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Editorial Brief

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We are delighted to present Volume 9, Issue 1 of the ASEAN Journal of Engineering Education (AJEE), which showcases nine timely and thought-provoking contributions that reflect the diverse, evolving, and interdisciplinary nature of engineering education across the ASEAN region and beyond. The articles in this issue offer rich insights into pedagogical innovation, technological integration, faculty development, and student-centered approaches that are shaping the future of engineering education.

The opening article investigates how scaffolded support in project-based learning (PjBL) influences students' development of metacognitive skills. Framed by Vygotsky's Zone of Proximal Development and constructivist learning theories, the study demonstrates that carefully layered scaffolding, such as reflective prompts and structured feedback, significantly enhances students' self-monitoring, comprehension, and motivation, particularly in cross-cultural design challenges.

A related study rethinks architectural engineering education by introducing adjustable boundary conditions within PBL environments. The findings suggest that balancing design freedom with structured parameters enhances creativity, technical understanding, and learner motivation, while also offering instructors a scalable framework to manage varying degrees of project complexity.

From a psychological perspective, one contribution highlights the strong influence of emotional intelligence on job satisfaction and performance among electrical and electronic engineering lecturers in polytechnics. The study emphasizes the value of integrating emotional intelligence training into faculty development programs to foster more resilient and effective teaching professionals.

Three papers in this issue focus on the theme of professional and pedagogical development. A qualitative analysis of immersive bootcamp-style training reveals how collaborative, experiential formats can reignite lifelong learning motivation among educators, encouraging the adoption of active learning, PBL, and digital tools. Complementing this is a comprehensive review of research methodologies in the Scholarship of Teaching and Learning (SoTL), which serves as a practical guide for educators seeking to conduct meaningful classroom-based research. A third article in this cluster reviews a foundational book on teaching transversal skills, advocating for the integration of communication, sustainability, and emotional regulation competencies into engineering curricula through play-based learning and tangible tools.

Reflective teaching practice is further explored through a narrative inquiry documenting the integration of service learning into a chemical engineering course. The study illustrates how community engagement initiatives not only deepen technical understanding but also cultivate leadership, communication, and reflective skills among students, highlighting the transformative potential of experiential learning in engineering education.

Two additional contributions turn to technology integration as a critical enabler of future-ready learning. A case study from the UAE explores the application of artificial intelligence tools such as ChatGPT and MATLAB Simulink in chemical engineering courses, demonstrating enhanced student engagement and personalized learning, while also addressing challenges related to ethics, access, and over-reliance. Another article examines the impact of integrating Learning Management Systems (LMS) with Six Sigma 4.0 in industrial training, revealing substantial improvements in knowledge retention, project outcomes, and process efficiency through data-driven, real-time feedback mechanisms.

Together, these articles reflect the field's commitment to continuous improvement, interdisciplinary collaboration, and responsiveness to emerging challenges in education and industry. As engineering education continues to evolve in the face of technological disruption and complex global demands, this issue offers valuable frameworks, evidence, and inspiration for educators, researchers, and policy-makers alike.

We trust that the insights presented in this issue will contribute meaningfully to ongoing conversations in engineering education and support the advancement of effective, inclusive, and future-forward teaching practices.

Assoc. Prof. Dr. Zaki Yamani Zakaria

Chief Editor,

ASEAN Journal of Engineering Education

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Contents

The Impact of Scaffolding on the Development of Metacognitive Skills in Project-Based Engineering Learning 1 - 10

Jinye Jia, Nurzal Effiyana Ghazali, Eileen Su Lee Ming, Mitra Mohd Addi

Rethinking Structural Design Education through Boundary Conditions and Design Flexibility in PBL 11 - 21

Semih Yildirim, Stuart Baur

Psychological Implication of Emotional Intelligence on Job Satisfaction and Performance of Electrical/Electronics Lecturers in Polytechnics in Southwest Nigeria 22 - 29

Olatunji Oriola Fadairo, Olusiji Olaseni Lemo, Mukaila Abiodun Yisa, Isaac Adeleye Aiyemoboye, Idowu Dare Aderinto

Enhancing Lifelong Learning Motivation Among Experienced Educators: A Qualitative Analysis of Bootcamp-style Professional Development 30 - 39

Mohammad Tazli Azizan, Brandon Liau, Fadzlina Mokhtar

Teaching Transversal Skills For Engineering Students: A Book Review 40 - 48

Jesse Totong, Tian Ye, Umawathy Techanamurthy

Seeing Growth Through Service Learning: My Journey with Separation Processes 49 - 57

Mazura Jusoh

A Review of SoTL Research Methodologies: A Guide to Conceptualizing and Conducting the Scholarship of Teaching and Learning 58 - 63

Mohamad Syahrul Nizam Ibrahim, Amirah Sariyati Mohd Yahya

Artificial Intelligence Integration for Shaping Future Engineering Education at Higher Colleges of Technology, UAE 64 - 72

Abdelrahim Mohamed Minalla

Optimizing Industrial Training in Industry 4.0: A Mixed-Methods Validation of an Integrated LMS and Six Sigma 4.0 Framework 73 - 80

Hanafi Ahmad, Nurul Fadly Habidin, Ahzila Wahida, Jamilahtun Md Ghazali, Farah Idayu Mohd Salleh, Rahimah Kasim, Zamrin Md Zin

The Impact of Scaffolding on the Development of Metacognitive Skills in Project-Based Engineering Learning

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Abstract
This research explores the impact of scaffolding in Project-Based Learning (PjBL) on the development of students' metacognitive skills. Metacognitive skills are crucial in engineering courses as they enable students to navigate complex tasks by self-monitoring and adjusting strategies. The research designed a multi-layered scaffolding approach incorporating structured tasks, staged feedback, reflective prompts, and group discussions to support learning and reflection in a "Cultural and Technological Food Cart Design Challenge." Based on Vygotsky's Zone of Proximal Development (ZPD) and constructivist theories, the scaffolding provided guidance at various learning stages, progressively enhancing students' understanding, monitoring, and information management skills. Using a mixed-method approach, quantitative data were collected through the Metacognitive Awareness Inventory (MAI) to track metacognitive progress, while qualitative data from daily reflection logs captured students' experiences. Results showed significant improvements in metacognitive skills in comprehension monitoring and information management ($p < 0.05$), though limited project duration restricted the development of planning and self-evaluation skills. The research offers optimization insights for scaffolding in PjBL, particularly highlighting the positive effects of scaffolding on emotional regulation and self-motivation in cross-cultural projects, providing a reference for future pedagogical practices in complex tasks.

Keywords: Project-Based Learning (PjBL), scaffolding, metacognitive skills, engineering project, cultural and technology design.

Introduction

Background and Problem

In modern engineering project courses, cultivating students' metacognitive skills is crucial (Jumaat et al., 2017). Metacognition refers to students' ability to recognize and regulate their learning processes, which directly impacts their performance in complex projects. Students with strong metacognitive skills are not only able to effectively handle uncertainties within projects but also continuously improve their performance and learning outcomes through self-assessment and strategy adjustments during task execution. In recent years, Project-Based Learning (PjBL) has gained widespread attention as a practice-oriented teaching approach (Admawati et al., 2018; Pokharel, 2021). Through the simulation of real-world tasks, PjBL helps students apply theoretical knowledge within projects, fostering critical thinking and problem-solving abilities. Compared to traditional exam-focused teaching models, PjBL is better suited for developing the core skills required of modern engineers, such as lifelong learning, decision-making, and teamwork.

In this context, Vygotsky's theory of the Zone of Proximal Development (ZPD) and constructivist theory provide theoretical support for scaffolding techniques in PjBL (Rahayu et al., 2022). ZPD theory posits that students achieve optimal learning outcomes within the "zone of proximal development," where, with appropriate support, they can accomplish tasks they would otherwise be unable to complete independently. In PjBL, scaffolding serves precisely this role by providing essential support that gradually leads students to achieve higher levels of task

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accomplishment. Constructivist theory, on the other hand, emphasizes that knowledge is constructed through active participation and accumulated experience (Jumaat et al., 2017). PjBL, through real task implementation and reflection, offers an environment that enables students to construct knowledge autonomously and continuously enhance their learning.

Traditional engineering project courses often focus on knowledge transmission, with assessments used to gauge students' mastery of the material. In PjBL, however, students engage in actual projects, solve real-world problems, and progressively build a structured knowledge base and skill set. The core of PjBL is to encourage students to learn and explore actively through realistic project tasks (Admawati et al., 2018; Blumenfeld et al., 1991). Nevertheless, the effectiveness of PjBL largely depends on the appropriate application of scaffolding support. Scaffolding, through structured guidance and staged feedback during the learning process, helps students achieve project goals incrementally, thereby effectively enhancing their self-management and regulatory abilities (Pokharel, 2021).

This research integrates reflective prompts and guided feedback, rooted in Vygotsky's ZPD theory and the cultural diversity of task design (Vygotsky & Cole, 1978). Unlike the scaffolding approaches described by Blumenfeld et al. (1991), which are predominantly applied in single-discipline projects, this research incorporates a multi-layered task breakdown and staged feedback within a cross-cultural context (Blumenfeld et al., 1991). This design not only enhances students' task management and reflective skills but also fosters their cultural adaptability and collaboration (Jumaat et al., 2017).

Significance of the research

The core function of scaffolding in PjBL lies in providing students with phased support and feedback, giving them clear guidance at each project stage, and encouraging timely reflection and adjustments. Existing research suggests that scaffolding plays a vital role in enhancing metacognitive skills (Jumaat et al., 2017; Pokharel, 2021). First, scaffolded support helps students effectively monitor their learning progress, integrate information, and apply knowledge to manage complex tasks (Admawati et al., 2018; Blumenfeld et al., 1991). Additionally, the staged feedback mechanism in scaffolding encourages students to reflect on and modify their learning strategies, fostering a sense of self-regulation, which is especially critical in engineering projects (Rahayu et al., 2022). For instance, scaffolding can help students quickly adjust strategies when encountering challenges, ensuring that the project progresses as planned.

In engineering project courses, cultivating metacognitive skills generally encompasses various aspects, such as task comprehension and monitoring, information management, learning plan adjustments, and self-reflection. Based on Vygotsky's ZPD theory, scaffolded support gradually reduces external assistance, guiding students to transition from relying on scaffolds to independently completing tasks, thereby continuously expanding their cognitive and knowledge application capabilities (Jumaat et al., 2017; Pokharel, 2021). Constructivist theory, in turn, highlights that through hands-on practice and autonomous exploration, students in PjBL not only acquire knowledge but also develop critical thinking and independent problem-solving skills (Admawati et al., 2018).

Building on existing PjBL frameworks, this research enhances students' metacognitive skills in complex tasks by employing a multi-layered scaffolding strategy. It incorporates a systematic support mechanism that includes structured tasks, staged feedback, reflective prompts, and group discussions, tailored to the needs of different learning stages, and helping students improve their comprehension monitoring and information management skills (Blumenfeld et al., 1991). Additionally, this research's "Cultural and Technological Food Cart Design Challenge" project introduces a real-world application scenario with cross-cultural elements, allowing students to gain in-depth experiences of diverse cultures through PjBL. This design enhances the realism and engagement of the project, helping students develop skills in information integration and adaptability across various cultural settings.

This research also adopts a mixed-method approach, combining quantitative analysis using the Metacognitive Awareness Inventory (MAI) with qualitative data from daily reflection logs, providing a multi-dimensional evaluation of scaffolding effectiveness, and ensuring empirical validity of the results (Pokharel, 2021; Rahayu et al., 2022).

Through a project-based design and multi-level support system, this research offers practical insights for optimizing scaffolding techniques in PjBL, particularly by providing innovative educational recommendations for diverse feedback and promoting self-regulation. These findings not only offer direction for improving teaching practices in engineering project courses but also lay a solid theoretical and practical foundation for future applications of scaffolding in cross-cultural and complex task environments.

Research Objectives

The primary aim of this research is to investigate how the integration of scaffolding techniques in PjBL engineering project courses can enhance students' metacognitive skills. Figure 1 illustrates the objectives are as follows:

1. *Evaluate the impact of scaffolding on students' comprehension monitoring, information management, and planning skills:* This objective

involves analyzing how scaffolding assists students in better understanding project requirements and enhancing efficiency in information processing and task management (Hobri, 2021). By providing clear task descriptions and goal breakdowns at the start of the project, scaffolding aims to establish a comprehensive understanding of the task, thereby facilitating subsequent information integration and application.

2. *Examine the long-term effects of structured support on students' self-regulation and reflective abilities:* This objective evaluates how scaffolding aids students in gradually developing reflective and self-regulatory skills during the project execution phase, thereby supporting future learning and improvement in similar projects (Jumaat et al., 2017).
3. *Provide optimized recommendations for applying scaffolding in engineering project courses* (Jalinus et al., 2023)*:* Based on the research's findings, this objective aims to offer practical methods for implementing scaffolding in engineering project-based courses to effectively develop students' metacognitive skills. For instance, by incorporating staged feedback mechanisms and designing reflective tasks, scaffolding can be optimized to help students enhance self-management and regulatory capabilities.

This research employs a mixed-methods approach, systematically evaluating the effectiveness of scaffolded support in PjBL tasks. Figure 1 illustrates the theoretical framework underlying this research, which integrates the principles of scaffolding and Project-Based Learning (PjBL) to develop students' metacognitive skills (Jumaat et al., 2017). The findings will provide theoretical and practical guidance for designing and implementing scaffolding in engineering project courses, thus enhancing students' metacognitive development and self-regulation in future educational practices (Blumenfeld et al., 1991).

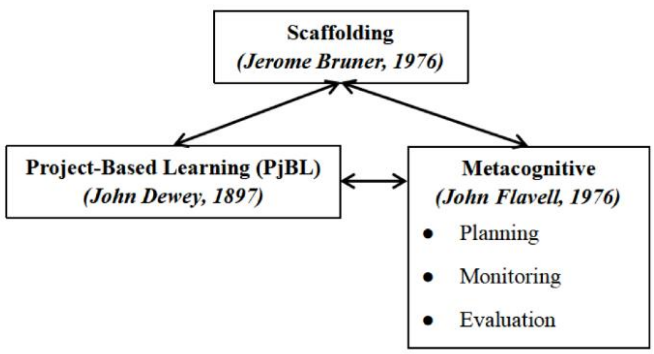

Figure 1. Theoretical Framework

Research Methodology

Research Design

This research adopts a mixed-methods research design, combining quantitative and qualitative analyses to evaluate the impact of scaffolded support on the metacognitive skills of students (Rahman et al., 2022). Participants engaged in a seven-day "Cultural Innovation Journey" project, with the central task being the "Cultural and Technological Food Cart Design Challenge."

The research involved 25 undergraduate students from diverse academic backgrounds. Although the gender distribution was uneven, efforts were made to balance the groups by ensuring similar gender ratios within each team. Teams were organized based on personality types (e.g., introversion/extroversion, determined by the MBTI test) and learning styles (e.g., visual, auditory, reading/writing, kinesthetic, based on the VARK questionnaire) to foster diversity and collaboration within each group (Rahman et al., 2022). This grouping strategy included a range of introversion/extroversion traits and multiple learning styles to maximize complementary skills among team members, maintain team dynamic balance, minimize external influences on scaffolding support outcomes, and provide a foundation for subsequent data analysis.

Figure 2 illustrates the scaffolding techniques were integrated into this multi-stages, cross-cultural project task to assess their effectiveness in enhancing metacognitive skills, such as comprehension monitoring, planning, and self-reflection (Pokharel, 2021). This theoretical framework is largely based on the Zone of Proximal Development (ZPD) introduced by Lev Vygotsky in 1978, which emphasizes that learning occurs most effectively within a 'zone' where students can achieve tasks with appropriate guidance that they could not accomplish independently. Additionally, constructivist theory, as outlined by Piaget, highlights the role of active participation and experience accumulation in knowledge construction (Blumenfeld et al., 1991; Vygotsky & Cole, 1978).

Scaffolding Support Design

In alignment with scaffolding theory, this research integrated the following scaffolding support measures in the PjBL activities to enhance students' metacognitive regulation (Hobri, 2021):

1. *Structured Steps:* The main project task was divided into multiple subtasks, each with clear goals and steps. For example, on the first day, students were tasked with observing cultural landmarks, examining architectural elements, cultural symbols, and culinary choices (Jalinus et al., 2023). This structured steps design focused students' attention on fundamental elements, fostering their development of design thinking.

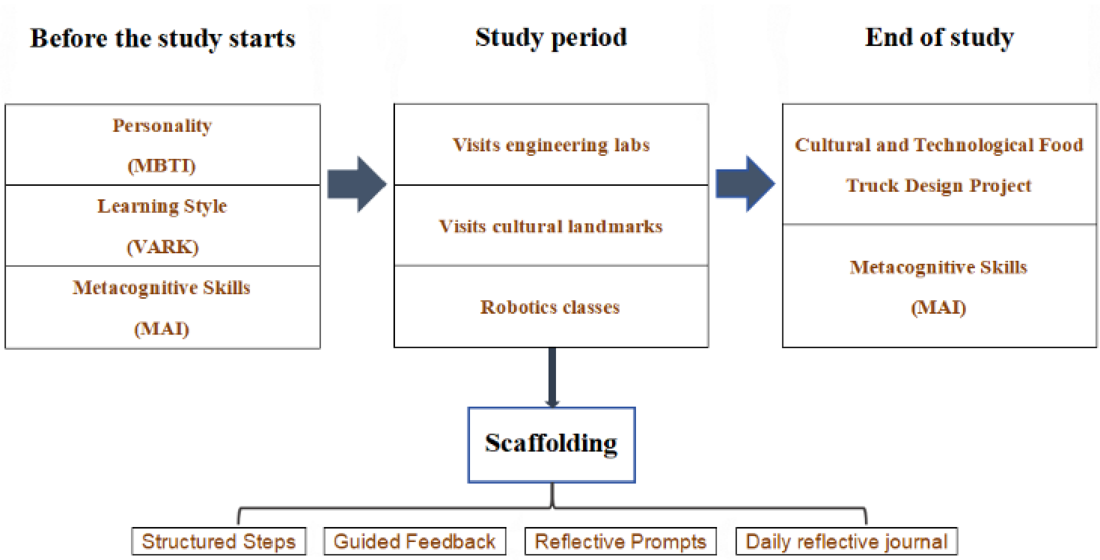

Figure 2. Project Framework

2. *Guided Feedback:* Feedback was provided at critical points based on project stages. At the end of each day, students received feedback on their observations and thought processes, particularly with reflective prompts on the second day and design reports on the third day (Blumenfeld et al., 1991). This feedback helped students reflect on their progress and adjust strategies to complete their tasks effectively.
3. *Reflective Prompts:* Daily reflective tasks were assigned to encourage students to document their design thinking processes, thereby promoting metacognitive skill development. Reflection logs included main observations, design inspirations, challenges encountered, and solutions attempted each day, enabling students to review and adjust their learning strategies throughout the process.
4. *Group Discussions （daily reflective journal and truck design project ）*: Each project phase incorporated group discussions and reporting tasks, where team members shared diverse perspectives to enrich understanding and improve design plans. Group discussions provided an interactive platform where students could gain insights from peers' feedback, further expanding their design thinking.

The task breakdown followed a multi-phase approach. For example, on the first day, students were assigned to observe cultural landmarks and extract architectural and cultural symbols; on the second day, they recorded their observations in reflective journals and shared their findings with team members (Pokharel, 2021). This step-by-step approach helped students decompose complex tasks and integrate cultural elements into their designs. Staged feedback was implemented through daily instructor reviews and group discussions, enabling students to adjust their learning strategies. For instance, one student shifted from 'simply imitating cultural symbols' to 'integrating multiple cultural elements into the design' following feedback.

Data Collection and Analysis

Multiple data collection methods were employed to ensure comprehensive and reliable results:

1. *Quantitative Data:* The Metacognitive Awareness Inventory (MAI) was used to assess students' metacognitive skills before and after the project. The MAI evaluates metacognitive abilities across four dimensions: comprehension monitoring, information management strategies, planning, and evaluation (Andari et al., 2020). A paired-sample t-test was applied to analyze changes in MAI scores pre- and post-project, assessing the effectiveness of scaffolding support.
2. *Qualitative Data:* Daily reflection logs and group feedback captured students' in-depth experiences related to task comprehension, strategy adjustments, and changes in metacognition. Coding and thematic analysis were conducted on qualitative data to identify behavioral changes in learning under various scaffolding support conditions and to explore metacognitive behaviors across different project stages (Rahayu et al., 2022).

Data Analysis Methods:

1. *Paired-Sample t-Test:* This test was conducted to analyze pre- and post-test MAI scores, verifying the statistical significance of scaffolding support in enhancing metacognitive skills (Rahayu et al., 2022).
2. *Thematic Analysis:* Qualitative analysis software (e.g., NVivo) was used to conduct thematic analysis on the reflection logs, focusing on students' expressions related to comprehension monitoring, planning adjustments, and reflective

evaluation (Pokharel, 2021). This helped to identify specific effects of scaffolding support.

3. *Correlation Analysis:* Relationships between different dimensions of metacognitive abilities in the quantitative data were examined, exploring interactions among comprehension monitoring, planning, and evaluation influenced by scaffolding techniques (Jumaat et al., 2017).

This research design ensures that quantitative and qualitative data complement each other, providing a multidimensional understanding of scaffolding support's role in enhancing metacognitive skills within PjBL tasks. By integrating quantitative and qualitative data, this research aims to capture the complex effects of scaffolding on metacognitive skills and offer empirical insights for optimizing scaffolding design in engineering projects.

Results

Quantitative Results

Table 1 tabulates the quantitative results from the MAI assessment, summarizing the changes in students' metacognitive skills across various dimensions before and after the project (Andari et al., 2020; Pokharel, 2021). It highlights significant improvements in comprehension monitoring and information management strategies. It demonstrates a significant improvement in students' metacognitive skills related to comprehension monitoring and information management strategies ($p < 0.05$), indicating that scaffolding support has a direct positive impact on students' reflective and information-processing abilities within project tasks (Andari et al., 2020). However, no significant improvement was observed in planning and self-evaluation ($p > 0.05$) (Čavić et al., 2023). Detailed quantitative analyses are as follows:

- *Significant Improvement in Comprehension Monitoring:* The average score for comprehension monitoring increased from 3.96 (pre-test) to 4.92 (post-test), reflecting an enhanced ability to reflect and understand the project process (p = 0.015) (Wengrowicz et al., 2018). For example, on day five, student A observed the layout of cultural landmarks and, with feedback from the instructor, was able to integrate her observations into her design by day seven. This suggests that with scaffolding support, students could more effectively monitor and adjust their learning strategies.
- *Improvement in Information Management Strategies:* Students' average score in information management strategies rose from 7.20 to 7.92 (p = 0.031), indicating an increased capacity to integrate and manage multiple sources of information (Marra et al., 2022). Specific feedback examples include student B, who noted the transition from observing colorful architecture to designing a food cart incorporating natural elements. This highlights their improved ability to synthesize and apply information in a cross-cultural project setting.
- No Significant Improvement in Planning and Self-Evaluation: No significant changes were observed in students' scores for planning and self-evaluation ($p > 0.05$), which may be attributed to the short project duration, as it limited opportunities for deep reflection and self-regulation (Sart, 2014). Some students reported that the project's time constraints and task demands made it challenging to engage in systematic planning and comprehensive reflection. For instance, student C noted that, within the limited timeframe, she could only perform basic reflection without the opportunity to delve into higher-level planning and self-evaluation strategies (Marra et al., 2022). The limited improvement in planning and self-evaluation skills can be attributed to the short duration of the project (Kazanjian, 2023). Several students noted in their reflective journals that, due to time constraints, they prioritized task completion over comprehensive project planning. For example, Student C stated, 'Despite the feedback, I primarily focused on the immediate tasks rather than engaging in detailed planning.' This indicates that short-term projects may not provide sufficient practice opportunities for the development of advanced metacognitive skills.

Table 1. Results for Metacognitive Skills

Metacognitive Skill	Pre-Test Mean	Post-Test Mean	p-value
Declarative Knowledge	5.24	5.48	0.282
Procedural Knowledge	2.68	2.92	0.341
Conditional Knowledge	3.80	3.68	0.612
Planning	4.48	4.64	0.527
Comprehension Monitoring	3.96	4.92	0.015*
Information Management Strategies	7.20	7.92	0.031*
Debugging Strategies	4.28	4.32	0.852
Evaluation	4.20	4.32	0.588

Qualitative Results

Table 2 demonstrates the thematic analysis of students' daily reflection journals and feedback. This research found that scaffolding support gradually enhanced students' task comprehension, information management, and flexibility in problem-solving strategies (Andari et al., 2020). Figure 3 shows students' feedback where all participants agreed that the PjBL experience not only broadened their perspectives and deepened their understanding of unique local cultures but also exposed them to a diversity of cultural influences (Rahayu et al., 2022). This exposure fostered growth in self-awareness and critical thinking, encouraging students to reflect on their beliefs and strategies (Aufa et al., 2021). As they engaged with different cultures, students improved their adaptability and collaborative skills, and these skills ultimately enriched their learning experiences with greater meaning.

Table 2. Students' Daily Reflection Journals and Feedback

Theme	Main Content	Reflected Metacognitive Skill	Feedback Reporting from Scaffolding Support
Task Completion	Students' descriptions of task completion, such as visiting cultural landmarks and observing booth layouts.	Planning and Execution Management	Clear task objectives make it easier for students to complete tasks. Staged task checklists and goal-setting aid in their self-management during execution.
Observation and Experience	Observations of culture, architecture, and other aspects, such as the design of mosques, booth layout, and decorations at landmarks like the Petronas Towers.	Comprehension Monitoring	Providing observation prompts and cultural background helps students gather more detailed insights, integrating cultural elements into design effectively. Reflective prompts help them gradually adjust design direction.
Design Insight or Inspiration	Inspiration for designs, such as combining religious elements of mosques with modern architectural styles or incorporating Malaysia's multicultural aspects.	Information Management Strategies	Reflection logs and staged feedback help students clarify design ideas and adjust plans flexibly. Students gradually refine their design direction, with inspirations closely linked to scaffolding support.
Challenges and Solutions	Challenges encountered and coping methods, such as spatial layout constraints, merging multicultural elements, and selecting materials.	Problem-Solving and Planning Ability	Regular feedback and group discussions provide support in tackling challenges. Students report that feedback and discussions enhance confidence and effectiveness in finding viable solutions.
Reflection and Feedback	Students' reflections on scaffolding support, particularly on reflection logs and feedback.	Self-Evaluation and Reflection Ability	Students find that reflection logs assist in reviewing and summarizing task progress, gradually improving design thinking and problem-solving skills. This support fosters metacognitive skill development, especially in evaluation and self-reflection.
Emotion and Attitude Evolution	Students' emotional shifts throughout the project, from initial tension and confusion to eventual confidence and a sense of achievement.	Emotion Regulation and Self-Motivation	Task breakdown and feedback support help students maintain a positive attitude through challenges and achieve a sense of accomplishment upon task completion.
Time Series Analysis	Trends in metacognitive skill development over the course of the project, such as from superficial observation to deep analysis and from simple imitation to proactive innovation.	Overall Metacognitive Skill Development	Continuous feedback and regular goal-checking support gradual improvement in students' metacognitive skills, enhancing their reflection and innovation abilities throughout the project.

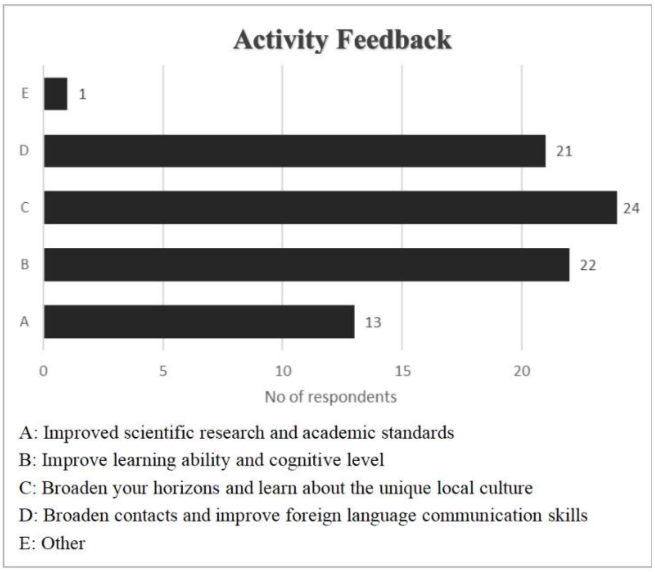

Figure 3. Students' Feedback

This combination of learning and reflection led to growth in adaptability, collaboration, and other key competencies, which further reinforced their metacognitive skills and positively impacted their problem-solving and innovative thinking abilities (Jumaat et al., 2017). Feedback suggests that scaffolding support helped students more fully understand and apply learned concepts, enhancing both cultural understanding and information integration skills, which are critical metacognitive skills needed to address complex problems.

The following summarizes the improvements in metacognitive skills facilitated by scaffolding support, alongside specific examples from student reflections:

- *Comprehension Monitoring:* Staged task feedback significantly enhanced students' comprehension monitoring, helping them clarify objectives and adjust strategies throughout the project. For instance, student D reported that the feedback from scaffolding allowed her to pinpoint her current task at each stage and make gradual adjustments to her design plan.
- *Information Management Strategies:* Students progressively learned to integrate multi-sourced information from diverse cultural contexts and incorporate this information into their designs. For example, student E noted on day six that the modern architectural style of the Petronas Towers inspired his design, leading him to effectively integrate various cultural elements in his subsequent work. This shows how scaffolding support guided students from observation to application, fostering the development of their information management skills.
- *Challenges and Solutions:* Students encountered challenges in design tasks, often related to integrating diverse cultural elements, spatial arrangements, and material selection. The scaffolding feedback and group discussions provided crucial problem-solving support. For instance, student F faced difficulties in merging modern and traditional elements. Through group discussions, he gained inspiration and successfully incorporated Southeast Asian cultural and modern technological elements in his design on day seven.
- *Self-Evaluation and Reflection:* Reflection logs encouraged students to review task progress and design ideas daily, gradually strengthening their self-evaluation and reflection abilities. Student G shared that the staged logs helped her better summarize task progress and adjust her design plan promptly, improving her self-evaluation skills.

These insights illustrate how scaffolding in PjBL fosters metacognitive growth, enabling students to refine their approaches to learning, problem-solving, and creative thinking in complex engineering tasks

Impact of the Project on Emotional Regulation and Self-Motivation

Through thematic analysis of students' daily reflection logs, the research found that scaffolding support played a significant role in helping students regulate emotions and enhance self-motivation, contributing positively to their learning experiences.

- *Emotional Regulation:* Early in the project, some students reported feeling nervous and confused due to unfamiliarity with the task content. However, as the project progressed, the scaffolding support—such as task breakdown, reflection logs, and feedback mechanisms—helped students maintain a positive attitude when facing challenges and gradually build confidence (Hobri, 2021). For example, student A noted that with phased feedback, she gradually overcame her initial anxiety and became more confident in tackling project challenges.
- *Self-Motivation:* By completing tasks and receiving instructor feedback, students generally felt a sense of accomplishment by the end of the project, recognizing their progress in design thinking and cultural understanding (Jumaat et al., 2017). Student H expressed appreciation for the project experience in her reflection on the seventh day, saying, *"I am very grateful to all the teachers for their hard work along the way."* This feedback illustrates that the scaffolding support not only boosted students' self-motivation but also enhanced their sense of achievement.

Time Series Analysis: Evolution of Metacognitive Skills

A time series analysis of metacognitive skill development during the project reveals how students gradually advanced to more profound levels of reflection and innovation under the guidance of scaffolding support (Jumaat et al., 2017).

- *From Surface Observation to In-Depth Analysis:* At the beginning of the project, students tended to focus on surface-level observations, but with scaffolding support, they gradually developed deeper analytical skills (Pokharel, 2021; Rahayu et al., 2022). For instance, student D initially concentrated on the decorative elements of the food truck on the fifth day, but by the seventh day, her focus had shifted to considering the environmental sustainability of materials and cultural adaptability, illustrating her progress in the project.
- *From Simple Imitation to Proactive Innovation:* Early on, students relied heavily on imitation in their designs; however, with iterative feedback, they transitioned to autonomous innovation (Andari et al., 2020). For example, the student I mentioned difficulties in integrating local cultural elements with design concepts at the start of the project but by the seventh day, she proposed a unique design combining cultural elements with modern aesthetics. This shift demonstrates how scaffolding helped students' progress from mere imitation to original creative expression (Jalinus et al., 2023).

Discussion

Interpretation of Results

The quantitative analysis in this research indicates that scaffolding support led to significant improvements in students' comprehension monitoring and information management strategies. This suggests that structured tasks and staged feedback provided students with clear learning pathways and specific goals, enhancing their ability to monitor and manage information throughout the task (Malik et al., 2023). Such improvements may result from the targeted guidance and timely feedback offered through scaffolding, which helps students focus on their objectives and gradually develop strategies for integrating and applying information. However, no significant improvements were observed in students' planning and self-evaluation skills in the short term. This may be because advanced metacognitive skills, such as planning and self-evaluation, generally require extended periods of practice to fully develop. Additionally, the limited project duration and task pressure may have restricted students' opportunities for reflection and self-evaluation. These findings suggest that fostering these higher-level metacognitive skills may require ongoing support beyond a single project to cultivate complex self-regulation abilities (Jumaat et al., 2017).

Integration of Qualitative and Quantitative Data

The integration of qualitative data further clarifies the differences observed in skill improvements in the quantitative results (Andari et al., 2020). Qualitative cases illustrate that scaffolding support helped some students gradually improve their task comprehension and flexibility in information management. For example, during the project, some students began incorporating observations into their design, demonstrating how task breakdowns facilitated her comprehension monitoring (Hobri, 2021). In contrast, feedback from some students indicated that the pressure of the short-term project impeded their ability to fully engage in self-evaluation and planning, corroborating the quantitative findings of no significant improvement in these skills. Future studies could explore more flexible timelines and additional reflection opportunities to determine if these adjustments influence results, thereby strengthening scaffolding support for metacognitive skill development.

Differences in Personality Types and Learning Styles

If data permits, future studies could analyze differences among students with various personality types (e.g., based on MBTI) and learning styles (e.g., VARK preferences) to better understand the impact of scaffolding on different student groups (Rahman et al., 2022). For instance, extroverted students may benefit more quickly from group discussions and interactions, while introverted students may require more structured tasks and individualized feedback to enhance information management and planning skills (Hobri, 2021). Exploring these individualized differences could help educators tailor scaffolding more precisely to maximize its effectiveness for diverse student groups (Rahayu et al., 2022).

Comparison with Existing Research

The findings of this research align with existing literature. Consistent with the results of Blumenfeld et al., scaffolding in PjBL significantly improved students' comprehension monitoring and information management skills (Blumenfeld et al., 1991). However, Blumenfeld et al. also emphasized the need for sustained and adaptive scaffolding, which this research supports by showing that certain metacognitive skills require long-term support and repeated reflection (Jumaat et al., 2017). In this short-term project, students showed no significant progress in planning and self-evaluation, indicating the need for dynamic scaffolding adjustments to support long-term skill development.

Limitations and Future Research Directions

While scaffolding in PjBL environments has shown positive effects in fostering students' metacognitive skills, certain limitations exist. The following areas, including sample size and project duration, dynamic feedback mechanisms, diversity of scaffolding types, cross-cultural adaptability, and practical applications, are discussed to provide a broader reference for future research and teaching (Kazanjian, 2023).

1. *Sample Size and Project Duration:* This research was conducted with a small sample size and over a relatively short project cycle, meaning that the findings may not fully reflect the long-term impact of scaffolding on metacognitive skill development. Future studies could consider expanding the sample size and extending the project duration to verify the enduring effects of scaffolding (Rahayu et al., 2022). A longer cycle would allow a more comprehensive capture of students' continuous progress in comprehension monitoring, information management, and self-evaluation, further supporting educators in selecting and applying scaffolding strategies with greater precision in instructional design (Pokharel, 2021).
2. *Dynamic Feedback Mechanism:* The current scaffolding design is primarily based on pre-set task structures and feedback methods, which, while promoting metacognitive skills to some extent, still lack flexibility and personalization. Future research could explore dynamic feedback mechanisms, such as AI-based adaptive feedback tools, that provide real-time guidance based on students' progress and performance (Jalinus et al., 2023). This type of feedback mechanism could more closely align with students' actual needs, offering immediate support when challenges arise, thus enhancing the application of complex skills like task planning and self-evaluation (Aufa et al., 2021).
3. *Effectiveness of Different Scaffolding Types:* Different types of scaffolding may have varying impacts on different aspects of metacognitive skills. For example, structured tasks may be more effective in improving students' comprehension monitoring, while reflective journals may be better suited for developing self-evaluation skills (Andari et al., 2020). Future research could further explore the optimized effects of combining various scaffolding types on different metacognitive skills. Through flexible application of multiple scaffolding combinations in course design, educators could more effectively support students in developing self-management and self-regulation skills (Jumaat et al., 2017).
4. *Cross-Cultural Adaptability:* With the globalization of education, the potential for applying scaffolding in PjBL projects within cross-cultural contexts has become increasingly evident. The results of this research suggest that scaffolding can help students better integrate and apply knowledge in diverse cultural environments (Malik et al., 2023). Future research could focus more on the applicability of scaffolding in different cultural contexts, exploring how scaffolding might support students in deepening their understanding of cultural differences and effectively incorporating multicultural elements (Ismail et al., 2024). Educators could design cross-cultural collaborative projects to encourage students to work in diverse teams, enhancing their cultural adaptability and flexibility in addressing complex problems (Wati et al., 2024).
5. *Practical Implications:* The practical application of scaffolding in engineering projects demonstrates valuable outcomes. By systematically integrating scaffolding techniques into course design, educators can adopt a "task breakdown-feedback-reflection" model to help students progressively adapt to complex project tasks, clarify task objectives, and develop gradual self-management and regulation skills (Admawati et al., 2018). Additionally, the use of scaffolding in cross-cultural project learning has shown to be effective; through incorporating cultural experiences and teamwork within project tasks, students can enhance their collaborative skills while understanding diverse cultures (Andari et al., 2020). This approach not only aids students in acquiring knowledge and skills but also strengthens their metacognitive development and cross-cultural adaptability, providing broader support for students in future work and learning environments (Ghazali et al., 2019; Rahayu et al., 2022).

In summary, this research provides empirical support for the effectiveness of scaffolding in enhancing students' metacognitive skills within PjBL. Future research should continue to optimize design aspects such as sample size, feedback mechanisms, types of scaffolding, and cultural adaptability to further improve the effectiveness of scaffolding in engineering project (Pokharel, 2021).

This research demonstrated the significant impact of reflective prompts and guided feedback in short-term projects, particularly in enhancing students' comprehension monitoring and information management skills. However, it also highlighted the limitations of short-term projects in fostering advanced metacognitive skills. By proposing strategies such as extending project duration and optimizing feedback mechanisms, this study provides new insights into the application of scaffolding techniques in complex engineering projects (Pokharel, 2021).

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Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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Rethinking Structural Design Education through Boundary Conditions and Design Flexibility in PBL

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Abstract
This study addresses the pedagogical challenge of balancing design freedom and instructional structure in architectural engineering education through the strategic use of boundary conditions. In typical Problem-Based Learning (PBL) settings, students often face unclear task scopes or overly rigid design constraints, which can hinder creativity or reduce engagement. To overcome this, the study proposes a structured PBL model that incorporates adjustable boundary conditions to guide, rather than limit, student learning. Drawing from both structural engineering principles and educational theory, the model uses written and visual design guides to define parameters within which students work. Three types of PBL projects—task, discipline, and problem—are discussed as scalable formats offering varying degrees of design flexibility. In practice, task-based projects were primarily implemented, with discipline projects explored to test adaptability. Hands-on scaled modeling activities enabled students to experiment with different building technologies and evaluate material behavior, strengthening their understanding of real-world construction constraints. Findings suggest that controlled flexibility not only supports technical learning but also enhances motivation and critical thinking. This boundary-based framework allows instructors to recalibrate project complexity according to course goals. Future research may examine how digital platforms such as BIM can expand the adaptability and interdisciplinary potential of this model in broader curricular settings.

Keywords: Problem-based learning, boundary conditions, architectural engineering pedagogy, design constraints and flexibility, curriculum innovation .

Introduction

Contemporary architectural engineering education emphasizes not only technical expertise but also a wide range of transferable skills such as interdisciplinary collaboration, communication, adaptability, and sustainability awareness (Kolmos & Graaff, 2015; NAE, 2004; OECD, 2021; Warin, 2015). As the complexity of built environments increases, graduates are expected to be equipped with capabilities that go beyond structural and material knowledge. Professional organizations and accreditation bodies worldwide increasingly emphasize the importance of innovation, real-world problem-solving, and cross-disciplinary teamwork (ABET, 2023; Pantazidou & Nair, 1999). These evolving expectations have led to the widespread adoption of active learning methodologies, particularly in Science, Technology, Engineering, and Mathematics (STEM) fields, where deeper engagement and knowledge retention are crucial (Freeman et al., 2014; Prince, 2004). Within this context, problem-based learning (PBL) has become a prominent pedagogical model due to its ability to immerse students in realistic scenarios and promote the development of critical engineering competencies (Kolmos et al., 2015).

Based on this theoretical foundation and the need for a concrete implementation model in architectural engineering, the authors designed a problem-based learning (PBL) framework to enhance instruction in building component design. The pedagogical structure draws from key concepts such as prefabrication, the open building approach (Cuperus, 2001; Habraken, 1961; Troyer, 1998), and prescriptive construction codes (Mehta, 2008; Sanchez-Garrido et al., 2023). The educational model integrates five structural technologies—timber framing, cold-formed steel framing, reinforced concrete prefabrication, autoclaved aerated concrete panels, and structural insulated panel systems—grouped as either stick-built or panelised systems. These building technologies form the foundation of a PBL-driven curriculum module embedded within an undergraduate architectural engineering course. Components of this previously proposed educational model in architectural engineering are depicted in Figure 1.

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The course examined in this paper, "Architectural Materials and Methods of Building Construction," was redesigned using a modular approach that combines lectures, hands-on tasks, discussion-based learning, and PBL. The course targets sophomore-level students who typically lack formal structural analysis training; therefore, prescriptive codes, rather than computational models, guide the learning activities. Foundational knowledge on construction systems is delivered through preparatory lectures and modules before students enter the PBL block. To successfully engage with the PBL tasks, students must understand not only the structural systems involved but also the constraints and expectations inherent to the assignment. This learning environment is characterized by a complex pedagogical framework that integrates structural systems, construction methodologies, and design tasks across different building types. To manage and evaluate this complexity, the current study adopts the concept of boundary conditions as a unifying lens that defines the scope and operational limits within the learning environment. This theoretical framing provides clarity on the extent of student freedom, task structure, and material constraints, all of which impact design flexibility and student outcomes.

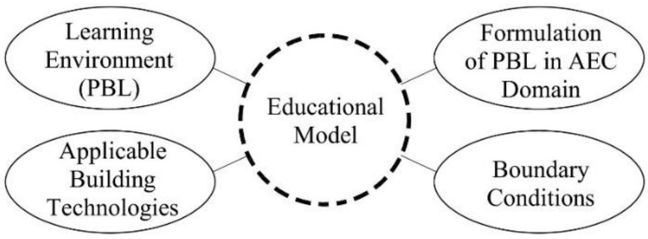


Figure 1. Components of the educational model for stick-built and panelized building systems.

The current study builds directly on two earlier studies by the authors that explored the use of PBL in architectural engineering education, focusing specifically on framing systems and building components (Yıldırım & Baur, 2014a; 2014b). In those studies, student feedback was systematically collected through surveys and structured observation, providing insight into how students perceive task complexity, interdisciplinary coordination, and time management under constrained conditions. These findings revealed specific challenges in navigating multiple layers of decision-making, particularly when students lacked clear guidance on scope boundaries and evaluation criteria. Such challenges are well-documented in engineering education research (Kolmos et al., 2015; Mills & Treagust, 2003), and align with the need for more explicitly defined learning frameworks. As a response, the current study introduces the boundary conditions framework to structure and clarify the pedagogical environment in which students operate. This refinement addresses earlier shortcomings and aims to enhance both student engagement and measurable learning outcomes.

As an outcome of this process, the research question posed in this study is as follows: What is the link between design flexibility and the type of PBL project? The hypothesis is that design flexibility and boundary conditions are directly proportional within the learning environment of building structural systems. This study defines "boundary conditions" as any limiting parameters—prescriptive, spatial, material, or procedural—that influence students' design decisions within a learning task. Although the survey results from previous work are not directly analysed here, they serve as the foundational input for developing the educational model discussed in this paper. By exploring how boundary conditions shape student engagement, task complexity, and learning outcomes, this study aims to contribute to a more structured and adaptable approach to PBL in architectural engineering education.

Materials & Methods

Theoretical Basis of PBL Framework

Problem-based learning (PBL) has continued to evolve as a student-centered approach that fosters active engagement and critical thinking, particularly in engineering and architectural education (Antepohl, & Herzig, 1999; Kolmos et al., 2015). PBL bridges the gap between theoretical instruction and practical application by placing students in scenarios that mirror real-world complexities. In this learning model, problems are not merely exercises but serve as the foundation for identifying knowledge gaps and promoting deep learning (Klegeris & Hurren, 2011; Servant-Miklos, 2019). Students take an active role in their learning process, collaborating in groups, reflecting on problem contexts, and synthesizing information to generate design solutions (Kuo et al., 2021).

Unlike traditional teacher-centered models, PBL requires instructors to act as facilitators who guide rather than dictate the learning process. Educators manage group dynamics, encourage discussion, and prompt inquiry rather than delivering prepackaged knowledge (Savery, 2006). These characteristics align with John Dewey's "learning by doing" philosophy, which remains a cornerstone of active learning practices (Forrester, 2004; Koschmann, 2014; Menendez et al., 2019). Recent literature emphasizes that effective PBL implementation depends heavily on context, including institutional culture, available resources, and student background (Chen et al., 2021; Mann et al., 2020).

Similar courses are present in the curricula of architectural and civil engineering departments globally, though implementation strategies vary depending on institutional and regional contexts (Kim et al., 2024; Naveh et al., 2022; Shekhar & Borrego, 2017). The current study builds upon these varied applications by examining a specific PBL initiative developed in an architectural engineering program, with a particular focus on the structural systems and building component design. A detailed account of how this study extends prior applications is integrated into the following sections.

To better understand how learning activities in PBL settings relate to student design outcomes, this study adopts a methodological framework that investigates two main parameters: the type of PBL activity and the role of boundary conditions in shaping the educational model. These two elements form the basis for the structure of this section. Subsection 2.1 provides a review of existing PBL activity types in engineering education, while Subsection 2.2 focuses on the boundaries within which these activities occur and how such constraints affect design flexibility and pedagogical effectiveness.

PBL Applications in Engineering and Architecture Education

Problem-Based Learning (PBL) has become a widely accepted pedagogical approach in engineering education for its capacity to develop students' ability to address complex, ill-defined problems. Its alignment with real-world challenges makes it especially relevant to the evolving demands of engineering practice (Bizjak, 2008; Canavan, 2008; Deng & Liu, 2023; Fapohundaa et al. 2023; Sarkawi et al., 2024; Sukacke et al., 2022). Active learning environments structured around PBL enhance students' readiness for professional settings that require collaboration, communication, and critical thinking (Fogg & Fendley, 2024; Patnawar, 2023).

Although PBL is not a new concept, its application in architectural and civil engineering programs has gained renewed pedagogical interest. Architectural engineering curricula increasingly incorporate design-oriented strategies to help students engage with the layered complexity of building design and construction. Studies show that PBL fosters deeper conceptual learning and encourages exploratory design approaches in architectural contexts (Kolmos et al., 2015).

In particular, hands-on methods such as scaled modelling support the translation of structural concepts into tangible outcomes. This tactile engagement improves student comprehension and supports long-term retention. Its effectiveness has been demonstrated in various structure-focused courses (Hidayat et. al, 2024; Vrontissi, 2015). PBL is also prevalent in capstone and design studio settings, which often frame learning around open-ended problems. Implementation models range from discipline-specific formats to interdisciplinary integrations (Mann et al., 2020), though adoption varies based on institutional and curricular readiness (Miklos & Kolmos, 2022).

Several architecture schools—such as Newcastle University (Australia) and Delft University (Netherlands)—were among the first to adapt PBL from medical education, with a focus on fostering design autonomy and critical inquiry (Banerjee, 1996; Smith et al., 2005). These early cases emphasized the benefit of embedding preparatory content before full immersion into PBL tasks.

From a methodological standpoint, three core PBL project types are commonly recognized: task projects, discipline projects, and problem projects (Graaff & Kolmos, 2003). Each offers a different balance between structure and freedom, with increasing flexibility leading to greater design openness. This typology informs the discussion of boundary conditions and design freedom in architectural engineering education.

In the current study, these project types serve as a lens to examine how pedagogical boundaries influence student autonomy and engagement. This provides the foundation for the next subsection, which explores boundary conditions in more detail.

Boundary Conditions in PBL from Structural and Pedagogical Perspectives

The concept of boundary conditions originates from mathematics, fluid mechanics, and engineering disciplines, where it typically refers to constraints or known values applied to the edges of a system in order to solve boundary value problems (Cadence, n.d.; Erochko, 2020; Karimpour & Rahmatalla, 2020; Simscale n.d.; Wikipedia, n.d.). In structural engineering, a boundary condition is defined as a location on a structure where either displacement or external force is specified. These constraints are essential to ensure solvability in static or dynamic structural analysis problems (Raney et al., 2015). For example, a beam supported by a hinge or fixed end has specific boundary conditions that directly affect internal force distribution and structural behaviour. In educational curricula, including civil and architectural engineering programs, boundary conditions are introduced through structural analysis courses to help students model realistic behaviour of buildings under various loads.

However, boundary conditions also take on a conceptual and methodological role in educational theory and design-based research. In organizational and educational theory development, boundary conditions define the limits or contextual scope of a theory—answering where, when, and for whom the theory applies (Busse et al., 2017). These conceptual boundaries are not physical constraints but rather methodological parameters that establish the relevance and generalizability of an approach or intervention. In recent literature on built environment pedagogy, such boundaries are seen as a framework to define the scope and applicability of design interventions and their evaluation (Sokol et al., 2022).

In the context of this study, the term boundary condition is intentionally used with dual meaning—drawing from both its technical roots in structural engineering and its methodological role in educational design. This dual usage mirrors the interdisciplinary nature of architectural engineering education, where engineering knowledge intersects with project-based pedagogies (Kolmos & Graaff, 2015).

To avoid confusion, the distinction is made explicit: Structural boundary conditions refer to the physical constraints applied to structural systems in analysis and design (e.g., fixed, pinned, roller supports). Pedagogical boundary conditions, as used in this study, refer to the predefined limits of the PBL activity—such as the scope of the project task, type of building system, and degree of design freedom provided to students.

In the proposed educational model, these pedagogical boundary conditions are articulated through instructional materials such as handouts and design guides. These documents define the boundaries of the PBL activity in two main ways: 1) Design Flexibility of Structural Systems: The type of structural system (e.g., frame, wall, slab) and the extent to which students can modify or select these systems based on performance goals and building type. 2) Constraints and Specifications for the PBL Activity: These include the selected building type, design criteria, material choices, site assumptions, and performance requirements.

By establishing clear boundary conditions in both the engineering and pedagogical sense, the activity helps students develop realistic and applicable design solutions while staying within a structured learning framework. This also ensures alignment with the learning objectives and assessment criteria of the course. As such, the boundary conditions become both a teaching tool and a reflection of the complexity students will encounter in their future professional roles.

Integrating Design Flexibility into PBL: A Case from Architectural Engineering Education

The classroom activity and its theoretical foundation were implemented in a course titled Building Construction at a mid-western public university in the United States (Yıldırım & Baur, 2014a and 2014b). At the beginning of the semester, a PBL-based task was introduced to students as an individual design project. The scope of the task included predefined building types and structural technologies. Despite these defined parameters, students were encouraged to generate unique design solutions within the provided framework, allowing them to explore their own design paths.

Design flexibility was a key pedagogical tool in this activity. Providing students with a spectrum of allowable solutions fostered ownership over their design processes and promoted creativity. Importantly, the design domain itself inherently constitutes a complex problem space. Thus, imposing strict limitations on design choices directly constrains students' capacity for problem-solving. To avoid this, the instructional model deliberately encouraged a shift from task-oriented projects—characterized by pre-defined outcomes—toward discipline-oriented projects that offer more autonomy and complexity. This transition allows students to engage more deeply with the problem space and develop advanced design strategies.

This conceptual shift is illustrated in Figure 2, where design flexibility emerges from the intersection of building type (e.g., rectilinear, diagonal) and building technology (e.g., stick-built, panelised). The diagram highlights how varying levels of planning and freedom (task vs. discipline projects) exist within the overlapping domains of technical constraints and typological decisions. The entire process is enclosed within a broader PBL context, underscoring the educational strategy behind this instructional model.

The use of boundary conditions also played a central role in framing the task. These were defined through a “Design Guide” and other supporting materials distributed to the students. The guide outlined the limits of the task environment, including specifications for building systems, materials, span dimensions, and performance expectations. This instructional strategy enabled the simulation of real-world design constraints, encouraging students to make informed decisions under bounded conditions—similar to how they would in professional practice.

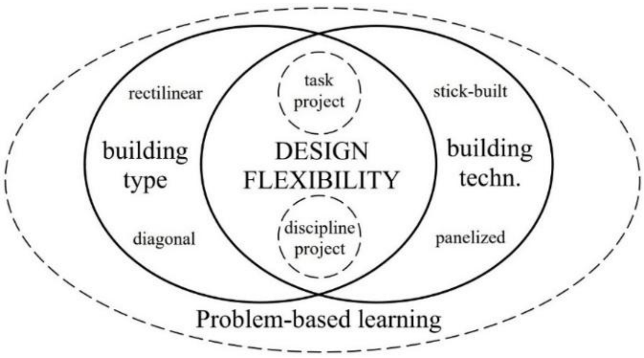


Figure 2. Conceptual framework of design flexibility in a PBL context, based on the interplay between building types, technologies, and project typologies

In this educational setup, boundary conditions referred not only to structural supports or force-displacement constraints—as used in structural analysis—but also to the pedagogical framework that shapes the limits and expectations of the learning task. This dual usage aligns with the theoretical framing discussed earlier in Section 2.2, where boundary conditions help define the scope, roles, and contextual limits of a problem-based task in architectural engineering education.

By integrating both flexible design options and clearly articulated boundary conditions, the case study aimed to simulate the complexity of real-world architectural design problems while maintaining the pedagogical structure necessary for effective learning.

Relation of PBL Project Type and Design Flexibility

Student motivation is strongly influenced by their level of engagement, and as evidenced in previous studies (Yıldırım & Baur, 2014), this engagement is enhanced when students are granted design flexibility. In other words, when students have opportunities to explore alternative design solutions beyond strict boundaries, they become more invested in the learning process. This is particularly evident in Problem-Based Learning (PBL) environments, where design is not only a pedagogical tool but also a complex problem domain in itself. Limiting design scope too narrowly may hinder students' ability to practice critical thinking and creative problem-solving. Therefore, the transition from task project to discipline project is intentional—it seeks to balance technical rigor with flexibility, thereby cultivating a richer learning experience.

In this case study, three categories of PBL project types were developed to represent varying degrees of design flexibility: task project, discipline project, and problem project. These categories align with increasing levels of complexity and open-endedness. A visual framework illustrating this gradation is presented in Figure 3.

Task projects are framed around typical housing units that comply with prescriptive codes and provide clear structural guidelines. These projects emphasize basic engineering principles such as load distribution and structural stability. The goal here is to simplify the problem space for initial comprehension. In this phase, students typically work with rectangular building types—commonly accepted as structurally efficient and compliant with standard codes. Approximately half of the floor plan in these designs is dedicated to support systems, while the remaining portion allows for limited flexibility within predefined constraints.

As students progress to discipline projects, they are encouraged to apply the foundational knowledge from task projects to more complex configurations. These discipline projects still maintain some boundary conditions (e.g., code compliance or construction technique), but now allow for more "out-of-the-box" design thinking. These projects challenge students to depart from typical patterns and explore unique architectural solutions while still respecting the principles of structural design.

At the upper level of design freedom lies the problem project, where constraints are minimized and creativity is maximized. This format promotes an open-ended inquiry model, asking students to identify, frame, and solve architectural problems that may not have one correct answer. The lack of predefined boundaries in this type allows for full engagement with both form and system logic, helping students internalize structural reasoning while exploring innovative solutions.

Team-based work is emphasized across all project types, cultivating soft skills such as communication, collaboration, and leadership. According to student feedback, this layered approach provided a clearer sense of progression and supported their design development across different complexity levels.

Figure 3 below graphically represents this progressive relationship among project types, boundary conditions, and design freedom. As students progress from task projects (c) to discipline projects (b), and eventually to problem projects (a), the degree of design freedom increases, and boundaries—often determined by building types or prescriptive codes—are gradually lifted to support out-of-the-box thinking.

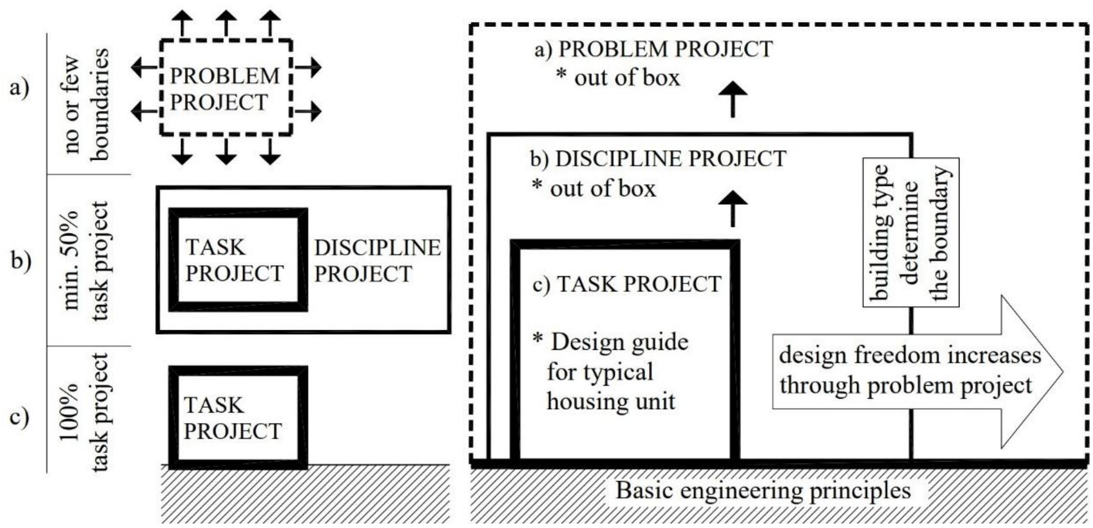


Figure 3. A conceptual framework showing the relationship between PBL project types and design flexibility in architectural engineering education.

Boundary Conditions in Task-Based PBL and Their Transition Toward Discipline Projects

In this activity, the framework for prefabricated construction is introduced through stick-built and panelised building systems. These systems establish the foundational boundary conditions that guide students throughout their PBL tasks. While implementation details may vary between courses, the pedagogical structure and core intent of the activity remain consistent.

Students begin with a design guide supported by written and visual documentation that emphasizes dimensional coordination, interface control, and construction logic. Within this context, twelve key parameters—ranging from decision-making levels to expected learning outcomes—form a flexible yet structured framework for guiding project-based learning. Figure 4 illustrates this framework through two interrelated diagrams. Figure 4a presents a scope–challenge map that positions each of the twelve parameters across two axes: design scope (horizontal) and challenge level (vertical). For instance, modular coordination and dimensional coordination are categorized as high-challenge but moderate in scope, while activity steps and types of building components occupy both high-scope and high-challenge zones. Figure 4b provides a flowchart of the instructional sequence, outlining how boundary conditions are applied and gradually relaxed to transition from task-based projects toward more flexible, discipline-specific work.

This methodology is operationalized through a four-stage instructional workflow: a) Orientation; The instructor introduces the educational model, student roles, and overall activity sequence, b) Design framework; Students engage in modular form development and dimensional coordination, c) Design Development; Prefabrication technologies and components are applied to develop structural layouts, d) Designs are assessed based on structural principles, evaluation criteria, and learning outcomes.

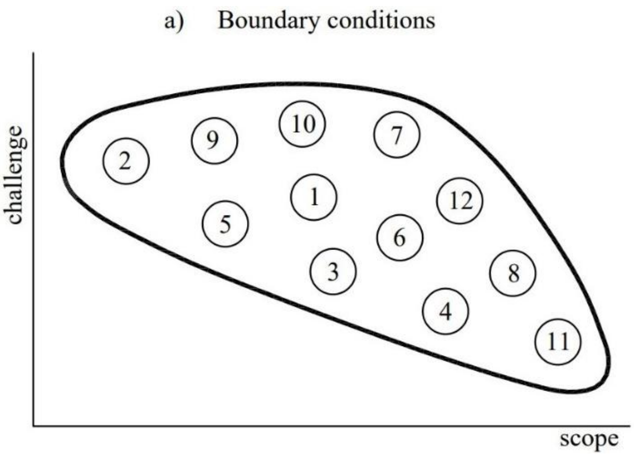
This structured yet adaptable system enables students to explore both technical requirements and creative possibilities in component-based architectural design. The use of modular units fosters a range of design solutions, reducing redundancy and encouraging individualized team outcomes.

Moreover, building types created by combining these modular units are also used as reference examples in discipline-specific designs. This approach enables students to move beyond the limitations of task-based housing models. The same modular methodology can be extended to discipline projects depending on the level of design freedom granted by the instructor.

Ultimately, this flexibility allows instructors to recalibrate the depth and openness of learning activities by adjusting the boundary conditions. Each of the twelve parameters functions as a dynamic lever—by altering just one (e.g., modular system scope or evaluation criteria), the project type can shift toward higher complexity and student autonomy. In doing so, the PBL environment becomes more tailored to course objectives and student readiness.

Findings and Reflections on PBL Application

This section presents findings and reflections derived from the implementation of the proposed PBL educational model. The evaluation is organized into three key areas: (1) learning outcomes observed during the activity, (2) specific challenges encountered throughout the implementation process, and (3) considerations for potential future research. These categories aim to offer both analytical insight and practical implications. The outcomes reported here may contribute to improving this educational framework and guiding the development of similar curricula in architectural engineering and related disciplines.



	b)	Flowchart
Orientation	1)	Educational model
	2)	Levels of decision making
	3)	Steps of the activity
Design Framework	4)	Types of building form
	5)	Modular (grid) system and dimensions
	6)	Dimensional coordination
Design Development	7)	Level of industrialization in building
	8)	Types of building technology
	9)	Types of building components
Iteration and Evaluation	10)	Basic principles of building technologies
	11)	Evaluation methodology
	12)	Learning outcomes

Figure 4. Boundary conditions and instructional flow of PBL tasks in structural systems. (a) Scope-challenge map. (b) Instructional flowchart.

Learning Outcomes in PBL Activities

Since the PBL activity involving stick-built and panelised building systems includes the hands-on assembly of scaled architectural models, the selection and evaluation of appropriate educational materials became an integral part of the learning process. In this context, "educational materials" refer specifically to the physical model-making materials used by students. The quality of the learning experience was found to be closely related to the properties of these materials, including their availability, affordability, ease of use (workability), and the quality of the final model outcomes.

Students experimented with seven different materials while modelling five distinct building technologies. Based on their modelling experience, they assessed each material according to the aforementioned criteria. This exercise allowed students to reflect on material performance and develop critical thinking about construction technologies and real-world constraints. The methodological foundation of this assessment is based on previous findings by the authors, which were revisited and adapted within the scope of the current study to align with experiential learning goals (Yildirim & Baur, 2014a; 2014b).

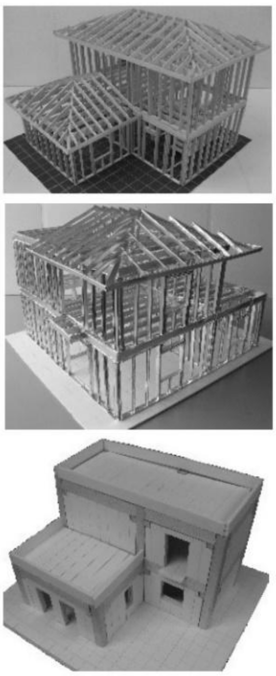
As a result of the hands-on modelling exercises conducted within the PBL framework, students re-evaluated various model-making materials based on their real-world performance during the activity. Table 1 summarizes the observed strengths and weaknesses of each material in terms of availability, affordability, workability, and the quality of the final product. This reassessment process served not only as a reflection tool but also as a core learning outcome, encouraging students to critically analyse material behaviour and its implications in architectural construction.

For instance, the timber framing system was effectively modelled using balsa wood at a 1:20 scale, while the cold-formed steel framing (CFS) system was tested at various scales such as 1:10, 1:20, 1:25, and 1:32 using materials like aluminium profiles, aluminium foil, and plastic model profiles. Despite initial assumptions, some materials proved ineffective: aluminium foil and versatile paper were particularly challenging due to assembly difficulties and lack of structural integrity. These realizations were derived directly from students' modelling attempts, leading to a deeper understanding of practical constraints in construction.

Similarly, reinforced concrete (RC) prefabricated systems and panelised approaches were modelled using foam board and 3D-printed plastic components at scales such as 1:20, 1:32, and 1:50. Students also observed how certain materials imposed limitations or provided advantages in replicating real-world systems. For example, while aluminium profiles yielded realistic and durable results, they were harder to manipulate without additional equipment.

The modelling activity fostered collaborative learning, problem-solving, and reflection on design-to-construction translation. Moreover, it enabled a tangible comparison of material behaviour, which students reported as instrumental in grasping structural logic. The compiled assessments (see Table 1) not only document material performance but also represent one of the core learning outcomes of the PBL process.

Table 1. Reassessment of model-making materials based-on learning outcomes.



	Material	Applicable building technology	Notes			
			Available	Affordable	Workable	Results
1	Balsa wood	Timber framing system	X	X	X	V
2	Foamboard	RC prefabricated, AAC panel, SIP systems	X	X	X	S
3	Aluminum profile	CFS framing system		X		V
4	Aluminum foil	CFS framing system	X	X		F
5	Versatile paper	CFS framing system	X	X		F
6	Stock-ready plastic model profiles	CFS framing system	X	X	X	V
7	3D Printer (plastic)	RC prefabricated, AAC panel, CFS framing system	X			E

P = Poor, F = Fair, S = Satisfactory, V = Very Good, E = Excellent

Addressing Pedagogical and Structural Challenges through Flexible PBL Design

Students generally expressed satisfaction with the PBL activity, as reported in earlier research by the authors, where comparative feedback suggested that the PBL approach had a more beneficial impact than traditional lecture-based learning environments (Yildirim & Baur, 2014a; 2014b). While that study included direct survey data, this paper reinterprets those findings from a pedagogical design perspective, emphasizing structural and material-related flexibility within PBL settings.

A recurring challenge identified by students is the lack of variety in building types and technologies over consecutive semesters. Performing the same design and construction tasks annually can lead to a sense of monotony. Enhancing flexibility in PBL activities helps avoid this repetition, strengthens engagement, and supports deeper, longer-term retention of knowledge. Flexibility becomes particularly relevant when examining two key aspects of the PBL model: building type and building technology.

Each of these aspects presents its own distinct challenges. On the side of building types, limitations are often imposed by prescriptive codes and standardized typologies embedded in architectural design guides. On the technology side, the main difficulty lies in sourcing workable and scalable model-making materials that reflect real-world construction systems. A strategic response to these constraints involves re-framing the project: shifting from a narrowly defined "task project" to a broader "discipline project," in which structural freedom and conceptual integrity are encouraged while still aligning with educational goals.

Figure 5 summarizes how such challenges can be addressed, and what effects these solutions have on student learning outcomes. For instance, the use of stock-ready plastic profiles in modelling cold-formed steel systems enables greater material flexibility and technical accuracy, which in turn leads to increased student satisfaction and a more meaningful engagement with the PBL process. Similarly, allowing broader interpretation of prescriptive codes empowers students to apply their technical knowledge with structural foresight gained from traditional coursework.

By introducing manageable forms of flexibility in both design parameters and modelling materials, the PBL framework can better support student autonomy, critical thinking, and applied problem-solving — essential qualities for emerging professionals in architecture and construction fields.

Directions for Further Research through Course Integration and Digital Platforms

Building Information Modelling (BIM) has become increasingly central in the Architecture, Engineering, and Construction (AEC) sector, offering substantial improvements in project coordination, stakeholder communication, and design integration. Over the last decade, with the rise of mobile computing and tablet-based tools, BIM has evolved into a powerful digital infrastructure that supports centralized data environments and collaborative workflows.

Within the scope of this study, which emphasizes educational implementation, coordination and communication skills have emerged as essential competencies for architectural engineering students. These are particularly relevant in project-based learning (PBL) contexts, where active engagement, interdisciplinary thinking, and real-time problem-solving are key components of the learning process.

Further research can explore how the boundaries and flexibility of PBL models might be expanded or redefined through two complementary pathways:

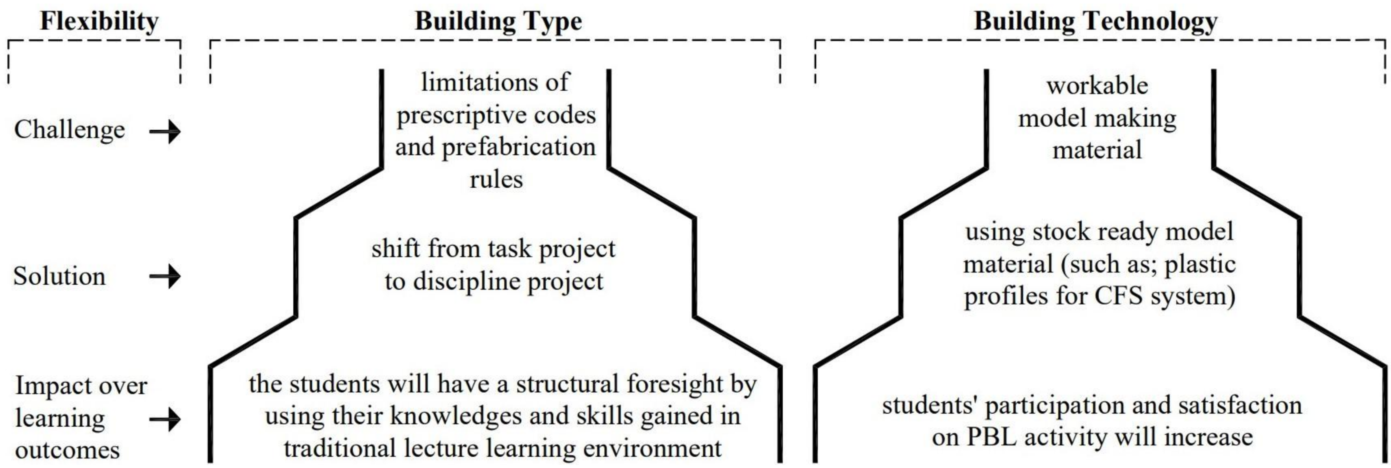


Figure 5. Challenges, solutions, and impacts on learning outcomes through maintaining flexibility.

- Extension into additional courses: The current educational model may be applied beyond design studios to include related building technology courses, enabling cross-course comparison and fostering broader interdisciplinary learning.
- Integration with digital platforms: Embedding PBL activities into BIM-based environments offers an alternative to traditional hands-on methods. While differing in format, both approaches share core values of feedback-driven iteration, active participation, and collaborative design. Comparative studies could examine how platform-based flexibility influences learning outcomes and student engagement.

In conclusion, aligning PBL models with technological developments (such as BIM) offers new avenues for expanding its pedagogical boundaries. Future studies may investigate how these integrations influence student autonomy, knowledge retention, and real-world preparedness across multiple learning contexts.

Conclusion

This study proposed a boundary condition–based educational model that integrates design flexibility into problem-based learning (PBL) environments in architectural engineering education. By framing instructional constraints through written and visual design guides, the model provided a structured yet flexible approach that supported both student autonomy and technical rigor. Boundary conditions, in both structural and pedagogical terms, served not as limitations but as guiding parameters that enabled deeper engagement with complex design challenges.

The model's progression from task-based to discipline-oriented project types illustrates how design flexibility can be gradually expanded while remaining aligned with course objectives. Although task projects were primarily implemented, limited applications of discipline projects provided insight into how increased autonomy and scope affect student motivation and performance. Varying project parameters—such as building type and construction system—was shown to mitigate repetitive patterns and foster longer-term knowledge retention.

Hands-on modelling activities using diverse materials enabled students to evaluate structural feasibility, construction logic, and material behaviour. These experiences bridged conceptual understanding and practical application, encouraging reflective thinking and problem-solving through tangible design processes. Material performance assessments became not only a feedback mechanism but also a central learning outcome.

Moreover, the ability of instructors to recalibrate the scope of PBL activities by adjusting specific boundary parameters proved essential for addressing varying student readiness and maintaining course adaptability. This study affirms that clearly articulated, adaptable boundary conditions enhance the effectiveness of PBL by linking pedagogical structure with creative freedom.

Future research may explore how digital learning platforms, particularly Building Information Modelling (BIM), can further extend this model, and how flexibility across tools, materials, and project types influences learning outcomes, interdisciplinary collaboration, and student agency in architectural engineering education.

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Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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Psychological Implication of Emotional Intelligence on Job Satisfaction and Performance of Electrical/Electronics Lecturers in Polytechnics in Southwest Nigeria

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Abstract

One of the most essential characteristics of any worker to cope with job stress and relate effectively with colleagues for optimal productivity is how well they can control their emotion. Hence, this study examined the psychological implication of emotional intelligence on job satisfaction and performance of electrical/electronic lecturers in Polytechnics in Southwest Nigeria. Descriptive survey design was employed for the study. Population for the study comprised of all the 73 lecturers in electrical/electronic department across the five Federal and State Polytechnics in Southwest Nigeria. Adapted instrument was used for data collection. Data were analyzed using mean and standard deviation, correlation and regression. The findings revealed that there is a significant relationship among electrical/electronic lecturers job satisfaction, job performance and emotional intelligence. Findings also revealed that emotional intelligence has a significant influence on job satisfaction (β= .864; $p < 0.05$) and performance (β= .685; $p < 0.05$) of electrical/electronic lecturers in polytechnics in Southwest Nigeria. It was concluded and recommended that lecturers with high emotional intelligence will rarely exhibit negative behaviors in a challenging situation. Therefore, institution authority should incorporate emotional intelligence-based training into professional development programs of lecturers to enhance their work experience and to improved educational outcomes.

Keywords: Emotional Intelligence, Job Satisfaction, Job Performance, Electrical/Electronics Lecturer.

Introduction

In Nigeria and all other countries across the globe, job satisfaction and performance are part of the major factors that determines the effectiveness of an organization and level of productivity. One of the most valuable things to any employee is their job since it allows them to make a livelihood through the contributions they make to their organization and their respective community. Besides, the role some employees plays on their job and how it impacts others constitute the core of their existence. This is the same with lecturers in higher institution whose job is directed towards molding the life of the young ones to become useful member of the society. This suggest that lecturing job is not to be handle anyhow either by any agency or Government parastatal but should be well taken care of so that lecturers can put their best to the job. Hence, satisfaction of lecturers on their job is very essential since it plays a significant role in man-power development of a nation.

The issue of job satisfaction is an area of great concern for several school personnel and school management since it determines how different employees perceived their job. Job satisfaction is a favorable feeling a person gets from his/her job. When someone feels satisfied enough to carry out their duties as required, they are said to be satisfied with their job. Sumedho (2015), defined job satisfaction as an employee's positive emotions which comes as a result of satisfaction they gain from or associate with their work. Ahmad & Abdurahman, (2015) stated that job satisfaction is important for lecturers since it contribute to their wellbeing and help them to be more effective in their job. Aziri (2011) stated that job satisfaction is a combination of an individual employee's likeable and unlikable moods or behaviors on their work schedule. He further states that satisfaction on a job represents the extent to which optimism is in line with actual advantages and rewards. This point to the fact that upon employment of lecturers to their job they have their own job desires, expectations, wants, and anticipations that define their purpose of working in that organization.

(Mohammed 2015) was of the opinion that workers' expressive link with their work is their job satisfaction regardless of whether they enjoy it or not. A good emotional reaction an employee has while

Fadairo, O. O., Lemo, O. O., Yisa, M. A., Aiyemoboye, I. A., Aderinto, I. D. (2025), Psychological Implication of Emotional Intelligence on Job Satisfaction and Performance of Electrical/Electronics Lecturers in Polytechnics in Southwest Nigeria, *ASEAN Journal of Engineering Education*, 9(1), 22-29. https://doi.org/10.11113/ajee2025.9n1.186

performing their duties or while they are physically present at work can also be interpreted as job satisfaction. According to Pan et al (2015), the level of job satisfaction differs among employees and the elements that contribute to one employee's job satisfaction may not be applicable to another in the same workplace and under the same circumstances. In view of this, employers of labour should always endeavour to promote a high degree of job satisfaction in their respective organizations or academic institutions. This would help lecturers to be more committed to their job thereby increase their level of job performance.

Job performance can be described as how well an employee performs their allocated tasks and obligations. It is an evaluation of the behaviour and accomplishments of the employee throughout their period of employment. job performance can also refer to achieving or establishing goals within a profession, role, or organization. According to Kannat (2021), job performance is the culmination of an employee's ability to do tasks as assigned. This point to the fact that capacity of a lecturers in their respective place of work is essential to their job effectiveness and determines how fast they can quickly complete any given task using available resources within a specified period of time. According to Gambill (2021) there are five essential components for job performance this include emotional commitment, the capacity to capitalize on strengths, a strong work ethic, the ability to forge strong bonds with others, and advanced self-leadership activities. Additionally, it illustrates how productive and efficient a lecturer is in their respective educational institutions. Lecturers in their various institutions are also graded and assessed based on how successfully they do their jobs. As a result, it is critical that lecturers in polytechnics perform well in order to keep their jobs and maintain a high degree of stability and thoughtfulness even in the face of adversity, which can be determined by their level of emotional intelligence.

Emotional intelligence involves perceiving, comprehending, and controlling one's emotions. According to Yusoff, Rahim, and Esa (2010), emotional intelligence at work place is the ability to manage our own emotions as well as those of people around us in order to provide a more positive and productive work environment. According to Frothingham (2022), emotional intelligence is the ability to recognize, regulate, and assess emotions. Lecturers with emotional intelligence are able to control both their own and other people's emotions. Employees with high emotional intelligence are able to efficiently manage their stress a claimed by (Mohamed & Nagy 2017). This keeps lecturers to perform at a level that is suitable and improves their capacity to handle both the physical and mental strain of their work. Davis (2019) in his study stated that workplace emotional intelligence can improve employee performance, retention, and occupational stress while increasing an organization's profitability. This point to the fact that success of social relationships in organizations, which ultimately result in great job performance, job satisfaction, and even success in life, may likely be determined by emotional intelligence.

Additionally, emotionally unstable lecturers may struggle to manage coworkers, students, and work-related stress, which could affect their productivity. Invariably, if such lecturers exhibit job unhappiness, it may result in absenteeism, frustration, and other health issues. Based on this, this study examines the psychological implication of emotional intelligence on the job satisfaction and performance of electrical and electronics lecturers in polytechnics in Southwest Nigeria.

Statement of Problem

Teaching at tertiary institution level requires tutors that are exceptionally intelligent and are emotional stable due to type of students under their tutelage. Besides, emotional intelligence is a pivotal attribute needed by lecturers to deliver effectively in their teaching, researches and community services. Alongside with this is the need for them to experience satisfaction on their job with a view to progress academically and getting to the pinnacle of their chosen career. This feeling of satisfaction would help in enhancing their level of commitment and performance.

Sadly, most polytechnics lecturers in southwest Nigeria are experiencing dissatisfaction coupled with emotional related issues on their job. This is due to unconducive environment to perform their job, low renumeration, lack of support from colleagues, too much of workload among others which is reflecting in how many of them are interacting with students, colleagues and their superior at times. Since a lack of emotional intelligence can result in attrition, brain drain, irritation, discontent, an emotional imbalance, sadness, annoyance, suicide, and a lack of devotion to one's job or absenteeism its consequences cannot be understated. This tendency could bode disaster for the educational institutions, particularly for electrical and electronic lecturers. Invariably the polytechnics will continue to produce unskilled, half-baked, unqualified and unemployable electrical electronic graduates, because they are trained by emotionally unstable lecturers who are dissatisfied on their job. Hence, the study examined the psychological implication of emotional intelligence on job satisfaction and performance of electrical/electronics lecturers in polytechnics in Southwest Nigeria.

Purpose of the study

The research work was carried out to determine the;

1. Level of Job Satisfaction among Electrical/ Electronic Lecturers in Polytechnics in Southwest Nigeria?

2. Level of job performance among Electrical Electronics Lecturers in Polytechnics in Southwest Nigeria?
3. Level of Emotional Intelligence among Electrical/ Electronic Lecturers in Polytechnics in Southwest Nigeria?

Research Questions

The following research questions were raised for the study:

1. What is the level of Job Satisfaction among Electrical/ Electronic Lecturers in Polytechnics in Southwest Nigeria?
2. What is the level of job performance among Electrical Electronics Lecturers in Polytechnics in Southwest Nigeria?
3. What is the level of Emotional Intelligence among Electrical/ Electronic Lecturers in Polytechnics in Southwest Nigeria?

Hypothesis

The following hypothesis were formulated to be tested at 0.05 level of significance:

1. There is no significant relationship among Electrical/Electronic Lecturers job satisfaction, job performance and emotional intelligence in Polytechnics in Southwest Nigeria.
2. Emotional intelligence does not significantly influence job satisfaction of Electrical/ Electronics lecturers in Polytechnics in Southwest Nigeria.
3. Emotional intelligence does not significantly influence job performance of Electrical/ Electronics lecturers in Polytechnics in Southwest Nigeria.

Theoretical Framework

Emotional Intelligence Model

Emotional Intelligence model was postulated by Salovey and Mayer (1990). The theory defined emotional intelligence as the ability to perceive, access, generate, and regulate emotions to assist thought and promote emotional and intellectual growth. The four-branches of the model includes: Perceiving emotions, using emotions to facilitate thinking, understanding emotions, managing emotions. In the context of electrical/electronics polytechnic lecturers, this model implies that lecturers who effectively manage their emotions or have high emotional intelligence can cope better with work pressures, interact constructively with students, and remain motivated leading to greater job satisfaction and performance.

Research Methods

In this study, a descriptive survey design was used. The study was conducted in Nigeria's southwest. Ekiti State, Lagos, Ogun, Oyo, and Osun Ondo are among the states that make up the region. The 73 lecturers in the Electrical and Electronics departments at the five Federal and State Polytechnics in Southwest Nigeria made up the study's population. Data was collected using an adapted instrument from Wong and Law Emotional Intelligence Scale (WLEIS 2002), Maria and Efstathios Job Satisfaction Scale (2018), and Goodman and Syvantek Job Performance Survey Scale (JPSS) (2002). Three experts validated the questionnaire. Two from Department of Industrial Technical Education, Tai Solarin University of Education's Ogun State and one from the Federal College of Education (Technical) in Akoka, Lagos State. The instrument's internal consistency was determined using the Cronbach Alpha reliability technique, yielding a reliability coefficient of 0.97. With the support of two research assistants, the researcher administered and collected the data for the study. Data was analysed with mean and standard deviation for answering research questions, while the hypothesis was tested correlation matrix and regression. In taking decision, the mean responses of the respondents were interpreted with the modified 4-point Likert Scale. 1 being the lowest and 4 being the highest. Any item with a mean score of 2.50 and above was accepted, while any item which the mean score is below 2.50 were rejected. For the Hypotheses, p-values which are less than or equal to 0.05 were rejected, while p-values greater than 0.05 were accepted. The decisions for correlations were based on both the strength and direction of the relationship.

Data Analysis and Results

Research Question 1: *What is the level of job Satisfaction among Electrical Electronics Lecturers in Polytechnics in Southwest Nigeria?*

Table 1 presents mean responses on the level of job satisfaction among Electrical/Electronic Lecturers in Polytechnics in Southwest Nigeria. lecturer's salary is fair for the work they do, their promotion comes as and when due, their benefits paid are commensurate with my job, their work condition is good for them, their process of work is well organized in my school, their job provides them the opportunity for challenging work among others. However, with an average mean of 3.00 which is greater than 2.50 the minimum level of agreement in the study. The table therefore revealed that Electrical/Electronics Lecturers in Polytechnics in Southwest Nigeria exhibit moderate level of job satisfaction.

Table 1. Mean responses on the level of job Satisfaction among Electrical/Electronic Lecturers in Polytechnics in Southwest Nigeria

S/N	ITEMS	MEAN	SD
1	My salary is fair for the work I do as an Electrical electronics lecturer.	2.85	.86
2	My promotion comes as and when due.	2.73	.69
3	My benefits paid are commensurate with my job.	3.07	1.00
4	My work condition is good for me.	3.07	.94
5	The process of work is well organized in my school.	2.87	.85
6	My job provides me the opportunity for challenging work.	2.93	1.00
7	There is great opportunity of me to advance in my career on his job	3.04	.89
8	I stand a fair chance for being promoted for hard work.	2.93	.93
9	There are benefits which are not given to me as and at when due.	2.88	1.07
10	I don't feel my efforts are rewarded the way it should be	3.16	.75
11	There is too much rivalry and bickering at work.	2.79	.79
12	I feel unappreciated by my organization, when I think of the payment.	3.31	.80
13	People get ahead as fast here as they do in other places.	2.85	1.12
14	I feel satisfied with my chances for salary increase.	2.91	.87
15	My workload is too much.	3.09	.97
16	I enjoy my coworkers support.	2.78	1.01
17	I receive regular training as a lecturer and do my work effectively	3.16	.95
18	There are few rewards for those who work here.	2.91	1.04
19	I am satisfied with my chances of promotion.	2.94	.98
20	My work makes me more fulfilled.	3.00	.94
	Average mean	**3.00**	

Research Question 2: *What is the level of job performance among Electrical Electronics Lecturers in Polytechnics in Southwest Nigeria?*

Table 2 shows mean responses on the level of job performance among Electrical/Electronic Lecturers in Polytechnics in Southwest Nigeria. All the 19 items have the mean value ranged from 2.58 to 3.39. The result shown in the table indicate that the lecturers actively participate in group discussions and meeting at work, they derive a lot of satisfaction, helping their colleagues with their job, they feel they can do with more challenging assignment, their superiors have confidence in their task delivery in Electrical Electronics, they demonstrate in-depth knowledge of subject matter while teaching/lecturing among others. However, with an average mean of 3.04 which is greater than 2.50 the minimum level of agreement in the study. The table therefore revealed that Electrical/Electronics Lecturers in Polytechnics in Southwest Nigeria exhibit moderate level of job performance.

Research Question 3*: What is the level of Emotional Intelligence among Electrical/Electronic Lecturers in Polytechnics in Southwest Nigeria?*

Table 3 outlines mean responses on the level of Emotional Intelligence among Electrical/Electronic Lecturers in Polytechnics in Southwest Nigeria. All the 22 items have the mean value ranged from 2.51 to 3.36. c the lecturers that they realize immediately when they lose their temper, they can reframe bad situations quickly, they are able to motivate themselves to do difficult tasks, they are always able to see things from other people's point of view, they are excellent listener among others. However, with an average mean of 2.95 which is greater than 2.50 the minimum level of agreement in the study., the table therefore revealed that there is moderate level of Emotional Intelligence among Electrical/Electronic Lecturers in Polytechnics in Southwest Nigeria.

Table 2. Mean responses on the level of job performance among Electrical/Electronic Lecturers in Polytechnics in Southwest Nigeria

S/N	ITEMS	MEAN	SD
1	I actively Participate in group discussions and meeting at work	2.94	.57
2	I derive a lot of satisfaction, helping my colleagues with their job	3.01	.66
3	I feel i can do with more challenging assignment	3.31	.78
4	My superiors have confidence in my task delivery in Electrical Electronics	2.81	.84
5	I demonstrate in-depth knowledge of subject matter while teaching/lecturing	3.43	.80
6	I make sure I always fulfill all the requirements of my job schedule.	2.88	.79
7	I complete my assignments, setting questions and marking scripts on time.	3.13	.90
8	I always adapt to my institution's organizational change from time to time.	2.90	.72
9	I have great passion for my work as an electrical/electronics lecturer.	2.90	1.03
10	I share professional knowledge and ideas among my colleagues.	3.12	.90
11	I do not spend time on unnecessary conversation at work.	3.39	.89
12	I am always punctual to work.	3.15	.66
13	I communicate effectively with my colleagues to ensure problem solving and good decision making.	2.84	.85
14	I am comfortable with my job flexibility.	2.94	.92
15	I inform my supervisor whenever I am unable to come to work.	2.58	.99
16	I always do more than is expected of me as an electrical/electronics lecturer.	3.13	.78
17	I complain about minor work related issues at times.	3.18	.80
18	I promptly come up with new solutions to solving problems.	3.25	.96
19	I fulfill specific job responsibilities.	3.09	.87
	Average mean	**3.04**	

Table 3. Mean Responses on the level of Emotional Intelligence among Electrical/Electronic Lecturers in Polytechnics in Southwest Nigeria.

S/N	ITEMS	MEAN	SD
1	I realize immediately when I lose my temper.	3.09	1.04
2	I can reframe bad situations quickly.	3.36	.73
3	I am able to motivate myself to do difficult tasks.	3.21	1.02
4	I am always able to see things from other people's point of view.	3.06	.85
5	I am an excellent listener.	3.19	.86
6	I know when I am happy.	2.84	.96
7	I am able to prioritize important activities at work and get on with them.	2.69	.92
8	I am excellent at empathizing with someone else's problem.	2.84	.91
9	I never interrupt other people's conversations.	2.93	.72
10	I usually recognize when I am stressed.	2.94	.98
11	Others can rarely tell what kind of mood I am.	2.99	1.07
12	I always meet deadlines at my place of work.	3.11	.81
13	I can tell if someone is not happy with me.	3.00	.87
14	I am good at adapting and mixing with variety of people.	3.06	.95
15	When I am 'emotional', I am aware of this.	2.51	.94
16	People are the most interesting thing in life for me.	3.03	.85
17	I believe in doing the difficult things first.	2.66	.88
18	I do not prevaricate or procrastinate.	2.90	1.13
19	Difficult people do not annoy me.	2.69	.84
20	I always know when I am unreasonable.	2.55	.99
21	Other colleagues are not difficult, just different.	3.12	.86
22	I can understand why my actions at times offend others.	3.22	.78
	Average mean	**2.95**	

Testing of Hypotheses

Hypothesis 1*: There is no significant relationship among Electrical/Electronic Lecturers job satisfaction, job performance and emotional intelligence in Polytechnics in Southwest Nigeria.*

Table 4 shows the relationship among Electrical/Electronic Lecturers job satisfaction, job performance and emotional intelligence in Polytechnics in Southwest Nigeria. Two of the three correlations are statistically significant at the 0.05 level. Two of the correlations are positive (r = 0.01 and 0.76) while the last correlation is negative (r = -0.68). The results from the table revealed a high and positive correlation between job satisfaction and performance (r = 0.76; p > .05) of Electrical/Electronic Lecturers. Also, a significant but negative (r = -.68; p < .05) relationship was established between job performance and emotional intelligence of Electrical/Electronic Lecturers in Polytechnics in Southwest Nigeria. Based on the results, the null hypothesis 3 was rejected. Hence, there is a significant relationship among Electrical/Electronic Lecturers job satisfaction, job performance and emotional intelligence in Polytechnics in Southwest Nigeria

Hypothesis 2: *Emotional intelligence does not significantly influence job satisfaction of Electrical Electronics lecturers in Polytechnics in Southwest Nigeria.*

Data presented in Table 5 revealed that emotional intelligence of Electrical Electronics lecturers in Polytechnics in Southwest Nigeria significantly influences their job satisfaction (F= 190.552, p= .000). Similarly, data in table revealed that the predictive/influential index (beta) of emotional intelligence is significant (beta= .864, p=.000). The emotional intelligence has the influential power on job satisfaction. Thus, null hypothesis which stated that emotional intelligence does not significantly influence job satisfaction of electrical/electronic technology lecturers in tertiary institutions is hereby rejected**.** This implies that emotional intelligence has a significant influence on job satisfaction of electrical electronics lecturers in polytechnics in southwest Nigeria.

Hypothesis 3: *Emotional intelligence does not significantly influence job performance of Electrical Electronics lecturers in Polytechnics in Southwest Nigeria.*

Data presented in Table 6 revealed that emotional intelligence of Electrical Electronics lecturers in Polytechnics in Southwest Nigeria is significantly influence their job performance (F= 57.546, p= .000). Similarly, data in table 6 showed that the predictive/influential index (beta) of emotional intelligence is significant (β = .685, p= .000). The emotional intelligence has the influential power on job performance. Thus, null hypothesis which stated that emotional intelligence does not significantly influence job performance of electrical/electronic technology lecturers in tertiary institutions is hereby rejected**.** This implies that emotional intelligence has a significant influence on job performance of electrical/electronics lecturers in polytechnics in southwest Nigeria.

Table 4. There is no significant relationship among Electrical/Electronic Lecturers job satisfaction, job performance and emotional intelligence in Polytechnics in Southwest Nigeria

	Variables	Mean	Std.	1	2	3
1	Job satisfaction	3.00	.92	1		
2	Job performance	3.04	.83	.76	1	
3	Emotional intelligence	2.95	.91	-.68**	.01**	1

**. Correlation is significant at the 0.01 level (2-tailed)

Table 5. Significant level of influence of Emotional intelligence on job satisfaction of Electrical Electronics lecturers in Polytechnics in Southwest Nigeria

Model	Sum of Squares	Df	Mean Square	F	Sig.	Beta	T	Sig	95.0% C I (UB-LB)
Regression	24.181	1	24.181	190.552	.000 b	.864	13.80	.000	1.300-.972
Residual	8.248	65	.127						
Total	32.429	66							

a. Predictors: (Constant), emotional intelligence b. Dependent Variable: job satisfaction

Table 6. Significant level of influence of emotional intelligence on job performance of Electrical/Electronics lecturers in Polytechnics in Southwest Nigeria

Model	Sum of Squares	Df	Mean Square	F	Sig.	Beta	T	Sig	95.0% C I (UB-LB)
Regression	5.470	1	5.470	57.546	.000b	.685	7.586	.000	.682-398
Residual	6.178	65	.095						
Total	11.648	66							

a. Predictors: (Constant), emotional intelligence b. Dependent Variable: job performance

Discussion of findings

This study found that there is a significant relationship among Electrical/Electronic Lecturers job satisfaction, job performance and emotional intelligence in Polytechnics in Southwest Nigeria. This support the study of Ouyang et al. (2015), who found that emotional intelligence is an individual attributes that is closely linked to job satisfaction and aids in controlling and lowering stress levels at work. This point to the that there is a link among these variables, since they assist one another in determining stability, wellbeing and productivity of a lecturer.

This study also found that emotional intelligence has a significant influence on job satisfaction of electrical electronics lecturers in polytechnics in southwest Nigeria. This is consistent with the findings of Akomolafe and Ogunmakin's (2014) study, which indicated that employee work satisfaction is significantly influenced by their level of emotional intelligence. Additionally, it also contradicts a previous study of Ismail et al, (2010) which found that academic staff' emotional intelligence is a partial moderator on their job satisfaction.

Additionally, this study also found that emotional intelligence has a significant influence on job performance of electrical/electronics lecturers in polytechnics in southwest Nigeria. This is consistent with research by Smith et al. (2022) that found that work attitude and emotional intelligence were important predictors of job performance. It also supports the findings of a study by Rohana et al. (2009) which found that people with higher emotional intelligence typically exhibit more creativity, better planning, and more motivation, all of which are likely to improve teachers' work performance. This indicate that emotional intelligence has is pivotal in determining the level of lecturer's productivity and how well they will handle stress related task assigned to them in their place of work.

Conclusion

The study concluded that being intelligent is one of the main qualities of good lecturer. However, having high intelligent quotient does not necessarily translate to being highly emotional intelligent. Because they are different characteristics which are important for lecturers to remain relevant and sustain their job. This is more essential for electrical/electronics lecturers due to the nature of their specialization and job demand which most times require brainstorming on some practical laboratory activities that can be stressful at times. Besides, a highly emotional intelligence lecturers are better able to recognize the needs and emotions of their students and peers, as well as being more motivating and encouraging. Furthermore, lecturers who possesses strong emotional intelligence are less likely to use destructive and defensive coping and decision-making strategies in any challenging situations. Additionally, incorporating emotional intelligence into hiring criteria, training programs, and appraisal systems by institutions can foster a more supportive and productive academic environment. In the same vein, policies that promote emotionally intelligent leadership, workplace well-being, and constructive conflict resolution can further improve lecturers' overall job experience and institutional outcomes.

Recommendation

Based on the findings of the study, it was therefore recommended that:

1. Polytechnics management should make sure that sufficient supervisory assistance is available to build good relationships and encourage collaboration among academic staff for the purpose of improving their job satisfaction.
2. Institution authority should incorporate emotional intelligence-based training into professional development programs of lecturers to enhance their work experience and contribute to improved educational outcomes.
3. Promotions and other forms of compensation or incentive should be provided by school management to motivate lecturers level of commitment and performance on their job.
4. An enabling and positive work environment should be put in place to enhance lecturers job satisfaction and performance.

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Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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Enhancing Lifelong Learning Motivation Among Experienced Educators: A Qualitative Analysis of Bootcamp-style Professional Development

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Abstract
This study examines the impact of professional development bootcamps—GENACITY, TENACITY, and TENSITY—on the lifelong learning motivation of experienced educators. The research utilizes a qualitative approach, collecting data through pre-bootcamp open-ended questionnaires, post-bootcamp focus group discussions (FGDs), and participant reflections. Framed within Kirkpatrick's Four-Level Training Evaluation Model and Constructivist Learning Theory, the findings reveal that the bootcamps fostered positive emotional engagement, practical skill acquisition, and behavioral change. Participants expressed increased motivation to implement new teaching strategies, such as active learning, problem-based learning (PBL), and cooperative learning, with many integrating tools like Canva and AI into their practices. However, participants also identified challenges, including time constraints and workload pressures, in sustaining the new strategies. The results indicate that immersive, collaborative professional development programs can reignite educators' passion for continuous learning and offer practical solutions for modern teaching environments. This study emphasizes the importance of reflective practices and follow-up support to ensure sustained impact and proposes that future initiatives prioritize experiential learning and peer collaboration. These findings contribute to the discourse on effective professional development and highlight the potential of bootcamps to address the evolving demands of lifelong learning. The study's limitations include its small, institution-specific sample, which limits generalizability. Future research should involve multiple institutions and larger samples, alongside longitudinal follow-up to validate sustained behavioral change.

Keywords: Lifelong Learning, Professional Development, Educator Motivation, Bootcamp Training, Constructivist Theory.

Introduction

The dynamic nature of education requires educators to continuously evolve their practices, embrace new technologies, and engage in lifelong learning to meet shifting demands. Lifelong learning—the self-motivated pursuit of knowledge for personal or professional development—plays a crucial role in ensuring educators remain effective throughout their careers (Alt & Raichel, 2020). However, experienced educators often face challenges such as time constraints, workload, and diminishing motivation, limiting their ability to engage in continuous professional development (Gumbo, 2020; Pichardo et al., 2021). Professional development programs must provide practical, motivating solutions to sustain engagement in lifelong learning.

In recent years, bootcamp-style professional development has emerged as an innovative approach to address the shortcomings of traditional workshops, which often fail to provide meaningful, long-term impact (Watson & Rockinson-Szapkiw, 2021; Yeh et al., 2021). Bootcamps emphasize immersive, experiential learning through collaborative activities, practical skill development, and real-world application. These intensive programs align with adult learning principles by focusing on relevance and immediate applicability, fostering both professional growth and intrinsic motivation (Bray-Clark & Bates, 2003). However, research on the specific impact of bootcamps on lifelong learning motivation—particularly among experienced educators—remains limited.

The study examines the effectiveness of three professional development bootcamps—GENACITY (The Generative AI Content Creator), TENACITY (The Next Canva Trainer Bootcamp), and TENSITY (The Next Skolar Trainer Bootcamp)—in fostering lifelong learning motivation among educators with over a

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decade of teaching experience, offered by a training & consultancy company called Skolar. GENACITY focused on empowering participants with generative AI tools for teaching and content creation, while TENACITY emphasized creative design using design tool like Canva to enhance classroom visuals. TENSITY, the final bootcamp in the series, integrated active learning strategies, including flipped classroom strategy, cooperative problem-based learning (CPBL) and scaffolding techniques, to promote more interactive and student-centered teaching practices. These bootcamps were designed to address the participants' need for practical skills that could be immediately applied in their classrooms. This study adopts a qualitative approach, using pre-bootcamp open-ended questionnaires, post-bootcamp focus group discussions (FGDs), and participant reflections to assess the bootcamps' impact on motivation, behavior, and learning outcomes. Kirkpatrick's Four-Level Training Evaluation Model provides a framework for analyzing the participants' experiences, examining the bootcamps' effectiveness through four dimensions: reaction, learning, behavior, and results (Kirkpatrick & Kirkpatrick, 2016). Additionally, Constructivist Learning Theory guides the study's analysis by emphasizing how educators actively construct knowledge through interaction, collaboration, and real-world application (Vygotsky, 1978).

Additionally, this study seeks to explore how bootcamps influence educators' lifelong learning motivation and identify the challenges they encounter in applying the skills learned. The findings contribute to the design of effective professional development programs by highlighting the importance of immersive, experiential learning in promoting sustained motivation and practical outcomes. By focusing on experienced educators, the study offers insights into the specific needs of mid-career professionals and addresses gaps in existing research on professional development in the context of lifelong learning.

Nevertheless, this study is limited by its focus on educators from one institution, thereby restricting the generalizability of findings. Furthermore, the longitudinal behavioral changes reported are based on participants' intentions rather than documented outcomes. This study addresses these gaps by explicitly examining educators' immediate motivation and perceived behavioral changes, suggesting future longitudinal studies to strengthen empirical robustness.

Literature Review

The concept of lifelong learning has gained increasing importance in the field of education, where educators must continuously evolve their practices to keep pace with technological advancements and shifting pedagogical trends (Alt & Raichel, 2020). Lifelong learning refers to the self-directed pursuit of knowledge throughout one's professional career, helping educators stay relevant and effective in addressing modern classroom challenges (Berkhout et al., 2018). However, experienced educators often encounter barriers to engaging in continuous learning, such as heavy workloads, time constraints, and declining motivation (Gumbo, 2020). Professional development programs, particularly those focusing on immersive and practical skill-building, offer a potential solution to sustain educators' motivation and facilitate lifelong learning (Watson & Rockinson-Szapkiw, 2021).

Generative AI (GenAI) is revolutionizing education by transforming how content is created, personalized, and delivered. As tools like ChatGPT and other large language models become integrated into teaching and learning (T&L), educators can benefit from AI's ability to enhance instructional design, streamline assessments, and foster personalized learning environments. Research has highlighted various dimensions of GenAI's potential. For instance, Castillo-Segura et al. (2023) found that generative AI can expedite systematic literature reviews by effectively classifying articles, thus accelerating research processes and enabling more timely academic work (Castillo-Segura et al., 2023). Similarly, Walczak and Cellary (2023) argue that the adoption of GenAI presents both opportunities and challenges for higher education, urging the need for curriculum reform and ethical AI literacy to prepare students and educators for a technology-rich future (Walczak & Cellary, 2023). Furthermore, Creely and Blannin (2023) stress that GenAI tools can reshape creative pedagogies, especially in teacher training, by encouraging innovative content creation while also raising critical questions about the evolving nature of creativity and student output (Creely & Blannin, 2023). These studies emphasize the importance of harnessing GenAI to foster adaptive, inclusive learning environments while addressing potential risks, such as algorithmic bias and the erosion of traditional academic practices.

In addition to this, another educational tool that could be adopted to enhance the teaching and learning process is Canva. Canva has emerged as a powerful tool in education, empowering both educators and students by enhancing creativity, collaboration, and teaching efficiency. The platform's accessible design interface allows users to create visually appealing educational content, including presentations, infographics, and worksheets, fostering more engaging learning environments. Vargas et al. (2022) demonstrated that Canva significantly enhances interactive learning, improving students' motivation, understanding, and participation in basic education settings (Vargas et al., 2022). Similarly, research by Pedroso et al. (2023) found that Canva promotes creativity and collaboration, helping students develop essential 21st-century skills through shared projects and group activities (Pedroso et al., 2023). Furthermore, Mudinillah et al. (2021) highlighted Canva's role in language education, where it increased students' interest and creativity in mastering new languages by transforming traditional lessons into interactive activities (Mudinillah et al., 2021). These studies underscore the growing importance of Canva in fostering lifelong learning among educators by enabling them to stay innovative, collaborative, and engaged in their teaching practices.

Educational tool or technology can only be benefited with the right use of pedagogy. Cooperative Learning, Problem-Based Learning (PBL), Flipped Classroom, and Active Learning are student-centered pedagogical strategies that enhance engagement, foster collaboration, and develop essential skills for both academic and professional contexts. Active learning is a pedagogical approach that emphasizes student engagement through participatory activities, shifting the focus from passive reception of knowledge to active involvement in the learning process. According to Azizan (2023), active learning aims to enhance cognitive engagement by encouraging students to interact with course content, instructors, and peers through structured activities. These activities promote critical thinking, problem-solving, and collaboration, which are essential skills for academic and professional success.

Active learning strategies yield positive results in both face-to-face and online learning environments. Azizan's study highlights the effectiveness of combining tools like Mentimeter, Canva, and breakout rooms with active learning techniques to enhance student engagement and learning outcomes. When students engage actively through reflection, collaborative tasks, and interactive quizzes, they are more likely to achieve a deeper understanding of the material and retain knowledge over time. Moreover, these methods foster persistence and sustained effort, which are critical components of cognitive engagement. Azizan (2023) found that the use of intermittent discussions, reflection activities, and problem-solving exercises helped students stay motivated, resulting in improved academic performance and satisfaction. This study underscores the importance of using technology-enhanced active learning methodologies to address the challenges of online education and achieve meaningful learning outcomes.

Cooperative Learning is an educational strategy in which students work together in small, structured groups to achieve a common goal. It emphasizes collaborative tasks that enhance both individual and group accountability, fostering teamwork, communication, and critical thinking skills (Gillies, 2016). In cooperative learning environments, students engage in meaningful activities that promote mutual understanding and social interaction, leading to improved learning outcomes and positive interpersonal relationships.

Problem-based learning, on the other hand, introduces real-world problems as the focus of learning, requiring students to explore solutions through inquiry and collaborative effort. PBL nurtures critical thinking, problem-solving abilities, and independent learning by placing students in the role of active investigators. These strategies align with modern teaching practices that emphasize active learning, collaboration, and student-centred instruction (Pichardo et al., 2021). Cooperative Problem-based Learning (CPBL) integrates cooperative learning principles with problem-solving tasks, encouraging students to work together to solve complex, real-world problems (Bray-Clark & Bates, 2003). This method promotes higher-order thinking skills and peer interaction, preparing students for collaborative work environments beyond the classroom (Kim, 2019).

Moreover, the flipped classroom shifts traditional teaching by moving lectures and instructional content outside the classroom, using in-class time for discussions, group activities, and problem-solving exercises (Watson & Rockinson-Szapkiw, 2021). Research indicates that combining cooperative learning with flipped classroom techniques improves student engagement, learning outcomes, and critical thinking skills (Fernández-Ferrer & Pizarro, 2022). Research shows that these strategies are effective in improving students' learning outcomes and motivation. Foldnes (2016) found that students in a flipped classroom with cooperative learning components performed better academically than those in traditional lecture settings. Similarly, Chang et al. (2022) demonstrated that combining PBL with cooperative learning enhanced students' problem-solving abilities and teamwork in programming courses. Moreover, Fernández-Ferrer and Pizarro (2022) emphasized that incorporating active learning strategies within flipped classrooms not only improves student engagement but also significantly enhances academic performance. These pedagogical methods encourage lifelong learning by equipping learners with essential competencies for both academic and personal growth. These strategies empower students to be more autonomous learners and develop essential skills for real-world applications.

The integration of Generative AI, Canva, and modern pedagogical strategies into teaching practices is essential for educators to remain relevant and effective in today's digital learning landscape. Research shows that adopting technology and innovative teaching methods can significantly improve student engagement, learning outcomes, and satisfaction (Ran & Josefberg Ben-Yehoshua, 2020). Moreover, as students increasingly engage with digital content, educators must be proficient in creating visually appealing and interactive materials to capture their attention (Yeh et al., 2021). Learning these skills also empowers educators to foster more inclusive and collaborative classrooms. For example, cooperative learning and CPBL encourage students from diverse backgrounds to work together, promoting social cohesion and empathy (Kim, 2019).

The flipped classroom model further supports differentiated instruction, allowing educators to tailor learning activities to students' individual needs and learning styles. However, implementing these strategies requires sustained professional development and ongoing support, as educators may encounter challenges such as time constraints, lack of institutional resources, and resistance to change (Gumbo, 2020). Bootcamps that focus on experiential learning, collaboration, and reflection provide educators with practical tools and strategies to overcome these barriers.

This study adopts Kirkpatrick's Four-Level Model and Constructivist Learning Theory as guiding frameworks. Kirkpatrick's model evaluates training outcomes through four levels: reaction, learning, behavior, and results (Kirkpatrick & Kirkpatrick, 2016). By assessing participants' immediate reactions to training, the model captures emotional engagement, which is essential for motivation. It then examines the learning outcomes, behavior changes, and long-term results, providing a comprehensive understanding of the program's impact. Meanwhile, constructivist learning theory emphasizes active participation, collaboration, and real-world application in the learning process (Vygotsky, 1978). This theory aligns with the bootcamp model, where participants engage in problem-solving tasks, collaborative activities, and reflection to construct knowledge. Scaffolding, a key element of constructivist pedagogy, ensures that learners receive structured support as they develop new skills, gradually becoming independent in their application (Kim, 2019).

Although constructivist theory emphasizes active learning and collaboration, practical limitations exist in adult learning contexts. Adults may face constraints such as heavy workloads, limited time for extensive reflection, and resistance to new learning paradigms. These practical challenges necessitate careful design and support mechanisms within constructivist-based professional development programs. While bootcamp-style professional development programs have shown promise in promoting professional growth, further research is needed to understand their impact on lifelong learning motivation among experienced educators. This study aims to fill this gap by examining the experiences of educators who participated in the GENACITY, TENACITY, and TENSITY bootcamps. Through qualitative analysis using Kirkpatrick's Four-Level Model and Constructivist Learning Theory, this research offers insights into the challenges and successes educators encounter in sustaining motivation and implementing new teaching strategies.

Methodology

Research Design

This study employs a qualitative research design using thematic analysis to explore participants' experiences across three professional development bootcamps—GENACITY, TENACITY, and TENSITY. The primary objective is to understand the bootcamps' impact on educators' lifelong learning motivation and pedagogical practices. A deductive coding approach was used, guided by Kirkpatrick's Four-Level Model and Constructivist Learning Theory. These frameworks provided a structured lens to assess participants' reactions, learning outcomes, behavior changes, and anticipated results.

Participants and Sampling

Each bootcamp involved 15 participants, with 90% overlap across the three bootcamps. All participants involved in this study were experienced educators from Technical and Vocational Education and Training (TVET) backgrounds at Kolej Kemahiran Tinggi MARA (KKTM) Kuantan. Participants had diverse subject expertise across areas such as automotive, manufacturing, robotics, and design engineering. They were actively engaged in promoting 21st-century skills initiatives at their institution. Although all participants came from the same institution, they brought diverse teaching experiences and subject expertise, creating a rich exchange of ideas and collaborative learning throughout the bootcamps.

A limitation of this study is the homogeneous sample of 15 educators from a single TVET institution. Although this facilitated deep qualitative insights, future research should involve diverse participants from various educational institutions to improve generalizability.

Table 1. Sampling of Participants' Detail

Bootcamp	Duration	Participant (n=15)	Demographic	Average Teaching Years
GENACITY	6 days (3 days + 3 days in 2 weeks) – Month 1	15	TVET Educators, KKTM Kuantan	5- 15 years
TENACITY	6 days (3 days + 3 days in 2 weeks) – Month 2	90% same cohort	Same as above (90% overlap from GENACITY)	5 -15 years
TENSITY	6 days (3 days + 3 days in 2 weeks) – Month 3	90% same cohort	Same as above (90% overlap from GENACITY)	5 -15 years

A detailed timeline of the bootcamps is presented below to illustrate the sequence of activities clearly.

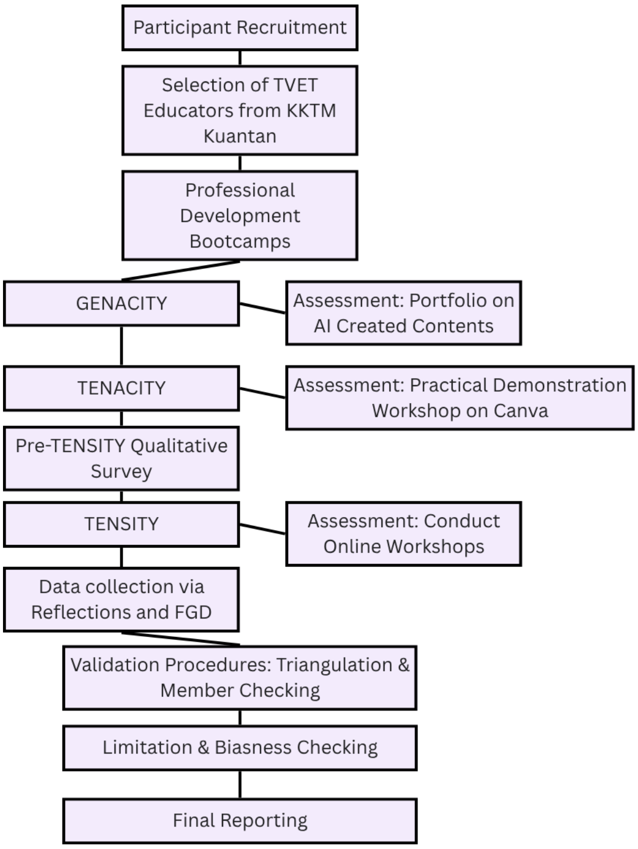

Figure 1. Timeline and sequence of professional development bootcamps (GENACITY, TENACITY, TENSITY) and corresponding data collection activities.

Data Collection Methods

The study employed three key data collection tools: pre-bootcamp questionnaires, post-bootcamp reflections, and focus group discussions (FGDs). Triangulation was conducted by systematically cross-validating data from pre-bootcamp questionnaires, participant reflections, and FGDs to enhance the reliability of findings and minimize individual researcher biases.

Pre-Bootcamp Questionnaires:

Administered two weeks before the TENSITY bootcamp, these semi-structured questionnaires captured participants' expectations and reflections on their experiences in the preceding GENACITY and TENACITY bootcamps.

Post-Bootcamp Reflections:

Participants provided reflections using Gibbs' Reflective Cycle. Reflections were collected midway through each bootcamp (after the first three days) and immediately after completion to capture evolving insights.

Focus Group Discussions (FGDs):

Semi-structured FGDs, lasting two hours, were conducted immediately after the final TENSITY bootcamp. Two facilitators led the discussions, and the sessions were audio and video recorded for transcription using Otter.AI and manually checked for accuracy.

Procedure

The bootcamps were conducted over a period of three months to provide ample opportunity for reflection, collaboration, and application. The bootcamps—GENACITY, TENACITY, and TENSITY—were conducted fully in-person, with participants and facilitators interacting face-to-face, fostering direct collaboration and engagement throughout the sessions.

- GENACITY Bootcamp (Month 1): Focused on the use of generative AI tools for content creation, including text, image, audio, and video transformations.
- TENACITY Bootcamp (Month 2): Emphasized visual design strategies using Canva, covering areas such as branding, video production, and proposal development.
- TENSITY Bootcamp (Month 3): Concentrated on active learning techniques, incorporating cooperative problem-based learning (CPBL) and flipped classroom strategies to foster student engagement.

Each bootcamp ran over two weeks with three days of sessions per week, allowing participants time for practice and reflection. At the end of each bootcamp, participants received professional competency certificates endorsed by a partnering university.

Data Analysis

A deductive thematic analysis was used to analyze the collected data. The themes were identified and mapped to Kirkpatrick's four levels (Reaction, Learning, Behavior, and Results) and aligned with constructivist learning principles.

The analysis followed these steps:

- Coding and Theming: Transcripts and reflections were systematically coded based on predefined categories.
- Triangulation: Data from questionnaires, FGDs, and reflections were cross-referenced to ensure consistency.
- Member Checking: The initial findings from the FGDs were shared with participants to validate the interpretations.
- Software Tools: A GPT-powered qualitative analysis channel was used to assist with data coding and theme extraction.

Data analysis involved deductive thematic analysis using predefined categories based on Kirkpatrick's Four-Level Model and Constructivist Learning Theory. Initial coding schemes were developed and clearly defined for consistent application. Two researchers independently manually coded a sample set of transcripts, also assisted with AI-assisted software, TurboScribe during the FGD. Comparison was made so it achieved an intercoder reliability rate of 85% before proceeding with full data analysis. Data were analyzed using qualitative analysis software (GPT-powered tools and manual review), ensuring thorough and unbiased interpretation.

Ethical Considerations

All participants were informed about the purpose of the research and provided written consent. Participants' anonymity was maintained throughout the study, and only aggregated findings were reported. Data were stored securely to protect participants' privacy, and no specific ethical challenges were encountered during the study. Given the facilitators' dual roles as researchers, potential biases were mitigated through rigorous member checking, triangulation of multiple data sources, and independent coding verification.

Findings and Discussions

The bootcamps—GENACITY, TENACITY, and TENSITY—provided an immersive learning environment where participants were exposed to modern pedagogical techniques, generative AI tools, and collaborative problem-solving frameworks. This section synthesizes participants' reflections and insights from FGDs, using Kirkpatrick's Four-Level Model and Constructivist Learning Theory to explore how the bootcamp contributed to their motivation as lifelong learners.

Reaction (Kirkpatrick Level 1)

Participants' emotional responses to the bootcamp were overwhelmingly positive. They described feelings of excitement, enjoyment, and gratitude for the opportunity to participate in a hands-on, collaborative learning experience. The workshops' interactive format, including role-play, group discussions, and Canva-based activities, was well-received.

- Participant Reflection: "*Seronok sangat belajar teknik baru, rasa macam dah bersedia nak apply dalam kelas saya. Tensity banyak beri keyakinan saya sebagai pendidik*."
- Translated reflection: *"I truly enjoyed learning new techniques; I feel ready to apply them in my class. TENSITY significantly boosted my confidence as an educator."*
- FGD Insight: Participants noted that the collaborative environment fostered a sense of community, which motivated them to engage actively throughout the sessions.

The emotional response from participants aligns with the constructivist principle that positive engagement enhances motivation. The bootcamp provided a supportive environment where participants felt valued, which is essential for cultivating intrinsic motivation and a desire for continuous learning. The interactive format of the workshops, incorporating role-play, group discussions, and Canva-based activities, fostered intrinsic motivation. This aligns with Paull et al. (2016), who emphasized the importance of positive emotional engagement as a driver for educators to embrace change and adopt new teaching strategies. This intrinsic motivation is a fundamental aspect of lifelong learning, as described by Garrison (1997), who highlighted that intrinsic motivation plays a crucial role in self-directed learning by fostering continuous curiosity and perseverance.

Positive emotional engagement, facilitated by interactive and collaborative bootcamp sessions, is well-aligned with Constructivist Learning Theory, emphasizing the importance of learner-driven engagement to foster intrinsic motivation and self-directed lifelong learning.

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Learning (Kirkpatrick Level 2)

The bootcamps were designed to equip participants with practical knowledge and skills, focusing on active learning strategies, cooperative learning structures, and generative AI tools.

Participants experienced peer teaching through jigsaw activities and role-play, which deepened their understanding by requiring them to teach others.

- Participant Reflection: "Role-play sangat membantu saya faham tentang behavior pelajar dan cara nak urus supaya semua contribute dalam kumpulan."
- Translated Reflection: "Role-play greatly helped me understand student behavior and how to manage the group effectively so that everyone contributes."
- FGD Insight: Many participants emphasized how scaffolding activities helped them connect theoretical concepts with real-world teaching practices.

The scaffolding techniques used in the bootcamp—such as breaking down complex topics into manageable parts—align with the How People Learn (HPL) framework (Bransford, 2000). As the participants delved deeper into the bootcamp, they collaborated together as a team adopting cooperative learning strategy to solve the given problems. This aligns with findings by Azizan (2018), who demonstrated that cooperative learning techniques significantly enhance deep learning and teamwork by engaging students in complex, real-world problem-solving tasks. Participants were able to progress from surface-level learning to deeper, more meaningful engagement with content, reinforcing their understanding of active learning, flipped classrooms, and CPBL. This experience reflects the constructivist view that learning occurs through active participation, reflection, and social interaction.

The bootcamps offered participants practical knowledge, particularly in using active learning strategies, CPBL, and generative AI tools. Activities such as jigsaw tasks and role-play facilitated peer teaching, deepening understanding through collaborative problem-solving. These approaches reflect the principles outlined by Lim and Choy (2014), who found that immersive faculty development programs enhance the application of problem-based learning by promoting key behaviors such as collaboration and student engagement. Furthermore, the scaffolding techniques employed during the bootcamp allowed participants to break down complex concepts, supporting deeper learning, as emphasized by Schumacher et al. (2013), who stressed the role of scaffolding in advancing cognitive engagement and self-directed learning.

Participants noted the effectiveness of scaffolding and peer teaching in understanding practical strategies; however, the time-intensive nature of such approaches highlights the practical limitations of constructivist methods in busy professional environments, suggesting the need for institutional support to maximize effectiveness.

Behavior (Kirkpatrick Level 3)

Participants demonstrated immediate behavioral changes by applying the techniques learned during the bootcamps. They also expressed a commitment to mentoring colleagues and sharing insights on social media platforms. This aligns with Edinger (2017), who found that training programs based on Kirkpatrick's model can foster long-term behavior change when participants receive practical tools and strategies. This behavioral change demonstrates the development of self-directed learning skills, a critical element of lifelong learning, as identified by Bolhuis (2003), who emphasized that educators equipped with self-directed learning skills are more likely to embrace continuous professional development. The followings are some output from the participants that reflect this stage.

- Participant Reflection: "*Saya dan team akan buat video marketing 7P's guna Canva dan cuba guna teknik flipped classroom dalam sesi kami."*
- Translated reflection: *"My team and I will create a marketing video on the 7P's using Canva and try implementing the flipped classroom technique in our sessions."*
- FGD Insight: Participants actively engaged in planning collaborative projects and discussed using TikTok to share modern pedagogical techniques.

This behavioral shift reflects the bootcamp's role in fostering self-directed learning skills, an essential component of lifelong learning. Participants not only adopted new strategies but also became advocates for change, promoting best practices within their institutions. The bootcamp provided a structured starting point for participants to explore and develop these skills, even as adults. Moreover, Azizan (2023) found that using active learning tools like Canva, Mentimeter, and breakout rooms in online learning enhances student engagement and promotes the adoption of innovative teaching practices. Throughout this bootcamp, the participants used a lot of educational tools such as Canva, Generative AI, Padlet and Mentimeter. This behavior shift reflects participants' transition from passive learners to active practitioners, a hallmark of lifelong learning (Blaschke & Hase, 2015).

Nonetheless, behavioral changes described here are primarily based on participants' expressed intentions immediately post-bootcamp. Future research should verify these intended behavioral changes through classroom observations, peer feedback, and analysis of teaching artifacts.

Results (Kirkpatrick Level 4)

The ultimate impact of the bootcamp extends beyond individual learning, as participants envisioned broader ripple effects within their institutions. They expressed a commitment to continuous learning and collaborative teaching, emphasizing the importance of peer support and interdisciplinary collaboration.

- Participant Reflection: "*Saya akan terus tambah ilmu dan guna teknik-teknik baru ini dalam PdP semester ini*."
- Translated Reflection: *"I will continue to gain knowledge and apply these new techniques in my teaching and learning activities this semester."*
- FGD Insight: Participants highlighted the importance of mentorship and collaborative initiatives, suggesting that the bootcamp had empowered them to mentor colleagues and initiate professional development projects within their institutions.

The bootcamp's structure and content fostered a culture of continuous professional development, reinforcing participants' commitment to lifelong learning. The participants' intentions to share knowledge, collaborate with peers, and mentor others demonstrate the bootcamp's alignment with Constructivist Learning Theory, which emphasizes the importance of learning within a community. This aligns with findings by Chukwuedo et al. (2021), who reported that lifelong learning interventions enhance educators' capacity to foster a culture of continuous learning within their organizations. These findings demonstrate how the bootcamps empowered participants to become change agents, facilitating a ripple effect that promotes lifelong learning within their educational ecosystems.

Although participants expressed a commitment to sustained behavioral changes and envisioned institutional ripple effects, this level of impact remains speculative. Comprehensive longitudinal research, involving concrete documentation of these impacts, is needed to confirm the bootcamp's effectiveness over time.

Challenges and Sustainability of Motivation

Despite the positive outcomes, participants identified several challenges, including:

- Time constraints for preparing flipped classroom materials.
- Managing group dynamics during collaborative activities.
- Need for interdisciplinary collaboration to fully implement CPBL strategies.
- Participant Reflection: *"Implement PBL perlukan masa dan kerjasama dengan pensyarah lain untuk berjaya."*
- Translated Reflection: *"Implementing PBL requires time and collaboration with other lecturers to be successful."*

These challenges reflect the realities of modern teaching but also highlight areas where institutional support is essential. Participants noted that peer collaboration served as a scaffold for developing self-directed learning skills, demonstrating that such bootcamps are critical starting points for educators seeking to become lifelong learners.

In addition, participants identified several challenges, including time constraints for preparing flipped classroom materials, managing group dynamics, and the need for interdisciplinary collaboration to fully implement CPBL strategies. These challenges mirror those highlighted by Moteri (2019), who emphasized that self-directed learning frameworks must address practical challenges such as time management and collaboration to ensure sustainability, and therefore recognising the challenges that will come to them is a positive sign for a self-directed learner.

The practical challenges identified by participants such as time constraints, workload management, and interdisciplinary collaboration did underscore constructivism's practical limitations. Institutional frameworks and support are essential to address these constraints and sustain the effective application of constructivist learning strategies in professional development.

Implications for Lifelong Learning

The bootcamp experience provided participants with valuable tools and frameworks to foster continuous professional growth. The use of scaffolding, role-play, and collaborative learning was instrumental in helping participants develop the skills needed to adapt to evolving educational landscapes. The bootcamp also encouraged participants to explore new technologies, such as Canva and generative AI, which are increasingly important in modern classrooms. The bootcamp experience provided participants with tools to foster continuous growth. The use of scaffolding, role-play, and collaborative learning activities helped participants develop critical skills for adapting to evolving educational demands. This aligns with Chaves (2007), who emphasized the importance of constructivist learning environments in promoting lifelong learning. Additionally, the commitment to mentoring colleagues and sharing knowledge on social platforms reflects the importance of communities of practice in sustaining professional growth, as outlined by Blaschke & Hase (2015) in their discussion of heutagogy and lifelong learning. By empowering educators with the confidence and skills to lead change, the bootcamp serves as an enabler for a larger ripple effect within the educational ecosystem.

Conclusion

This study demonstrates that immersive bootcamp-style professional development programs—such as GENACITY, TENACITY, and TENSITY—play a pivotal role in reigniting educators' motivation for lifelong learning and equipping them with practical, relevant skills. Framed within Kirkpatrick's Four-Level Training Evaluation Model and Constructivist Learning Theory, the findings indicate that these bootcamps foster positive emotional engagement, deeper learning, behavioral changes, and long-term impact within educational institutions. Participants reported increased motivation to implement new teaching strategies such as active learning, CPBL, and flipped classroom techniques, as well as confidence in using technology tools like Canva, Generative AI, and other digital platforms in their teaching practices. The bootcamps effectively facilitated self-directed learning by encouraging educators to become active learners and practitioners. This behavioral shift aligns with the principles of heutagogy, where learners take ownership of their development, further reinforced by the collaborative and reflective nature of the bootcamps. Moreover, the study highlights those participants not only adopted new strategies but also embraced mentorship roles within their institutions, suggesting that bootcamps have the potential to initiate ripple effects that promote continuous learning at an institutional level.

However, the findings also reveal several challenges, including time constraints, workload management, and the need for interdisciplinary collaboration to fully implement strategies like CPBL. These challenges emphasize the importance of institutional support and follow-up initiatives to ensure sustained application of the skills acquired during the bootcamps. Recognizing these challenges is a positive indicator of participants' growing self-awareness as lifelong learners, as they prepare to overcome obstacles through collaborative efforts and professional communities of practice. Fig. 2 illustrates how the bootcamps contributed to participants' development as lifelong learners. In addition to this, the authors would like to emphasis that relatively small sample size, potential selection bias, possible researcher bias due to facilitators' dual roles, and the lack of long-term follow-up would be some of the limitations for this research. The authors suggested these as areas for future research.

In conclusion, the study underscores the value of experiential, collaborative professional development programs in motivating lifelong learning among experienced educators. Bootcamps that integrate technology tools, reflective practices, and active learning frameworks not only enhance teaching effectiveness but also cultivate intrinsic motivation for continuous growth. Future professional development initiatives should prioritize experiential learning, peer collaboration, and ongoing support to sustain the momentum generated during such programs. These findings contribute to the broader discourse on professional development and offer valuable insights for designing effective training models that align with the evolving demands of the educational landscape.

The study acknowledges key limitations, including a relatively small sample size, potential biases from facilitator-researcher dual roles, and reliance on self-reported behavioral intentions. Future studies should address these limitations through larger, diverse samples, multi-institutional contexts, and longitudinal analyses with documented behavioral outcomes.

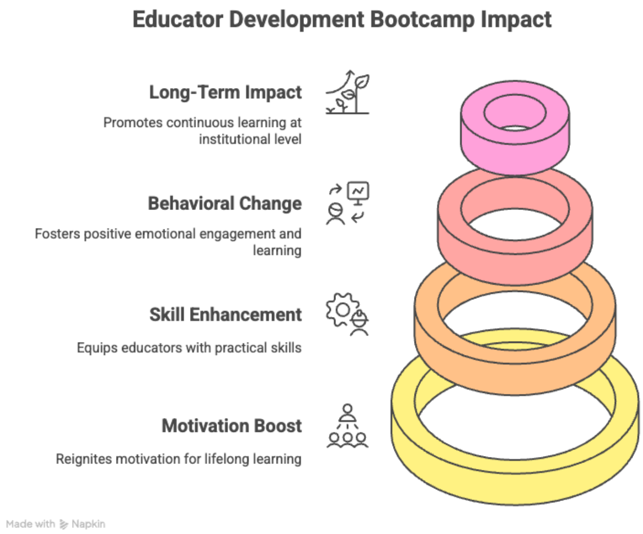

Figure 2. The conclusive findings of the bootcamp impact towards lifelong learning of the educators

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Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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Teaching Transversal Skills for Engineering Students: A Book Review

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Abstract
Teaching Transversal Skills for Engineering Students by Siara Isaac and Joelyn de Lima presents a comprehensive and practical framework for embedding transversal skills in engineering education through the innovative use of tangible objects and experiential learning. The book is based on the 3T PLAY project at EPFL, which was funded by the LEGO Foundation. It provides a robust conceptual foundation and practical activities to equip engineering students with essential non-technical competencies, including communication, sustainability, risk management, and emotional self-regulation. The book is valuable for educators seeking structured, evidence-informed, and engaging strategies to improve the acquisition of transversal skills. While its strengths lie in its playful pedagogical framework and practical guides, the book could further benefit from expanded coverage of cultural adaptability and broader case studies from non-European contexts. Nevertheless, the work stands as a pioneering contribution to engineering education and pedagogical innovation.

Keywords: Transversal skills, engineering education, experiential learning, tangible objects, 3T PLAY.

Introduction

Transversal skills — often known as soft, professional, or generic skills — have gained increasing prominence in engineering education, particularly due to the evolving demands of modern engineering practice. Engineers are no longer expected to only solve technical problems but also to work in diverse teams, manage projects, and respond to societal and ethical issues. Recognizing this gap, the book *"Teaching Transversal Skills for Engineering Students*" presents an innovative and actionable approach to systematically integrating the development of transversal skills into engineering curricula (Martins et al., 2021).

Developed as part of the 3T PLAY project at the Swiss Federal Institute of Technology in Lausanne (EPFL) and supported by the LEGO Foundation, the book introduces a "trident framework" — Knowing, Experiencing, and Learning from Experience — to design low-stakes, hands-on, and iterative learning experiences using tangible materials like LEGO or pasta. It combines theoretical grounding with ready-to-use activity templates, making it highly relevant for educators, instructional designers, and institutional planners (Manzini 2021).

The following section presents a chapter-wise summary and evaluation of the book's practical insights and academic contributions.

Chapter Summaries

Table 1. Summaries each Chapter

Chapter	Enhanced Summary
Chapter 1: How to Develop Engineering Students' Transversal Skills	This introductory chapter is pedagogically rich and grounded in both conceptual and empirical research. It defines transversal skills as critical, non-technical process competencies—such as collaboration, reflection, communication, adaptability, and ethical reasoning—that must be integrated with technical skills for holistic engineering education. The authors challenge the prevalent "hidden curriculum" assumption, where transversal

	skills are presumed to develop implicitly through group work or internships. Instead, they argue for deliberate and scaffolded learning. The chapter introduces the 3T PLAY Trident Framework — consisting of: • Knowing (conceptual knowledge of a skill), • Experiencing (hands-on, embodied practice using tangible objects), • Learning from Experience (structured reflection to promote transfer). Drawing on Kolb's Experiential Learning Cycle, embodied cognition, and constructivist learning theory, the authors advocate for micro-experiential learning. These brief, engaging, hands-on activities mimic real-world complexity while keeping cognitive load to a minimum. Tangible materials are used not just to "play" but to represent abstract concepts, make thinking visible, and foster meaningful interaction. This framework sets a robust foundation for transversal skill development that is replicable, adaptable, and research-informed.
Chapter 2: Retrospective Discussions to Improve Team Collaboration	It provides a specific approach to help groups learn to collaborate more efficiently by engaging in reflective practice. They state that, even though college students are accustomed to working in groups, they often struggle to discuss how their team operates. The main idea is to use retrospective discussions, which help teams think seriously about their work process rather than just the finished results they achieve. With the help of reflection cards, it becomes easier to see both the problems and positive aspects in areas such as how questions are asked, who handles different roles, and how accountability is shared. They employ team learning theory and social constructivism to demonstrate that reflection should be viewed as a

	collaborative and group-based activity. Through this activity, students learn to notice when members of a group may be demanding rights, their power is being abused, and members don't speak up, allowing group assumptions to influence their actions. Another essential aspect of management is developing trust and safety, as these are essential for providing honest feedback. Presenting teamwork as a skill people can strengthen, the author gives form to what was before, just a concept in team reflections. Teachers have detailed plans, instructional aids, and options to customize the activity to suit the size of their class and the way it is taught.
Chapter 3: Giving and Receiving Constructive Feedback	One of the most intense and crucial topics in this chapter is dealing with both giving and receiving feedback, mainly when it is negative. As the authors note, while feedback is essential in teams, people frequently give it poorly or avoid giving it since they dread facing conflicts. Practicing difficult conversations is the primary focus of the education process. Learners first examine ways to provide effective feedback: avoid criticizing personality flaws, offer specific details, and always approach their growth in a positive light. During the Experiencing phase, students practice giving and receiving difficult feedback by using ready-made scripts or cards that involve challenging, challenging situations. The act of scaring induces genuine fear in the players, enabling them to better match the challenges found in real life. Participants at this stage write in their journals and then discuss aspects of emotional control, good listening, and standard communication errors in a group setting. This approach is grounded in the theory of emotional intelligence, conflict resolution frameworks, and

	principles of nonviolent communication. The authors also embed guidance on cultural considerations, particularly relevant in international classrooms where feedback norms vary.
Chapter 4: Values-Based Negotiation and Sustainability	This approach differs from the conventional perspective on sustainability, as it focuses on how stakeholders agree on suitable values and principles. They are encouraged to build a LEGO model that demonstrates how they view sustainability (for instance, fairness, minimalism, and long-term). After creating their models, students must work together to form a standard model. During this playful game, it becomes clear that there are meaningful debates in the real world about which values to prioritize in sustainability, such as efficiency, equity, short-term gains, and long-term plans. In this chapter, Fisher and Ury's approach to ethically driven negotiation, value-sensitive design, and frameworks for understanding morality are used. It inspires students to examine and consider the SDGs from an ethical perspective. It also provides students with the opportunity to learn how to defend their own beliefs while being understanding of others. The chapter is special because it brings sustainability in a way that involves people in dialogue, making it relevant and easy to understand.
Chapter 5: Building Coaching and Peer-Teaching Skills Through Play	Although coaching is often viewed as a high-level job, I am presenting it as a key skill that anyone can develop in everyday work situations. It describes coaching as a set of actions that are useful for helping people learn, cooperate, and interact with one another. The basic activity involves students playing while communicating: one assembles a LEGO duck and guides the other person to build it without showing an example.

	Constrained communication highlights some standard flaws in coaching: instructions are sometimes unclear, important thoughts are often left unspoken, questions prove unhelpful, and misunderstandings can occur. Students soon notice how tough it can be to express their thoughts clearly, support each person's rights, and encourage common understanding. With guidance, they assess whether they provide beneficial advice, create questions that aid understanding, and consider what learners need to learn effectively. The activity employs approaches such as Vygotsky's Zone of Proximal Development, dialogic teaching, and peer learning in education. This chapter views coaching as an essential skill that any team member can learn, rather than being limited to central leadership or mentorship roles. The framework describes coaching as a set of behaviours that people can observe and use to facilitate learning, communication, and teamwork. In the central part, students play and learn insightful lessons: one creates a LEGO duck and assists another student in making a similar duck, but never reveals the original model. Using these constraints draws attention to typical errors during coaching, including blurry directions, unannounced expectations, ineffective questions, and misunderstandings between individuals. Soon, students notice how tough it is to discuss ideas openly, allow individuals to be independent, and reach a common understanding. By reflecting, they assess their ability to advise students effectively, use open-ended questions, and provide help tailored to the individual

	learner. The way students learn is supported by theories such as the Zone of Proximal Development, dialogic teaching, and peer learning. They make clear that coaching is not only a technique but also an activity that takes place in groups and supports the exchange of critical knowledge among team members. Pupils learn scaffolding, paraphrasing, active listening, and diagnostic questioning in a friendly environment where mistakes are expected and can be addressed. Playa has a very calming effect that encourages individuals to enjoy experimenting with new ideas. It is not enough to duplicate the duck perfectly; a coach must adapt it, control the meeting's flow, respond to suggestions, and guide the learning process effectively. As a result, students gradually transition from simply learning information to actively helping others grow, which is essential for engineers collaborating with other experts.
Chapter 6: Teaching Risk Awareness and Planning in Project Work	Risk planning involves devising solutions ahead of time and collaborating with others in the present. Here, learners are invited to design and build a physical object, such as a small sculpture, within a specified time frame. At the midpoint, the facilitators introduce occasions known as risk events, such as equipment problems, team members leaving, and unexpected changes in the goals. Due to these unexpected events, students must review risk matrices, adjust their strategies, and redistribute essential resources almost immediately. We should develop strong problem-solving skills, accept failures, and improve at adapting to new situations. By incorporating ideas from project management, agile methodology, and resilience engineering, this activity

	facilitates a clearer understanding of planning concepts. Touchable items, such as differently coloured bricks or dice, help make the concept of risk tangible and aid in people's understanding and retention of it. Notably, the chapter suggests that learning from failure is an integral part of the teaching process. Instead of dwelling on failures, students are motivated to understand and improve themselves in the face of failures. Such activities encourage them to reflect on their initial ideas, examine their response to pressure in decision-making, and assess how adaptable their resource management is. The chapter is helpful for instructors since it provides various examples for discussing risk, clear guides for debriefing teams, and reflective questions to aid in summarizing lessons and improving students' readiness for complex real-world projects.
Chapter 7: Creating Psychological Safety in Engineering Teams	Although psychological safety is crucial for teamwork and academic performance, it is rarely discussed in technical education. It provides helpful steps for educators and students to improve and support psychological safety in engineering teams. For this activity, students transform ideas about safety, feelings, or team norms into symbolic constructions, such as "safe spaces" or "trust bridges." They can be used to initiate conversations about inclusion, active listening, openness, and fostering respectful behaviours within a team. They also examine past team experiences to identify what factors helped or hindered psychological safety. Drawing on Amy Edmondson's findings, this task offers practical ideas for developing teaching skills and understanding our emotions, encouraging students to be more self-aware and sensitive in social situations. It helps

	students, particularly those who are not the same, to form a team where everyone respects each other and is open from the start. It is suggested that educators introduce this team task early in the term and revisit it periodically during the project to support the team's growth and development. Additionally, team charter templates, online questionnaires, and methods for observing behaviour can all help create and maintain a secure environment, enabling students and instructors to collaborate and achieve their long-term objectives.
Chapter 8: Designing Transversal Skills Activities Using the Trident Framework	The last chapter explains how teachers can plan their own transversal skills activities using the 3T PLAY Trident Framework. Building on what was learned earlier in this book, instructors are advised to choose more than the set activities and instead play an active role in planning and implementing lesson content that fits their specific context. The chapter introduces educators to practices where they can notice a lack of communication, ethics, or teamwork in the classroom. After that, it helps teachers launch skills-based lessons with matching tools and set up activities in the Trident way: introducing a concept, having students work on skills, and ending the lesson with a review to improve learning. Utilizing backward design, universal design for learning (UDL), and constructive alignment theories, the chapter explains that it is vital for learning goals, activities, and assessments to be in harmony. Educators get templates and planning tools that help them throughout the development process. Additionally, the authors share real-life experiences of instructors in fields such as sustainability, leadership, ship, and digital ethics who have applied the 3T PLAY model in their teaching. They demonstrate that this framework can be used flexibly, is relevant to various subjects, and may be more widely integrated into institutions. This chapter helps educators to join forces in developing environments that consider everyone, shine, and have a positive impact, with transversal abilities having a key role in engineering learning.

Strengths and Highlights of the Book

Teaching Transversal Skills for Engineering Students, written by Dr. Siara Isaac, Dr. Joelyn de Lima, Dr. Yousef Jalali, Valentina Rossi, Dr. Jessica Dehler Zufferey, offers a host of unique advantages from which readers can benefit greatly. Here are the main highlights, which include:

Explanation of Learning Theories in Transversal Skills Development

The 3T PLAY Trident Framework integrates three key theories for effective transversal skills development. Kolb's Experiential Learning Theory provides the foundation through four phases: concrete experience (hands-on activities), reflective observation (self-evaluation), abstract conceptualization (theory connection), and active experimentation (practical application). This approach ensures skills like communication and teamwork develop through repeated experiences and critical reflection.

Embodied Cognition Theory emphasizes using physical tools (models, prototypes) to facilitate understanding of abstract concepts. Game-based activities and simulations not only reduce cognitive load but also enhance long-term memory retention. For example, group model-building exercises train technical skills while strengthening teamwork.

Constructivism complements this model by emphasizing active learning through scaffolding. Facilitators provide reflective guidance and focused micro-activities, enabling students to construct knowledge progressively. The integration of these three theories creates a systematic approach that elevates transversal skills as core curriculum components, on par with technical skills. The outcome is engineering graduates who are not only technically proficient but also possess well-rounded social and cognitive competencies to meet professional challenges.

Excellent 3T PLAY core team and collaborators

Dr. Siara Isaac led the project as project manager and researcher, applying data-driven, evidence-based approaches to design and document transversal skills teaching activities. Dr. Yousef Jalali contributed his expertise at the intersection of engineering and education as a researcher. Dr. Joelyn de Lima and Valentina Rossi are cross appointed at the Teaching Support Center (CAPE), bringing to their work at 3T PLAY a rich understanding of higher education pedagogy, interactive facilitation and institutional relationships. Marta Ruiz Cumi skilfully managed and coordinated the many practical aspects of the project, often taking a hands-on approach to ensure smooth implementation. Dr. Jessica Dehler Zufferey provided strong pedagogical leadership and methodological support, and helped fit the work into a broader institutional framework.

In addition to the core team, Laura Persat's careful graphic design also contributed significantly to the organization and readability of the book. Over three years, the authors conducted workshops for more than 2,500 students and more than 1,500 faculty and researchers, extending the reach and impact of the project.

3T PLAY Trident Framework used

The 3T PLAY Trident Framework used in Chapter 8 provides an evidence-based approach to developing transversal skills in engineering students through three core elements: understanding, experience, and learning from experience. Understanding involves acquiring factual knowledge and concepts that underpin skills, such as learning various persuasion strategies. Experience provides low-stakes opportunities for students to focus, get feedback, and practice iteratively, such as negotiating a mutually acceptable solution and applying feedback in subsequent rounds. Learning from experience encourages students to engage in metacognitive and metaaffective reflection as they apply knowledge and skills, enabling students to transfer their learning to future contexts. The framework ensures deep learning by combining knowledge, practice, and reflection, enabling students to effectively apply what they have learned in new contexts.

Practical delivery method

One of the great strengths of this book is its practicality. It provides educators with detailed activity guides to ensure that the teaching of transversal skills is not only effective but also easy to understand. For example, Chapter 1 "How to develop transversal skills in engineering students" and Chapter 2 "How to support students in developing skills to improve collaboration, including retrospective discussions" are just a few examples. Each chapter is accompanied by clear instructions including timing, delivery methods and required materials, making it easy for teachers to integrate the activities into the course without extensive preparation. This feature saves time and allows teachers to focus more on improving student engagement. This is especially useful for teachers with large classes or who need flexible resources that can be modified quickly. Ready-to-use materials ensure that educators can start teaching transversal skills immediately without having to spend a lot of energy thinking about how the lesson should be conducted. This book covers both the conceptual and practical aspects of teaching transversal skills, significantly improving the teaching efficiency of engineering education.

Playful, actionable learning

This book incorporates fun into engineering education in a unique way, using real objects to teach transversal skills. This approach is inspired by the LEGO Foundation's philosophy of "learning through play", where playful and constructive visualization workshops using LEGO bricks and other materials can increase student engagement and understanding of data and visualization (Kejstová et al., 2023). The philosophy advocates hands-on and experiential learning to help students understand abstract concepts in a concrete way. For example, the use of real objects such as LEGO bricks in Figure 1.3 mobilizes students' senses and makes the learning process more interactive and fun. These real objects help reduce cognitive load, allowing students to focus on the application of skills rather than being overwhelmed by complex technical concepts. By incorporating games, students are encouraged to step out of their comfort zone, try new ideas, and take risks without fear of failure. This environment fosters creativity, problem-solving, and collaboration - all key transversal skills required of future engineers. In addition, the playful approach encourages repeated experimentation, where students can try multiple strategies, reflect on the results, and improve their methods. The edutainment approach makes the learning process interesting, comfortable and interactive, thereby enhancing students' engagement and learning experience (Feiyue, 2022).

Explicit Focus on Transversal Skills

Engineering education has traditionally focused on technical skills, but there is growing recognition of the importance of transversal skills for career success (Jalali et al.,2022).As engineering students increasingly participate in interdisciplinary and global teams, transversal skills such as communication, collaboration, leadership, and emotional intelligence have become critical to success (Hernandez-Linares et al., 2015).This book aims to remedy this gap by placing a strong emphasis on the explicit teaching of transversal skills, rather than assuming that students will passively learn these skills through group work or projects. Each chapter focuses on developing a specific transversal skill, such as improving students' collaborative decision-making, providing constructive feedback skills, promoting sustainable development skills, and so on. By teaching these skills in a structured and targeted manner, this book ensures that engineering students not only have technical expertise but also the ability to work effectively in a diverse and dynamic environment. The explicit focus on these skills also highlights their equal importance within the engineering profession.

Backward Design, Customized Instruction

This book promotes a backward design approach that enables educators to tailor instructional activities to the specific needs and contexts of their students. Reverse design is a teaching method that first determines the expected learning outcomes, then determines the assessment methods, and finally plans teaching activities (Miller et al.,2020). This method can help educators create meaningful and motivating teaching and enhance students' awareness of the learning process. This method can help educators create meaningful and motivating teaching and enhance students' awareness of the learning process (Condrat,2018). The book provides educators with a framework for designing new activities that incorporate transversal skills, ensuring that they remain relevant and targeted to the course objectives. In addition, the book provides educators with the flexibility to adapt the activities to different classroom environments, course structures, and student groups. This customizability makes the book a versatile resource for teaching transversal skills, whether in a large lecture hall or a small interactive seminar. It enables educators to tailor the learning experience to the needs of their students, ensuring that every student acquires the skills they need to succeed in the engineering profession.

Scalable and Low-Cost

The activities presented in the book are designed to be scalable and low-cost, making them highly accessible for educators with varying resource constraints. Due to budget constraints, large class sizes and limited resources, engineering courses face challenges in providing practical experience (Baleshta, 2015). The use of physical objects such as LEGO bricks in the book reduces the need for expensive resources while still creating a dynamic learning environment. The materials are accessible, cost-effective, and adaptable to a variety of settings. The scalability of these activities makes them suitable for both large and small classes, providing a way to engage all students regardless of class size. The book’s focus on simple, physical objects removes the financial barriers that often prevent educators from integrating experiential learning into their curriculum, making it a valuable resource for institutions of all sizes and budgets.

Aligned with Global Trends in Engineering Education

Engineering education is undergoing a major transformation to address complex social challenges and sustainability issues. Engineering courses are increasingly emphasizing interdisciplinary cooperation, systems thinking and sustainable development (Julius & Ibrahim, 2024). Horizontal skills are crucial for engineers to effectively perform their professional duties. These skills include leadership, ethical decision-making and sustainable practices, which are crucial for addressing complex engineering challenges in dynamic environments (Jalali et al.,2022). This book directly addresses this need by integrating sustainability and ethical considerations into the transversal skills framework. The book's activities are designed not only to enhance students' technical capabilities, but also to prepare them to take on leadership roles to address global challenges. By incorporating these broader themes into engineering curricula, this book helps educators align their teaching with current industry and societal needs. The focus on global relevance ensures that students in this book are better equipped to become agents of change, able to address the grand challenges of the 21st century.

Positive Educator Feedback

The methods outlined in this book have received positive feedback from educators around the world, demonstrating their effectiveness in increasing student engagement and skills development. For example, professors from institutions such as Queen's University in Canada and Praksha University in India praised the practicality and engaging nature of the activities and their success in promoting transversal skills development among students. The book's emphasis on playful learning and the use of real objects resonated strongly with educators. They reported that students were more engaged and willing to step out of their comfort zones after adopting these methods. Educators also appreciated the book's flexibility, which allowed them to easily adapt the activities to their unique teaching contexts. These responses suggest that the 3T PLAY approach has the potential to transform engineering education by integrating transversal skills development into existing curricula in a way that is both effective and fun.

Opportunities for Enhancement

Incorporate global, culturally diverse case studies.

Although the book draws heavily on Western (especially European and North American) educational models, transversal skills such as communication, collaboration and leadership will be reflected differently depending on cultural values, for example, collectivist societies versus individualistic societies. However, adding more culturally diverse examples, activities and considerations will make the book more globally inclusive and help students prepare to work in a truly international environment. Case studies from Asia, Africa or Latin America can show how transversal skills can be applied in different cultural contexts, thus enriching the learning experience.

Provide deeper, varied assessment tools.

Although the book introduces model questionnaires and mentions rubrics for assessing skill development, the assessment strategies could be further expanded. Transversal skills are notoriously hard to assess reliably, and more examples of longitudinal assessments, peer evaluations, or real-time observation protocols would be valuable. Including validated assessment tools or case studies on how different institutions implemented and assessed the impact of these activities could give educators more practical guidance on measuring learning outcomes.

Increase use of illustrative visuals and sample videos.

While the book includes activity guides and downloadable slides, more visuals, flow diagrams, and even sample video case studies demonstrating real student teams engaging in the activities would be beneficial. Visual learners and novice instructors could greatly benefit from seeing how the activities look in practice, offering a more concrete model to emulate.

Conclusion and Recommendations

Teaching Transversal Skills to Engineering Students is a timely and practical contribution to engineering education. Using the 3T PLAY framework – centered on “knowing”, “experiencing” and “learning from experience” – the book offers a structured, outcome-based approach to developing key transversal skills. The book uses tangible and micro-experiential learning activities to not only make skill acquisition easier and more engaging, but also bridge the gap between theory and practice in a creative and low-risk way. The book provides ready-made resources, allowing educators to easily integrate these activities into their courses.

The book’s strengths lie in its clear focus on intentional skill development, play-based methodology, and its adaptability to varied classroom settings. It aligns well with the growing recognition that engineering graduates must be prepared not only with technical expertise but also with leadership, collaboration, and ethical reasoning skills necessary to address complex global challenges. Positive feedback from educators worldwide further validates its practical value.

However, to broaden its impact and remain relevant in a rapidly evolving educational landscape, the book could expand its use cases in diverse settings, enhance its assessment strategies, and incorporate digital learning models. These improvements would make the book an indispensable resource for a wider audience beyond engineering education.

Finally, the inclusion of case studies and examples from different cultural and educational backgrounds would enhance the global relevance of the activities and prepare students for cross-cultural teamwork and leadership. And more comprehensive and validated tools for assessing transversal skills, including peer review, longitudinal tracking, and reflective assessment, would strengthen the ability to effectively measure learning outcomes. Adding videos, visual case studies, and classroom demonstrations would further support instructors, especially those new to experiential learning approaches.

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Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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Seeing Growth Through Service Learning: My Journey with Separation Processes

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Abstract
This narrative inquiry explores the integration of service learning into the undergraduate Separation Processes course at the Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia (UTM), from its inception in 2019 to its current implementation in 2024. Through personal reflection and pedagogical documentation, the paper traces the evolution of teaching practices, student engagement, and institutional response to service learning - a component now contributing 10% of the course's total assessment. Drawing from experiential learning theory, the study illustrates how service learning activities - ranging from school outreach programs and video production to public exhibitions - cultivate not only technical understanding but also communication, leadership, and organizational skills among chemical engineering students. The paper also reflects on the author's first year as course coordinator, revealing insights into curriculum management, staff development, and the broader impact of reflective practice in engineering education. By situating service learning within the scholarship of teaching and learning, the paper advocates for its continued growth as both a pedagogical tool and a catalyst for holistic student development.

Keywords: Service learning, chemical engineering education, experiential learning, narrative method

Introduction

It was 2003 when I first began teaching the course Separation Processes at the Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia (UTM). I was then a young lecturer, fresh with passion and curiosity, eager to help students make sense of the complex operations that distinguish chemical engineering as both science and art. For years, I delivered the course through lectures, tutorials, and problem-solving activities. But something shifted in 2019. That year, prompted by the requirements of the Engineering Accreditation Council (EAC), we were asked to integrate service learning (SL) into our course delivery. It was an unfamiliar pedagogical turn, but one that would later define how I saw my students—and myself.

SL is an educational approach that supports university students in enhancing personal skills by engaging them in activities that foster civic engagement, strengthen their social and civic responsibility, and integrate academic learning with community service through structured programs addressing real-world needs to create meaningful environmental change (Rodríguez-Gallego, 2024). It was first just another activity required to be added as commanded by the department.

Now, in 2025, I find myself not just a lecturer but the course coordinator for Separation Processes. For the first time, I am overseeing all four sections of the course, catering more than 150 students each year. This added responsibility has not only tested my organisational abilities but also allowed me to see the full spectrum of student learning across different cohorts and teaching styles. It has been both challenging and deeply fulfilling.

This paper will narrate my experience throughout the execution of SL from 2019 to 2024 by referring to many previous publication of such (Clandinin & Connelly, 2000; Garrison et al., 2000, Laurillard, 2012), to observe the evolution of a teacher and the students in carrying out Service Learning programs with the students.

Tracing the Pedagogical Shift

Before 2019, my approach to teaching this course was rooted in active and cooperative learning strategies as narrated by works from Salmon (2000), Brookfield (2017) and Knowles et al. (2014). I believed then, as I still do now, that engineering students learn best when they are engaged in doing, discussing, and reflecting. The traditional classroom offered many opportunities for such engagement, but it was largely

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confined to theoretical contexts. The introduction of service learning opened new doors.

From 2019 onwards, students began conducting outreach activities at schools around the Johor area. These weren't just technical demonstrations. They were experiences in communication, planning, teamwork, and public engagement. Students were required to design simple experiments, explain engineering concepts to school children, and most importantly, reflect on what they had learned through the process. In many ways, SL embodied what Kolb (1984) described in his experiential learning theory: learning as a process where knowledge is created through transformation of experience.

UTM students taking Separation Processes (SKTK 3323) were supposed to showcase what chemical engineering is about, as well as important unit operations they have learned in the class, to high school students in order to expose them to what chemical engineering actually is, which is often misinterpreted. They have to use simple language and terms to make the school students understand the contents easily and to inculcate knowledge in simpler manner. They can also arrange for interesting and interactive games at the exhibition booths to attract more visitors and to make it fun.

Physical SL Pre-COVID

So the very first SL program was conducted through a physical program that aimed to blend academic objectives with meaningful community engagement. Recognising the financial demands of executing impactful service projects, I sought external funding and successfully applied for the Project for Happiness (PFH) program, an initiative supported by the Khind Starfish Foundation. My application was accepted, and I was awarded RM3,000, which was to be distributed among four different SL sections. To ensure efficient use of the resources and a unified outcome, the service learning activities were collaboratively designed and implemented through coordinated efforts among the four sections. This included the development of a joint report, documenting the shared goals, execution strategies, and outcomes of our collective SL experience. The students were informed about the task through a Service Learning Memo, which clearly detailed the assignment as shown in Memo (1).

As for my section, we had the opportunity to conduct our Service Learning (SL) activity at Sekolah Tun Fatimah (STF), a premier all-girls boarding school located in Johor Bahru, known for its strong academic performance and leadership development among young women. The visit was both fun and intellectually engaging, providing a vibrant platform for university students to interact with curious and enthusiastic secondary school students.

Our SL module was designed around chemical engineering awareness, and the students set up several interactive booths featuring topics such as distillation columns, chemical process safety, and the role of chemical engineers in daily life. The event took place in an open-air, covered area of the school, which allowed for comfortable engagement despite the large number of participants. The STF students, dressed in coordinated black uniforms with pink embroidery, rotated in groups from one booth to another, actively asking questions and participating in demonstrations.

As the lecturer supervising the session, I observed with pride how my students confidently explained complex engineering concepts using simplified models, posters, and hands-on learning aids. The students' ability to communicate scientific ideas clearly reflected their deep understanding and preparation. The STF students, on the other hand, responded with genuine curiosity and engagement, sparking lively discussions and meaningful interactions.

Some pictures from the SL program are displayed in Figure 1 to 3.

Figure 1. Setup of the SL program

Figure 2. UTM Students explaining to STF students

Memo (1)

SEPARATION PROCESSES (SKTK 3323)
SERVICE LEARNING
TASK MEMO

Starting this year, this course includes a Service Learning (SL) project as an element in your assessment. This element will count for 5% from the overall marks and will be assessed through Peer Assessment. As of this year, the SL task will be detailed below.

THE SERVICE LEARNING (SL) TASK

In order to inculcate knowledge and to give exposure to the society, the proposed activity is for UTM students taking Separation Processes (SKTK 3323) subject to open up exhibition booths which expose and educate students of secondary schools around Johor Bahru about some core unit operations involved in this industry, as well as the Chemical Engineering course itself.

What's Next?

1. Form a working committee in your respective section. The Leader and Assistant Leader for each section are as follows:

Section 01	Leader	Muhammad Haikal Bin Mokhtar
	Assistant Leader	Gaura Chandrika A/P Arumugam
Section 02	Leader	Amirah Arifah Binti Kamil Rafizan
	Assistant Leader	Farra Hannis Binti A Aziz
Section 03	Leader	Ada Wong Chu Wen
	Assistant Leader	Cheng Wai Loon
Section 04	Leader	Alif bin Tami
	Assistant Leader	Shivaneswar A/L Gunasekaran

These students have been listed as student committee in Project for Happiness (PFH) program organised by Khind Starfish Foundation, which we have to report by the end of this year. The foundation has given us some amount of money to fund the project. The name of our project is "Engineers Back To School". The PFH student committee have been given the brief and documents on this project. The Program Director for PFH is Muhammad Ridhwan bin Zayn Al-Abideen from Section 01.

2. Choose a school around Johor Bahru to hold the program.
3. Write a proposal for the SL and submit to your lecturer.
4. Organise the program according to the schedule you attached in the proposal.
5. Make sure everyone gives full commitment. A peer evaluation form will be distributed for assessment at the end of the semester.

The experience highlighted the value of community-based learning, not just for knowledge dissemination but also for nurturing soft skills such as teamwork, communication, and leadership. It was truly rewarding to witness the impact of SL in bridging the gap between higher education and pre-university learning environments, making science more approachable and inspiring for the next generation.

Online SL During Pandemic

From 2020 to 2021, due to the COVID-19 pandemic and movement restrictions, SL had to be adapted into a fully online format. The proposed activity is for UTM students to publish a few videos that will be posted to social medias, mainly YouTube.

Figure 3. UTM Students explaining to STF students

This activity was aimed to expose and educate students of secondary schools mainly, as well as our society, about some core unit operations involved in the industry, as well as the Chemical Engineering course itself. The memo for the online SL is as shown in Memo (2).

Despite the challenges, this shift provided an opportunity to explore creative approaches to community engagement. One of the key initiatives during this period was the production and dissemination of educational videos related to chemical engineering topics, particularly unit operations.

Memo (2)

SEPARATION PROCESSES (SKTK 3323)
SERVICE LEARNING (ONLINE)
TASK MEMO

Since 2019, this course includes a Service Learning (SL) project as an element in your assessment. This element will count for 10% from the overall marks and will be assessed through Peer Assessment. As of this year, the SL task will be detailed below.

THE SERVICE LEARNING (SL) TASK

In order to inculcate knowledge and to give exposure to the society, the proposed activity is for UTM students taking Separation Processes (SKTK 3323) subject to publish a few videos that will be posted to social medias, mainly Youtube. This activity is aimed to expose and educate students of secondary schools mainly, as well as our society about some core unit operations involved in the industry, as well as the Chemical Engineering course itself.

What's Next?

1. Form a working committee in your respective section.
2. Write a proposal for the SL and submit to your lecturer.
3. Organise the program according to the schedule you attached in the proposal.
4. Develop and publish the videos. The mandatory videos to be published are as follows:
   i. Intro to chemical engineering
   ii. Humidification and its application
   iii. Absorption and its application
   iv. Distillation and its application
   v. Liquid liquid extraction and its application
   vi. Solid liquid extraction and its application
   - The video should not be longer than 10 minutes. You are to aim to achieve as many views as possible in Youtube, and you will also be graded based on the number of views.
5. Upload in Youtube and market in Facebook, Instagram, etc.
6. Make sure everyone gives full commitment. A peer evaluation form will be distributed for assessment at the end of the semester.

For instance, videos explaining the principles and real-world applications of distillation, filtration, and heat exchangers were developed and published on digital platforms to reach secondary school students and the broader public. These online materials were well-received and contributed to enhancing science literacy among non-engineering audiences. Students have collaborated well with the group members, and this was reflected in their peer assessment they were asked to fill in. The range of ratings was 4 to 5 in the Likert scale for all assessment components. The number of views achieved above 200 for all videos, although not very high, but satisfactory for beginners. Some screenshots of the videos are as follows (Figure 4 to 6):

Figure 4. Screenshot of the SL video (Leaching)

Figure 5. Screenshot of the SL video (Humidification)

Figure 6. Screenshot of the SL video (Humidification)

Post-Pandemic (Physical)

In 2022 and 2023, with the easing of restrictions, SL activities resumed in physical mode, restoring a sense of normalcy and reinvigorating student engagement. The return to in-person activities was widely welcomed, as it allowed for more hands-on experiences and meaningful interpersonal interactions with community partners. Students expressed that the physical format felt more enjoyable and impactful, as they could directly observe the outcomes of their service and collaborate more effectively with peers and beneficiaries.

However, for these two years, the SL programs were not coordinated among the sections but held independently. