Knowledge Requirement of Incorporating Artificial Intelligence in Engineering Education through TPACK

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Abstract
It is believed that Malaysians have no interest in the field of engineering education. Engineering curriculum development and educator development are neglected. As a result, most of engineering educators deliver the contents lack or without pedagogical knowledge. It becomes worst when they incorporate artificial intelligent applications in their classrooms without pedagogical knowledge. Therefore, this work is to create awareness among engineering educators about the knowledge that they need before using artificial intelligence in their classroom. The first author describes her experienced incorporating technology/artificial intelligence in engineering education. She discussed initial knowledge that engineering educators need before they are capable to teach a subject using artificial intelligence based on Technological, Pedagogical and Content Knowledge (TPACK) framework. However, this knowledge alone may not be translated into quality teaching. Therefore, the first author discussed Community of Inquiry (CoI) and she believes that CoI is a venue for engineering educators to simulate the knowledge. As a conclusion, TPACK can be modelled as engineering educators' professional knowledge and CoI as assessment method.

Keywords: Technology Knowledge, Pedagogy Knowledge, Content Knowledge, Engineering Education, Community of Inquiry.

Engineering Program in Malaysia

Engineering program in Malaysia are offered at both undergraduate and graduate levels that covers a wide range of topics. The quality of engineering programs controlled by Engineering Accreditation Council (EAC) and Board of Engineers Malaysia (BEM). The accreditation is carried out to ensure that the program produce competent and skilled engineers who met worldwide standards.

EAC standard is the foundation for the creation of engineering curricula. According to EAC Standard 2020 (Engineering Accreditation Council, 2020), an engineering program should have a minimum of 135 Student Learning Time (SLT) credits based on a semester of instruction that lasts 14 weeks. These credits should be divided into:

a) At least 90 SLT credits must be in engineering, including engineering sciences and projects relevant to the student's field of study.
b) The remaining SLT credits must have enough general education material to support the technical curricula material.

Figure 1 is a general description of the Malaysian engineering program.

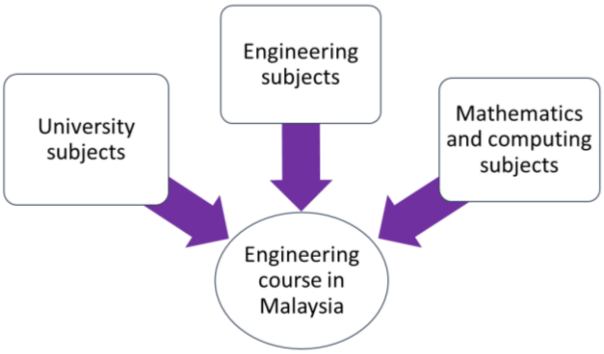

Figure 1. General description of the Malaysian Engineering Program

The components can be divided into three parts: university subjects with often general content, core subjects relevant to the student's area and computing and mathematics subjects. As a result of this structure, the curriculum is designed for students to obtain plenty chances with analytical critical, constructive, creative and evidence-based thinking within engineering complex problems. The sophisticated engineering activities, knowledge profile and problem-solving components of the curriculum are all taken seriously by EAC.

Artificial Intelligence in Engineering Education

Artificial Intelligence (AI): What it is? John McCarthy provides the following definition: *"It is the science and engineering of creating intelligent machines, particularly clever computer programs. Although it is related to the related to the related job of utilizing computers to comprehend human intellect, AI should not be limited to techniques that can be observed by biological means"* (Mccarthy, 2007). There are many applications of AI build for academic purposes. It is commonly seen in speech recognition, customer service, computer vision, healthcare, personal assistant and e-commerce are some of the more typical uses.

AI has the ability to enhance student learning and support engineering educators in the field of engineering education. Jose L. Martin Nunez & Andres Diaz Lantada introduced the concept of "artificial intelligence-aided engineering education" to describe the use of AI techniques and resources to enhance the entire teaching-learning process in higher education. Therefore, it has a big impact on engineering education, from curriculum planning and development to teaching and learning (T&L) strategies, teaching methods, assessment and on learning outcomes.

