectivism learning theory paved the way for the current scholars' efforts to investigate and introduce artificial intelligence (AI) in the learning process (Singh et al., 2022; Fitria, 2021).

Artificial Intelligence (AI) Tools

For several decades, advanced technology has begun to play a vital role in all aspects of daily life in

Minalla, A. & Fawad, H. (2025), Artificial Intelligence Integration for Shaping Future Engineering Education, *ASEAN Journal of Engineering Education*, 9(1), 64-72. https://doi.org/10.11113/ajee2025.9n1.193

society. Therefore, scholars agreed on the importance of integrating technology, such as Artificial Intelligence, in education (Dai et al., 2022); also, Aruleba (2022) added that students must have a good understanding of AI technologies at both higher education and K-12 classrooms alike.

There is an unlimited number of AI tools, in the order of thousands, and they have kept increasing significantly daily. Subjectively, Ema Lukan claims that she recommended 55 of the best AI tools, across 25 different categories, after carefully trying and testing all available options. Lukan's list covers about 25 categories such as, "Search Engines, Social Media Management, Graphic Design, App Builders & Coding, Presentations, Knowledge Management, Research & Education, Grammar and Writing Improvement, Generation and Editing of texts, videos, images, presentations, emails, voices, music, etc." Lukan has provided information related to usability, challenges, limitations of free versions, premium pricing, and personal preferences for each selected AI tool (Lukan, 2025).

The era of AI demands the transformation of the traditional teacher–student relationship into a teacher–AI–student dynamic. Therefore, integrating AI into education is crucial for students and teachers alike to engage safely and meaningfully with AI. However, there is a lack of coherent professional development programs to enable students and teachers to assume their roles in the era of AI. To fill this gap, UNESCO has developed two AI competency frameworks, one for students and another for teachers (UNESCO, 2021 & 2022).

The AI competency framework for teachers defines the knowledge, skills, and values teachers need to acquire in the age of AI. The framework includes five aspects: Human-centred mindset, Ethics of AI, AI foundations and applications, AI pedagogy, and AI for professional learning. To be competent across these five aspects, teachers have to achieve three progression levels: Acquire, Deepen, and Create (UNESCO, 2021, p. 22). The AI competency framework for students includes four aspects: The human-centred mindset, ethics of AI, AI techniques and applications, and AI system design. To achieve competency, each of these aspects has three levels of progression: Understand, Apply, and Create (UNESCO, 2022, p. 18).

The Constructivism Learning Theory (CLT)

Constructivism Learning Theory (CLT) is based on learners constructing knowledge (constructions) through experience, active learning processes, and learners' existing knowledge (Hirst 2022; Dewey 2018; Walshe, 2020). The two main types of constructivism are: Cognitive constructivism, which is based on Piaget's theory of 1953. It relates learning to the learner's stage of cognitive development. Piaget developed this theory based on his work on children's cognitive development. The other one is the Social constructivism that is based on Vygotsky's social learning theory of 1962. This theory emphasizes the collaborative nature of learning, which means, in addition to their stage of cognitive development, learners develop knowledge from people interactions, among themselves, their culture, and society. However, both of them are based on active learners (on control) constructing and storing new knowledge based on their prior knowledge, while educators act as facilitators (Brundiers and Wiek, 2014).

Technological Pedagogical Content Knowledge (TPCK) Framework

Teaching at higher education is a complex and dynamic field that requires a range of knowledge systems (Glaser, 1984; Shulman, 1986, 1987). Historically, college educators have focused only on Content Knowledge (CK) through their graduate programs. To improve educators' performance, Pedagogical Knowledge (PK) has been introduced independently of CK (Ball & McDiarmid, 1990). The 21st-century technological advancement shapes engineering education. Thus, Technological Knowledge (TK) has become an important element of teacher knowledge. However, these three systems of knowledge have been considered separate and independent of each other. In contrast, Mishra and Koehler (2006) developed the TPCK framework, as shown in Figure 1, which emphasizes the connections, interactions, affordances, and constraints between and among content, pedagogy, and technology. They provided the following definition of each system of knowledge: "i) Content Knowledge (CK) is knowledge about the actual subject matter that is to be learned or taught; ii) Pedagogical Knowledge (PK) is deep knowledge about the processes and practices, or methods of teaching and learning; and iii) Technology knowledge (TK) is knowledge about standard technologies, such as books, chalk and blackboard, and more advanced technologies, such as the Internet and digital video. This involves the skills required to operate particular technologies." (Mishra and Koehler, 2006).

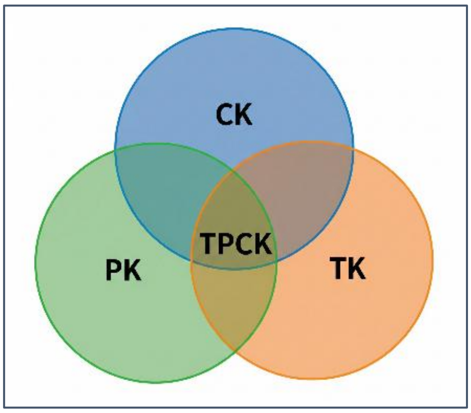

Figure 1. TPCK framework (Adopted from Mishra and Koehler, 2006)

Methodology

Theoretical Framework

This case study is guided by a combination of the Constructivist Learning Theory (CLT) and the Technological Pedagogical Content Knowledge (TPCK) Framework. The CLT examines the engagement of engineering students in constructing knowledge, while TPCK understands how engineering educators improve student outcomes by integrating AI into their classrooms.

The CLT is a student-centred learning philosophy that emphasizes students actively engaged in the learning process. In other words, students construct knowledge based on their existing experiences and interactions among themselves, their culture, and society. At the same time, the educator acts as a facilitator who is capable of engaging and encouraging learners toward an active learning process, a deep understanding of the subject matter, and metacognitive skills. The CLT provides a perspective to explore engineering students' experiences with AI in their learning process (Tan et. al., 2021; Prince et. al., 2020)

As shown in Figure 1, the TPCK framework describes knowledge as a complex interaction among three bodies of knowledge, namely Content Knowledge (CK), Pedagogical Knowledge (PK), and Technology Knowledge (TK) (Mishra and Koehler, 2006).

Table 1 shows the convergence of CLT and TPCK across three elements, namely AI tools, students, and educators.

Table 1. Theoretical integration of CLT and TPCK across three aspects

Aspect	CLT	TPCK
AI Tools	To foster students' engagement, motivation, and independence in the learning process.	Aligned the three elements of Knowledge (CK, PK, and TK).
Students	Examine students' experiences with AI in the learning process.	--
Educators	--	Investigate educators' capabilities to integrate AI in constructivist T&L models.

As shown in Figure 2, the conceptual framework for this study is shaped by the necessity to introduce AI tools, such as ChatGPT and Simulink, into engineering education, as emphasized by UNESCO (2021 & 2022). It assumes that the fusion of AI tools with constructivist instructional approaches, e.g., Problem-Based Learning (PBL), can enhance engineering students' learning experiences and better prepare them for future job market requirements. As mentioned above, this study is grounded in Constructivist Learning Theory and guided by the Technological Pedagogical Content Knowledge (TPCK) framework, reflecting a conceptual integration between emerging technologies and evidence-based teaching methodologies.

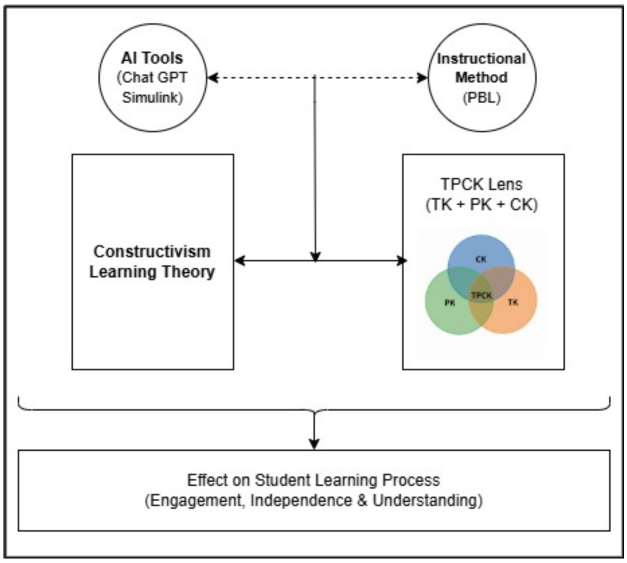

Figure 2. Conceptual framework

Purpose of the Study

The objective of this paper is to explore and advance the level of AI utilization in engineering classrooms at the Higher Colleges of Technology (HCT). To achieve this objective, the paper formulates the following three research questions, which are aligned with the theoretical framework, engineering topic, AI tools, and instructional method:

i. What is the extent of AI tools' utilization by engineering students at HCT?

ii. What is the level of AI tools' integration in engineering classrooms at HCT?

iii. What are the challenges of introducing AI in engineering education as perceived by both students and instructors?

Scope of the Study

The scope of this study is limited to the integration of AI platforms into the Chemical Engineering Program at HCT; however, the analysis can be expanded to include other engineering departments or even all other programs.

Method

This paper uses a qualitative approach to collect and analyze primary and secondary data (Creswell, 2017). This research used two data collection instruments: i) Focus group discussion (FGD), as a primary data source, and ii) documentary analysis, secondary data. The collected data were organized, analyzed, and tabulated.

Two focus groups, FGD1 and FGD2, were formed to interview 9 engineering educators and 11 undergraduate engineering students, respectively, regarding their understanding and utilization of AI tools, as well as their insights into the role of AI tools in current and future engineering programs at HCT. The face-to-face discussions were carried out between June 3rd and June 12th, 2025, and they were recorded, upon all participants' verbal consent, using the voice recording feature within the Microsoft Teams platform (MS Teams). The discussions lasted approximately 51 and 55 minutes, respectively. Afterward, the voice records were transcribed using MS Teams. Transcribed data was analyzed using thematic analysis to gain in-depth insights.

The qualitative secondary data includes: i) Syllabi and T&L materials of a few chemical engineering courses: Heat Transfer, Thermodynamics, Chemical Engineering Modelling and Simulation, Sophomore Design Project (SoDP), and Capstone Senior Design Project (CDP). ii) AI Features Within HCT's Learning Technology Tools. iii) Copies of SoDP, CDP, and heat transfer projects (HCT-Chemical Technology).

Data analysis

The collected data were organized, analyzed, and tabulated. The data analysis followed Bryman's thematic analysis (Bryman, 2021) and was guided by the principles of CLT, effect on students' learning process, and TPCK framework (educators' practices across the related bodies of knowledge (CK, PK, and TK). The voice-recorded discussions were transcribed, analyzed, and followed by the interpretation of the findings.

Findings of the Study

Documentary Analysis

As summarized in Table 2, the various types of documents were obtained from the HCT Portal and analyzed to understand the integration of AI tools into T&L chemical engineering at HCT. These documents include chemical engineering course materials, student performances, including AI-generated reports, and AI infrastructure and resources available for engineering students and educators at HCT (HCT-Chemical Technology).

Course materials proved a lack of AI features in most chemical engineering courses, except design projects and modelling, and simulation courses. This fact is evident in students' performance and AI-generated works, as explained in section 3.2.1. Also, the analysis showed that HCT owns a state-of-the-art learning technology infrastructure, which has been improving over time. Recently, most of HCT's learning technology tools have been equipped with AI features, such as Blackboard Learn Ultra, Nearpod, Kahoot, Book Widgets, Padlet, McGraw-Hill, Camtasia, Active Presenter, Microsoft, and Adobe Express. All of these tools are available for students and educators to improve their T&L process; however, the lack of stand-alone AI tools, such as ChatGPT, Google Gemini, DeepSeek, etc., is one of the main challenges facing the full integration of these tools into education at HCT, Section 3.2.2.

Table 2. Types of documents and focus of analysis

Document Types	Examples	Analysis Focused on
Chem Eng Course Materials	Syllabus, Curriculum, T&L Activities, Assessment Tasks	Evidence of AI tool integration.
Student Performance	CDP & SoDP Reports, Simulink Models, Presentations, etc.	Evidence of AI utilization
AI-Generated Content	ChatGPT: Transcripts, Images, Code, Simulations, etc.	Evidence of AI competency
AI-Infrastructure	Accessibility & Cost of Implementing AI Technologies	Cost & Implementation Challenges
AI features within HCT's learning tools	Blackboard Learn Ultra, Nearpod, Kahoot, Book Widgets, Padlet, McGraw-Hill, Camtasia, Active Presenter, Microsoft & Adobe Express	Support teaching practices

Focus Group Discussion (FGD)

This section discusses the study findings, which were divided into 3 sub-sections: First, AI utilization at HCT; then the benefits of AI utilization; and the challenges of AI utilization as perceived by students and teachers.

AI Utilization at HCT

The two FGDs demonstrated the popularity of AI tools and their utilization by engineering students and educators. All participants in the FGDs have been significantly engaged with several AI tools across various application areas. categories to help them in their learning process. Table 3 lists many AI tools that have been identified and utilized by students and educators. As illustrated in the table, AI tools, mainly ChatGPT, helped students in tutoring, simplifying and explaining engineering concepts, writing reports, supporting students' design and research projects, generating PowerPoint presentations, producing videos, and generating educational materials such as quizzes, flashcards, and lesson plans. At the same time, many engineering educators use and encourage their students to use AI tools, such as ChatGPT, Google Gemini, and DeepSeek, in their learning process.

Table 3. AI tools and their area of application

AI Tools	Application Area	Remarks
Chat GPT	General-purpose conversational AI	Wide range of tasks: Education, business, research, & daily life
Google Gemini	General-purpose conversational AI	Most advanced set of LLMs: For writing, brainstorming, learning, information, and summarizing
DeepSeek	Problem solving	Chinese AI model where LLMs can be created efficiently and affordably, challenging the traditional way to build cutting-edge AI
Quizlet	Testing, Quizzes, Flashcards	Making flashcards and getting ready for tests
Qwen	Problem solving	Helpful in getting human-like output
Quilt Bot	Summarizer, Paraphrasing, No Plagiarism	A tool for short essays, rewording stuff without plagiarizing
Gamma & Slide Go	Generate PowerPoint	Helps with presentations and super-fast
Math Way	Calculator	For solving mathematical problems
Grammarly	Catch grammar and style errors	Find grammar mistakes and make writing look better
Hemingway Editor	Makes complex ideas readable	Simplifying complicated sentences
DeepL	Translation	Translates languages
Canvas	Conversational AI	Design Tool, Editing and Creating Images, Photos, etc.
Simulink MATLAB & ASPEN Plus	AI-Enhanced Simulation and Modelling SW	For solving and visualizing complex mechanical, electrical, and general engineering problems

Although many AI tools have emerged from the two FGDs, see Table 3, the following section discusses the perceptions of chemical engineering students (FGD2) and their teachers (FGD1) about the utilization of five AI tools, as examples, namely Google Gemini, ChatGPT, as a general-purpose conversational AI, ASPEN Plus and MATLAB Simulink, as AI-Enhanced Simulation and modelling Tools, and Canvas, conversational AI tool.

Google Gemini

Engineering educators assign real-world engineering problems to be solved, validated for accuracy, and corrected by students. For example, the following heat transfer assignment was solved using Google Gemini and compared with a textbook solution to demonstrate human intuition versus AI iteration in a heat transfer example.

In Heat and Mass Transfer: A Practical Approach (Çengel & Ghajar, 2011), Example 3-7 examines heat transfer in a spherical container. Both the textbook (human approach) and Gemini (AI-based approach) calculate the same final mass of ice (2079 kg) but differ in methodology.

It's interesting to analyze the different approaches taken by a human solver (as suggested by the textbook's likely methodology) and Gemini in solving the heat transfer problem, particularly concerning the initial guess for the outer surface temperature (Ts2), knowing that the temperature of a chilly interior and a warmer exterior are (0°C) and (22°C), respectively.

The human solver, guided by engineering intuition, assumed an initial surface temperature of 5°C, close to the colder interior (0°C). This estimate minimized error and enabled rapid convergence, often within a single iteration.

In contrast, Gemini, lacking experiential insight, used a more neutral estimate of 15°C, midway between the interior and exterior temperatures. This choice required multiple iterations to refine the result, though it still achieved the correct answer. This Comparison highlights the following:

- Human expertise allows for informed initial estimates that leverage understanding of physical phenomena, potentially speeding up iterative solutions.
- Gemini's approach, while systematic and accurate, demonstrates that a less "intuitive" starting point can increase the computational steps required for convergence.
- However, for an AI, executing multiple iterations is trivial in terms of time and effort, ensuring accuracy even with a suboptimal initial guess.
- However, both methods converge with the correct answer, but the human approach shows the efficiency gained from understanding the physical phenomena.

ChatGPT Conversational AI Tool

ChatGPT, an AI model developed by OpenAI Inc., is the most widely used AI tool to perform various tasks over a wide range of applications in education, business, research, and daily life issues. At HCT, ChatGPT helped students debug syntax issues while learning Python programming or simulating an engineering process in MATLAB.

ChatGPT was used to explain engineering concepts and provide a step-by-step solution, for instance: (i) ChatGPT explained the difference between the Log Mean Temperature Difference (LMTD) and the Number of Transfer Units (NTU), and gave concrete examples related to applications of LMTD and NTU. (ii) ChatGPT helped to provide simplified solutions to homework problems related to chemical engineering core courses such as heat transfer, unit operations, and equipment and plant design.

Engineering educators mainly utilize ChatGPT to help students perform various engineering tasks. Below are two examples of a ChatGPT-generated design of experiment for students' design projects, Sophomore Design Project and Capstone Design Project, respectively: i) Figure 3 illustrates the synthesis of nicotine from tobacco waste. ii) Figure 4 illustrates seawater electrolysis for the production of green hydrogen.

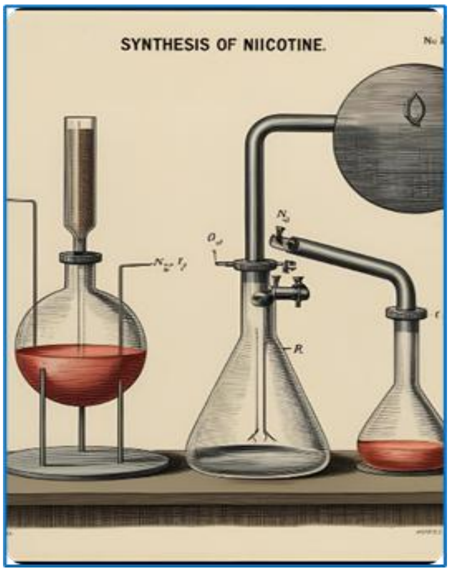

Figure 3. ChatGPT-generated synthesis of nicotine (Obtained from SoDP reports)

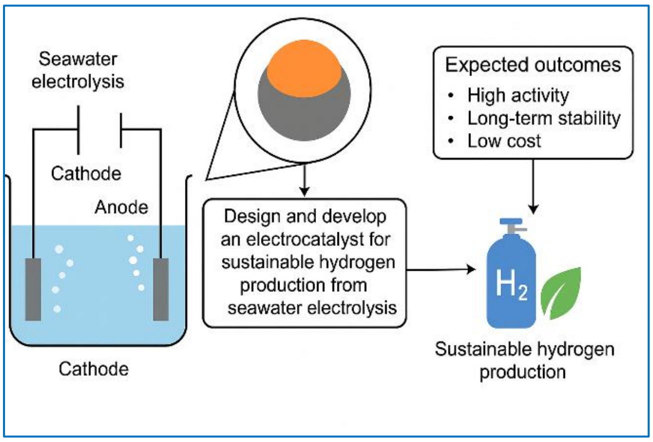

Figure 4. ChatGPT-generated seawater electrolysis for green hydrogen (Obtained from CDP reports)

MATLAB Simulink

Simulation using MATLAB Simulink helps students to visualize the dynamic behavior of real-life systems. Some examples from the heat transfer course are: (i) Simulation of transient conduction to visualize and understand the thermal gradients over time along a metal rod. (ii) Simulation of the effect of flow rates and temperature variations on the performance of a heat exchanger. (iii) Simulation of temperature profiles along both parallel and counter-current heat exchangers.

ASPEN Plus

ASPEN Plus is an AI-enhanced modelling and simulation software for solving and visualizing chemical engineering systems. At HCT, ASPEN Plus is used for one of the junior chemical engineering core courses, called Chemical Engineering Modelling and Simulation course (CHE 4613). Also, the chemical engineering Senior Capstone Design Project requires modelling and simulation of the main project processes using ASPEN Plus. The following are a few examples of students' high performance using ASPEN Plus during the 2024-25 academic year:

- During the Spring of 2024-25, students enrolled in CHE 4613 at Al Dhanna city campus achieved an average GPA of 3.6/4.0.
- By the end of the Fall semester, a group of 3 students participated and won the annual ASPEN Plus competition. Figure 5 shows the winning project: Production of Cumene by the Alkylation of Benzene.
- Figure 6 illustrates the simulation of the Equipment Design for Capturing Carbon Dioxide from the atmosphere (Capstone Design Projects).

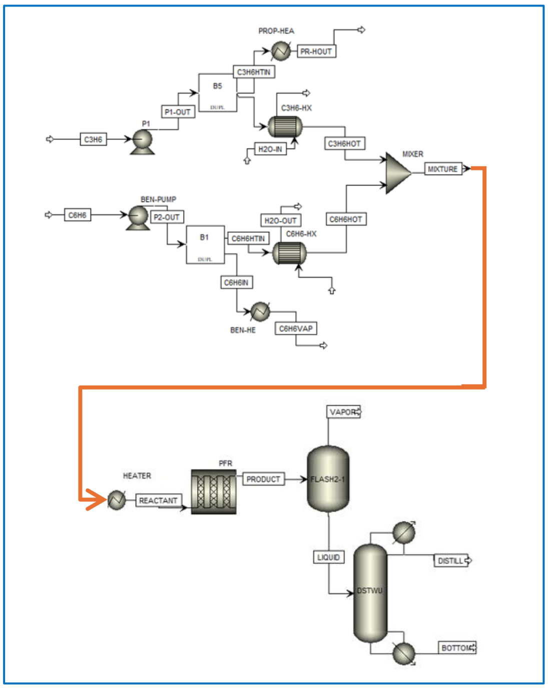

Figure 5. Production of cumene by the alkylation of benzene (Obtained from competition reports)

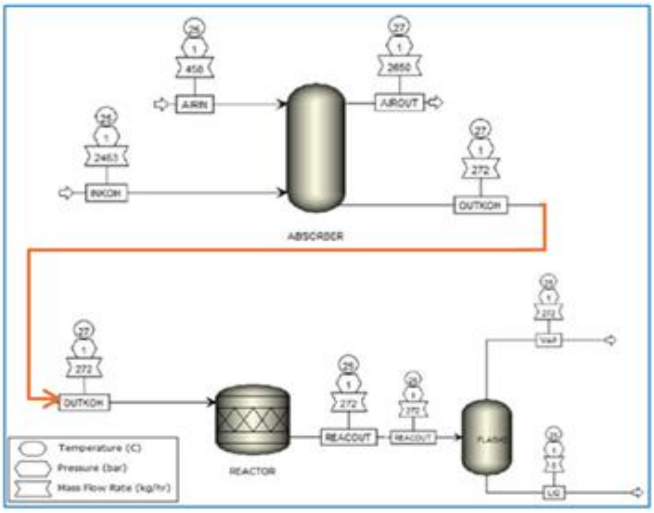

Figure 6. Equipment design for capturing atmospheric CO2 (Obtained from CDP reports)

Canvas AI tool

Both engineering students and their instructors have been using Canvas as a design tool. The platform offers templates for presentations, posters, etc., in addition to creating and editing images, photos. As an example, Figure 7 illustrates the importance of personal protective equipment (PPE) in the electrical and electronic lab.

Figure 7. PPE in the electrical & electronic lab

Benefits of AI Utilization at HCT

The findings reveal that integrating AI in education offers significant benefits for the students' learning process, including their engagement, independence, deep understanding, and active learning.

All participants in the two FGDs believe that AI techniques have become a motivational and engagement tool. Using these techniques helps students to become more confident and motivated to work independently or as a team to understand abstract engineering concepts and to examine problem-solving steps, hence improving student learning outcomes. Also, AI tools encourage engineering students to become more active learners who can control their learning goals and gain a deep understanding of the subject matter.

Additionally, Educators consider AI tools beneficial in engineering education, and they can enhance different aspects of the T&L process. For example, AI tools offer adaptive learning platforms to customize content for individual students. Also, AI can help prepare teaching materials, assessment tasks, automate grading, scheduling, and efficient administration. All these features free up teachers' time to be utilized in more creative efforts for the students' benefit.

Challenges of AI Utilization at HCT

The integration of AI in education, while promising and beneficial for the learning process, including personalized learning, improved academic outcomes, and enhanced student engagement, confronts several challenges. The participants in the FGDs identified the following:

- AI Techniques can be used as a cheating tool. For instance, students can generate assignment solutions using AI tools without understanding the material or engaging in the learning process. This undermines academic integrity and leads to superficial understanding and a lack of critical thinking skills. To address this issue, educators need to be aware of the misuse of AI and develop appropriate strategies and methods for assessing students' work.
- Teachers may lack the technical knowledge (TK) and skills required for effective use of AI tools in classrooms. Providing teachers with professional development programs is essential for the successful integration of AI in the classroom.
- Students' excessive reliance on AI techniques for completing assignments or solving problems may lead them to undermine the objective of education and inhibit their critical thinking and problem-solving skills. Educators should guide and encourage students on the proper way of using AI as a learning tool.
- Lack of understanding of how an AI tool provides a solution to a specific problem, recommendation, or evaluation of a given situation hinders students' ability to utilize these tools in their learning process. Students must receive training on how to effectively use these tools.
- There is a risk of unreliable and inaccurate AI-generated information due to limitations in training and inherent algorithmic biases. Therefore, AI-generated content should always be checked for accuracy and bias.
- Additionally, another challenge is accessing free AI techniques, such as ChatGPT Plus. Capitalizing on its already advanced LMS infrastructure, I believe HCT can develop and implement AI platforms, along with the required professional development programs, to advance its education programs for future job market requirements.

Discussion

The findings of this study reveal both the promise and challenges of integrating AI tools such as ChatGPT and AI-enhanced simulation and modelling software, e.g., MATLAB Simulink and ASPEN Plus, in chemical engineering education at HCT. Grounded in the Constructivist Learning Theory, the findings show how AI tools, when accompanied with an appropriate constructivist instructional approach (PBL), can promote student engagement, confidence, and deep learning. However, several challenges were identified by both students and educators. To address these challenges, HCT needs to develop strategic policies and regulations, design and implement professional development programs for students and educators, and adopt ethical considerations to ensure responsible and effective AI integration.

AI Integration and TPCK Framework

The document analysis indicated that HCT possesses an advanced technology infrastructure with embedded AI features (including tools like Blackboard Learn Ultra, Nearpod, Adobe Express, etc.). However, the actual integration of AI tools is limited to only a few chemical engineering subjects. It is worth noting that standalone AI tools such as ChatGPT and DeepSeek are not formally incorporated across the curriculum. This means that there is a misalignment between technological capacity and pedagogical practice. Addressing this misalignment is necessary to fully realize the potential of TPCK.

However, the inclusion of MATLAB Simulink and ASPEN Plus in simulation and design courses demonstrates successful synergy among the three bodies of knowledge (CK, PK, and TK). As well, in the case of AI-enhanced simulation and design SW, educators have demonstrated strong integration of CK, PK, and TK.

Benefits and Challenges: Constructivist Learning Perspective

Both FGDs confirmed that AI tools support student-centred learning philosophy, allowing students to: Independently explore and understand abstract concepts through simulations (e.g., heat exchanger modelling in Simulink); confidently engage in inquiry-based learning using ChatGPT for clarification and feedback; and develop autonomy and confidence in solving real-world problems. These findings confirm the role of AI tools in facilitating cognitive and social constructivism, such as self-directed learning and conceptual construction, and collaborative problem-solving, respectively. Also, educators can enhance their teaching efficiency by using AI to automate assessment, personalize learning content, and streamline material preparation. Thus, educators can use their free time creatively for student-centred engagement.

Also, several challenges emerged during the FGDs, due to the integration of AI in education; among them are: Students' dependency and overreliance on AI tools may compromise their critical thinking and problem-solving skills. The lack of adequate technical knowledge among educators represents a huge obstacle to proper AI integration in education. Academic integrity is one of the concerns due to the misuse of generative AI. The limitations of free access to advanced AI tools (e.g., ChatGPT Plus) limit the advancement of AI tools in education. The availability of basic AI models, such as ChatGPT, represents a huge risk of misinformation spread.

Therefore, HCT has to establish policies and regulations related to these challenges, ethical principles, and the responsible use of AI tools in education.

Conclusion

This case study illustrates that while HCT is technologically equipped to support AI-enhanced learning, its full potential across engineering education has not been achieved yet. The constructivist and TPCK perspectives reveal that when AI is used purposefully (e.g., in simulation, modelling, and inquiry tasks), it fosters student engagement, confidence, and deep understanding of subject matter. At the same time, to get the most out of AI's benefits in education requires curriculum redesign, faculty and students training, in addition to ethical and pedagogical guidelines. Moreover, HCT has the potential to introduce the AI technology not only as tools, but also as a complementary element in instructional design, supported by a competency-based learning (CBL) framework.

Finally, as AI continues to transform our daily life, including the academic field, this study may offer reasonable insights into how academic institutions, like HCT, can leverage AI tools to graduate future-ready engineers who are capable of facing pressing global issues, such as climate change, global poverty, and cybersecurity threats, just to name a few.

Recommendations

- HCT should launch professional development programs that focus on: Building technological knowledge (TK) for effective use of AI tools. Utilizing AI tools in the redesign of engineering curricula, and not just capstone design projects. Designing AI-generated formative and summative assessment tasks and teaching materials, such as tutorials, quizzes, flashcards, explainer videos, and simulations. Maintaining academic integrity while using AI
- HCT needs to promote ethical and responsible use, while using generative AI, understanding and dealing with bias and inaccuracy, and verifying AI-generated content.

- As well, students need continuous training sessions while using generative AI, understanding and dealing with bias and inaccuracy, and verifying AI-generated content. Also, they should revise academic integrity policies to explicitly address AI-assisted work, with guidelines for acceptable use.
- HCT should establish an 'AI-Research and Innovation Unit' for continuous evaluation of AI impact on the overall learning process, studies on new AI tools, and workshops and publications on best practices.

Acknowledgement

The authors would like to express their sincere gratitude to the HCT's chemical engineering students and their educators at Al Dhanna Campus, who participated in the FGDs and shared their thoughtful insights about their experience with AI tools in education. Also, Special thanks to Dr. Ranjith Bose and Dr. Moath Awawdeh, who provided us with AI-generated images as part of their students' SoDP and CDP projects. Lastly, appreciation goes to all those who contributed indirectly through discussions, feedback, or technical support.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

Aruleba, K., Dada, O. A., Mienye, I. D. and Obaido, G. 2022. Demography of machine learning education within

Ball, D. L., & McDiarmid, G. W. (1990). The subject matter preparation of teachers. In W. R. Houston (Ed.), Handbook of research on teacher education (pp. 437–449). New York: Macmillan

Brundiers, K., & Wiek, A. (2014). Do we teach what we preach? An international comparison of problem-and project-based learning courses in sustainability. Sustainability, 5(4), 1725-1746

Bryman, A. (2021). Social research methods, 6th edn. Oxford: Oxford University Press.

Çengel, Y. A., & Ghajar, A. J. (2011). Heat and mass transfer: A practical approach (4th ed.). McGraw-Hill.

Creswell, J. W. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. Sage publications.

Dai, Y., Liu, A., Qin, J., Guo, Y., Jong, M. S.-Y., Chai, C.-S. and Lin, Z. 2022. Collaborative construction of artificial intelligence curriculum in primary schools. Journal of Engineering Education, Vol. 112, No. 1. Hoboken, Wiley Periodicals LLC, pp. 23–42. Available at: https://doi. org/10.1002/jee.20503 (Accessed June 17, 2025)

Dewey, J. (2018). Democracy and education by John Dewey: With a critical introduction by Patricia H. Hinchey.

Downes S (2006). Learning Networks and Connective Knowledge. Retrieved from http://itforum.coe.uga.edu/paper92/paper92.htlm

Downes, S. (2005). An introduction to connective knowledge. Stephen's Web. http://www.downes.ca/cgi-bib/page.cgi?post=33034

Downes, S. (2019). Recent work in connectivism. European Journal of Open, Distance and E-Learning (EURODL), 22(2), 113-132.

Fitria, T. N. (2021, December). Artificial intelligence (AI) in education: Using AI tools for teaching and learning process. In Prosiding Seminar Nasional & Call for Paper STIE AAS (Vol. 4, No. 1, pp. 134-147).

Glaser, . R. (1984). Education and thinking: The role of knowledge. American Psychology, 39(2), 93–104.

Goldie JG. (2016). Connectivism: A knowledge learning theory for the digital age? Med Teach. 2016 Oct;38(10):1064-1069. doi: 10.3109/0142159X.2016.1173661. Epub 2016 Apr 29. PMID: 27128290.

Gupta, S. (2022). Learner-centred training design: a definitional review. International Journal of Human Resources Development and Management, 22(3-4), 167-179.

Hirst, W. (2022). Breaking from the Past: Bartlett's Role in Rethinking Memory: Remembering: A Study in Experimental and Social Psychology, Frederic Bartlett. Social Research: An International Quarterly, 89(2), 319-328.

Komerath, N. (2021). A technology countdown approach to historical timelines. Modified paper presented at the WAVES2020.

Lukan, E. (2025). The 55 Best AI Tools for 2025. https://www.synthesia.io/post/ai-tools

Mishra, P., & Koehler, M. J. (2006). Not "what" but "how": Becoming design-wise about educational technology. In Y. Zhao (Ed.), What teachers should know about technology: Perspectives and practices (pp. 99–122). Greenwich, CT: Information Age Publishing.

Prince, M., Felder, R., & Brent, R. (2020). Active student engagement in online STEM classes: Approaches and recommendations. Advances in Engineering Education, 8(4), 1-25.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4–14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57(1), 1–22.

Siemens, G., Rudolph, J., & Tan, S. (2020). "As human beings, we cannot not learn". An interview with Professor George Siemens on connectivism, MOOCs and learning analytics. Journal of Applied Learning and Teaching, 3(1), 108-119.

Siemens. G. (2005). Connectivism: A learning theory for the digital age. International Journal of Instructional Technology and Distance Learning. 2(1). Retrieved from http://www.itdl.org/Journal/Jan_05/article01.htm

Singh, S. V., & Hiran, K. K. (2022). The impact of AI on teaching and learning in higher education technology. Journal of Higher Education Theory & Practice, 12(13).

Tan, C., & Ng, C. S. (2021). Constructivism in education. In Oxford Research Encyclopedia of Education.

UNESCO. (2021). AI competency framework for teachers. United Nations Educational, Scientific and Cultural Organization. https://unesdoc.unesco.org/ark:/48223/pf0000377079

UNESCO. (2022). AI competency framework for students. United Nations Educational, Scientific and Cultural Organization. https://unesdoc.unesco.org/ark:/48223/pf0000381317

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.

Walshe, G. (2020). Radical constructivism—von Glasersfeld. Science education in theory and practice: An introductory guide to learning theory, 359-371.

Walshe, G. (2020). Radical constructivism—von Glasersfeld. Science education in theory and practice: An introductory guide to learning theory, 359-371.