The most well-liked AI applications that currently used in engineering education is a generative pre-trained transformer model (GPT) called ChatGPT. It creates content in response to an interaction with a prompted query and order. On March 14, 2023, OpenAI released the latest ChatGPT, ChatGPT4. It is more collaborative and innovative than ever. When working with users on creative and technical writing activities like songwriting, screenwriting or figuring out a user's writing style, it can generate, edit and iterate with them.

According to ChatGPT features, engineering education can benefit from personalized learning, the development of critical thinking and problem-solving skills, the promotion of active learning, and the ability for students to receive rapid feedback on their works. Besides that, it can benefit students in researching new engineering topics, cutting-edge research and industry trends and can be used as a resource for strengthening engineering principles.

The application of AI in teaching and learning comes with debates. Most debates surround ChatGPT for concern on plagiarism and students' cheating (Anders, 2023). Yet, the potential of using ChatGPT for teaching and learning has been actively discussed in literatures for its potential to aid deep learning for users. Looking at this opportunity, this paper discussed the potential usage of ChatGPT within teaching and learning theory.

Incorporating Technology in Engineering Education Classroom

It takes more effort to integrate technology than just picking an application and utilizing it in class. The first author is passionate in incorporating technology into engineering lessons. The subjects she has taught are listed in Table 1.

The first author has been assigned to various topics each year, as seen in Table 1. Despite having only a few weeks to prepare before the start of the semester, she is extremely motivated to use technology into her teaching and learning activities (T&L). Therefore, according to her experience, there are challenges arose: (a) "what should be delivered?," (b) "how can be delivered?" and (c) "in what way technology can be incorporated? There often time which teaching engineering courses and university courses is not within her research area, making it an issue with teaching delivery. Later she discovered question on "how can be delivered" is actually related to the topic matter. Inability to digest the subjects' content for teaching, has directly affects how content is presented in lectures.

She begins experimenting with numerous technology applications that are available online or shared by colleagues. Table 1 shows how she made an effort to include technology into her lessons. ChatGPT is the recent technology aid adopted for teaching purposes. Regardless of the intention, the enthusiasm, however it does not count for the classroom design and effectiveness of delivery.

Table 1. List of subjects that has been assigned to the first author

Year	Semester	Course	Technology Used
20222023	2	Data Communications and Networks	Cisco Packet Tracer – Networking Simulation Tool, Wireshark, ChatGPT, UTM eLearning, Discord
		Extra-Curricular Experiential Learning (University Subject)	Google Form, Google Sheet, UTM eLearning, Discord
	1	Capstone Project	Google Form, Jamboard, Discord
		Network Programming	Python, UTM eLearning, Discord
		Graduate Attribute (University Subject)	Jamboard, Coggle, UTM eLearning, Discord
20212022	2	Data Communications and Networks	Cisco Packet Tracer – Networking Simulation Tool, Discord, Wireshark, Zoom, UTM eLearning

		Graduate Attribute (University Subject)	Padlet, Discord, UTM eLearning
		Computer & Communication Networks	Zoom, UTM eLearning, Discord, UTM eLearning
	1	Signals & Systems	Explain Everything, Zoom, Jamboard, Discord, UTM eLearning
		Capstone Project	Google Form, Jamboard, Miro, Discord
		Graduate Attribute (University Subject)	Padlet, Discord, UTM eLearning
20202021	2	Electromagnetic Field Theory	edpuzzle, CMap, Zoom, Discord, UTM eLearning
	1	Introduction to Scientific Programming	MATLAB, Discord, UTM eLearning
		Capstone Project	Google Form, Jamboard, Miro, Discord
		Graduate Attribute (University Subject)	Padlet, Discord, UTM eLearning
20192020	2	Introduction to Scientific Programming	MATLAB, UTM eLearning
		Digital Electronic	Kahoot, UTM eLearning
	1	Signals & Systems	MATLAB, UTM eLearning
		Capstone Project	Miro
		Graduate Attribute (University Subject)	Google Form, UTM eLearning
20182019	2	Network Programming	Python, Sketchboard, UTM eLearning
		Broadband & Multimedia Networks	Network Simulator 3 (NS3), UTM eLearning
	1	Signals & Systems	Padlet, Schoology, MATLAB, UTM eLearning
		Capstone Project	Miro, UTM eLearning
20172018	2	Digital Electronic	Jigsaw Planet, Quartus II, UTM eLearning
	1	Signals & Systems	Padlet, MATLAB, UTM eLearning
		Capstone Project	Miro, UTM eLearning
20162017	2	Electronic	UTM eLearning
		Electronic Circuit	UTM eLearning
	1	Signals & Systems	Padlet, MATLAB, UTM eLearning
		Capstone Project	Miro, UTM eLearning

One of her major entry points to make the delivery theoretically driven is keynote lecture on Technological, Pedagogical, and Content Knowledge (TPACK). Coincidentally, the keynote speaker at one of the conferences she was attending had discussed the TPACK framework. She then realized that picking and implementing technology in the classroom is more complicated than she had previously thought.

Having this conversation reflectively allow existing practice to be continuously questions for further improvement. With strong commitment for engineering education, attending engineering education conferences and publishing articles is meaningful as part of professional growth in becoming good engineering educator.

Technological, Pedagogical and Content Knowledge (TPACK) Framework

A theory of knowledge is necessary for engineering educators in order to help them make sense of what they are doing and to give them control over their own inquiry processes. The theory of knowledge can be characterized as the practical knowledge of engineering educators, which refers to knowledge that has mostly been acquired through educator's professional experience. By examining the "what, how, and why" of information, engineering educators' knowledge can be evaluated. The "what" are the contents, the "how" are the methods of delivery and the "why" explain why the contents and methods of delivery should be adapted to particular disciplines.

Sadly, there is a dearth of pedagogical and philosophical understanding among engineering educators (Ghazali et al., 2021). Making things getting worse when engineering educators lack the experience to use technology. Talking about technology, many of engineering educators received their degrees at a time when educational technology was not as advanced as it is now. As a result, engineering educators lack the knowledge and confidence to integrate technology in T&L. However, to remain relevant as educator in a higher education institution, engineering educators must adapt to the contemporary environment, which includes the existence of AI in the education sector.

Several works used TPACK to enhance engineering education when integrate technology in T&L. (Fahadi & Khan, 2022; Khalid et al., 2023; Maria Moundridou &

Kyparisia A. Papanikolaou, 2017; Mutanga et al., 2018). The TPACK framework was introduced by Punya Mishra and Mathew Koehler in 2005. It is an extension from Schulman's proposed pedagogical content knowledge (PCK) in 1986 (Koehler & Mishra, 2009). The basis of PCK was that pedagogy and knowledge are two different types of knowledge that can intersect to produce new types of knowledge, such as information about how to teach content in a given subject area. Another new dimension of knowledge is introduced in TPACK through the use of technology in T&L as shown in Figure 2. The technology is referred to as AI implementation in a classroom environment in the discussion context of this paper.

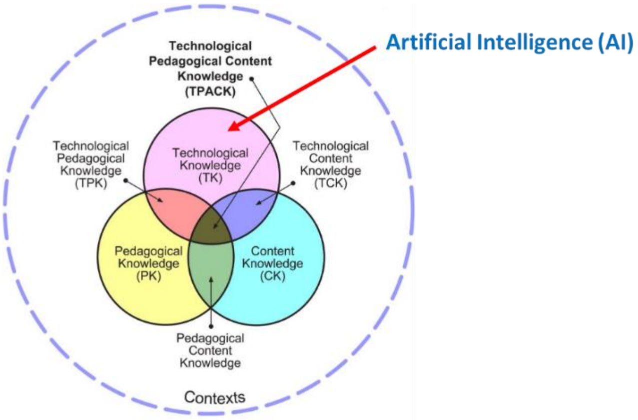

Figure 2. TPACK (Koehler & Mishra, 2009)

A. *Content Knowledge (CK)*

Going back to "what", "how" and "why" in the first paragraph, content knowledge (CK) represents "what", which this is seen from engineering educators' subject-specific knowledge. The material that must be covered in university subject is distinct from the material that must be covered in engineering core subjects. For instance, Graduate Success Attributes course. This domain specific knowledge would comprise understanding of concepts, theories, ideas, organizational frameworks, understanding of evidence and proof as well as understanding of established processes and methods for acquiring such information, as mentioned by Shulman (1986).

Knowing the deeper knowledge principles of the subjects that engineering educators need to teach is important for engineering educators because knowledge and the nature of research vary widely throughout fields. For instance, in the context of engineering, this would entail familiarity with engineering facts and ideas, the engineering method and evidence-based reasoning. Lack of solid foundation in subject matter knowledge can be costly; for instance, educators may give lectures that are shallow (read from slides alone), convey inaccurate information and worst-case lead to student misconceptions.

B. *Pedagogical Knowledge (PK)*

Pedagogical knowledge (PK), which refers to educators' knowledge of the T&L procedures, methods, and strategies, provided the solution to the "why" question. This encompasses broader educational concepts, principles, and objectives. Teachers should be able to understand how students acquire knowledge, develop skills, establish learning routines, and foster positive learning attitudes. Therefore, understanding cognitive, social and developmental theories of learning as well as how to apply them in the classroom is a requirement for engineering educators.

C. *Pedagogical Content Knowledge (PCK)*

Pedagogical content knowledge (PCK) is overlapping between content and pedagogy that creates a new knowledge that involves teaching and learning methods, curriculum, assessment and reporting, circumstances that foster learning, as well as connections between pedagogy, curriculum and assessment. Effective instruction links students' prior knowledge to alternative teaching strategies that accommodate common misconceptions and strategies for addressing them. Additionally, engineering educators that have PCK will have T&L approaches that are flexible and take into account different perspectives on the same problem or idea.

D. *Technology Knowledge (TK)*

Technology knowledge (TK) cannot be defined due to its shifting nature (Koehler & Mishra, 2009). Technology advancements happen quickly. Thus, engineering educators must adapt to these changes in order to stay relevant throughout a lifetime of open-ended involvement with telecommunication technology.

E. *Technological Content Knowledge (TCK)*

Technological content knowledge (TCK) outlines the interactions between technology and content. It is important to know which technology is better suited to conveying the content of any discipline. Technology might limit the types of delivery method that are feasible, but it can also make it possible to create newer and more diversified delivery method.

Engineering educators should master more than the subject matter that they teach; they also need to be aware of the particular technology that are the most effective for addressing subject-matter learning in their fields as well as how the technology may very depend on the content.

F. *Technological Pedagogical Knowledge (TPK)*

Technological pedagogical knowledge (TPK) discusses how engineering educators understand the usage of particular technologies that can affect T&L. It includes being aware of the pedagogical possibilities and constraints provided by various technology tools, taking into account how well they connect with suitable pedagogical designs and techniques within particular disciplinary contexts and developmental contexts.

Engineering educators must understand how various technologies might help or hurt students' learning outcomes and how to successfully incorporate them into lesson plans. With this knowledge, engineering educators may decide how best to employ technology to improve the teaching and learning process.

G. Technological Pedagogical Content Knowledge (TPACK)

The term "TPACK," or technological pedagogical content knowledge, refers to a broad and integrated body of knowledge that combines content, pedagogy and technology. It results from the interplay between these three fundamental components.

Engineering educators must comprehend how concepts can be represented using technology, how pedagogical methods can use technology to effectively teach content and how technology can address students' learning obstacles if they are to possess TPACK. Engineering educators also need to understand students' prior knowledge, epistemological ideas and how technology can help reinforce epistemologies.

Engineering educators should incorporate TPACK because every teaching circumstance comes across mixes material, pedagogy and technology in a different way. There isn't a single technology answer that works for all lecturers, subjects or teaching styles. The ability of engineering educators to navigate the intricate interactions between curriculum, pedagogy and technology within particular situations leads to effective solutions.

Oversimplified solutions or failure might result from disregarding the complexity of any knowledge component or the relationships between them (Koehler & Mishra, 2009). Engineering educators must therefore acquire fluency, cognitive flexibility and a nuanced awareness of the relationships between content, pedagogy and technology in various contextual contexts. Consideration of TPACK as a professional knowledge construct requires this in-depth knowledge of teaching using technology.

Community of Inquiry (CoI) Framework

Upon reviewing TPACK literatures, she made an attempt to take part in pedagogy and technology-related training. Community of Inquiry (CoI) complements TPACK framework, where TPACK examines the theory, while CoI examines the implementation of the technology. She published a papers discussing online class design using CoI (Ghazali, 2021). The framework of CoI is illustrated in Figure 3.

As described above, the relationship between TPACK and existing practices is seamless. One reasons for that is the clear relationship between TPACK components to be modelled by engineering educators as their professional knowledge. Holding this knowledge may not be translated into quality teaching. This is how, the first author experience frustration when realizing activities designed for students is disengaging. Since TPACK can be considered as cognitive pre-requisite for engineering educator, CoI on the other hand has its role as venue for educators to simulate the knowledge.

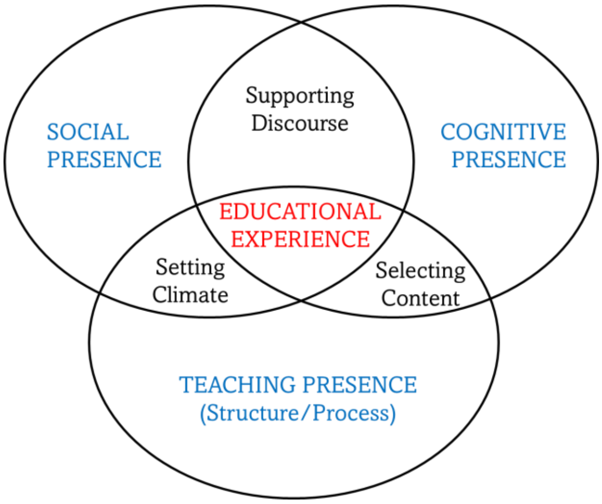

Figure 3. Community of Inquiry (CoI) Framework

CoI consists of three essential elements which are social presence, cognitive presence, and teaching presence that develop educational experience. Social presence creates open communication, group cohesion, and a trusted environment. Cognitive presence relates to learners who are able to construct and confirm meaning through the developmental phases of inquiry – a triggering event, exploration, integration, and resolution. The third element, teaching presence is linked with the design facilitation and direction of a community of inquiry. In summary, CoI is where "students listen to one another with respects, build on another's ideas, challenge one another to supply reasons for otherwise unsupported opinions, assist each other in drawing inferences from what has been said, and seek to identify one another's assumptions" (Lipman, 2003). CoI framework is based on the collaborative and individually constructivist learning experience.

Discussion

Based on her experienced, she would like to make a few suggestions to improve the quality of engineering students because they are output of the program. The ideas have been divided into two categories: faculty management and engineering educators.

Faculty Management

According to the TPACK framework, engineering educators must be knowledgeable about the subject, pedagogy, the technology he plans to employ, and knowledge of how all of these relate before they can begin teaching. Therefore, if the management wants the engineering educators to teach something that is not in the field, support such as holding training that will be conducted by someone in engineering education field not from education and pairing the engineering educators with engineering educators who is an expert in the subject will help the 'new' engineering educators to develop themselves before they start to teach. Furthermore, allowing engineering educators especially who are just started the career to teach for at least three semesters before being changed to a new subject. The goal of this is to give the engineering educators to make reflection of their lessons and improve them.

Engineering Educators

Engineering educators themselves must reflect on their own teaching methods and work with an education specialist to create their reflection, which must then be published. The T&L activities are actually greatly improved by this way.

Conclusion

As mentioned earlier, incorporating technology or in this case we are focusing on AI, is not just picking the application. It is beyond that. It is actually a process, where it involves input to the engineering educators, processing of the input and assessment of the process as shown in Figure 4.

Engineering educators should aware that they need input that is mentioned in TPACK framework. The results obtained by this TPACK framework becomes input to the implementation in the class. The input is processed during the implementation in the classroom. From the implementation, assessment can be done using CoI frameworks, to check either planning from TPACK is worked or not. If it does not work, the reason of it should be identified either from input or process of the input.

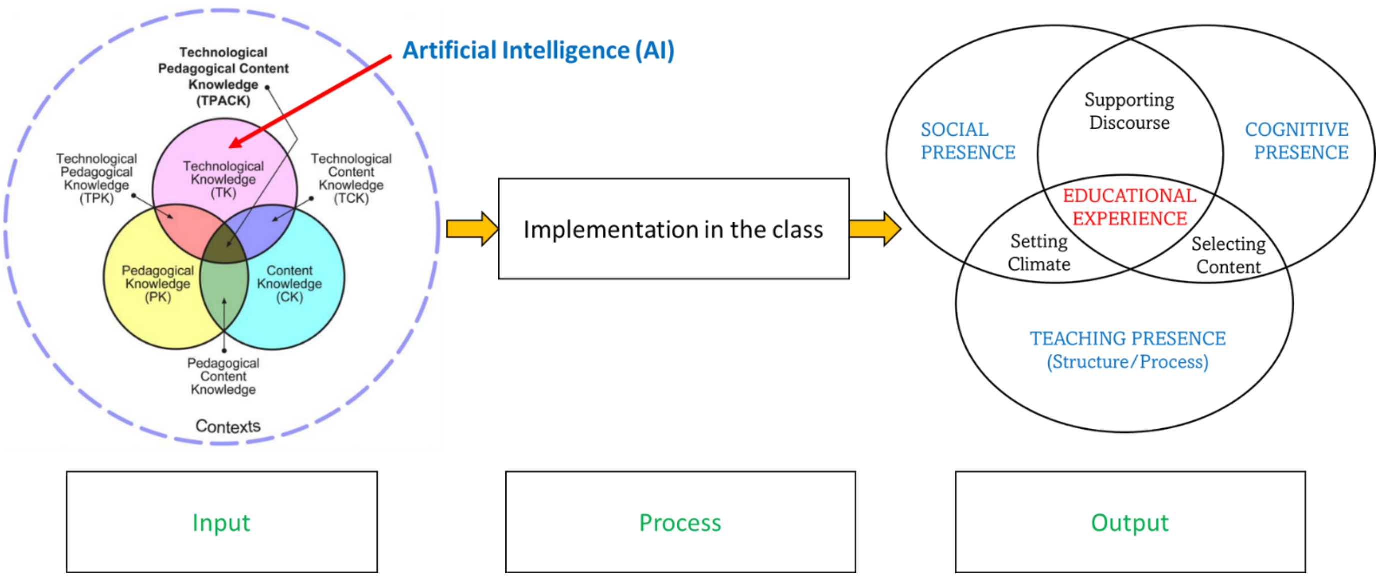

Figure 4. Knowledge requirement for engineering educators

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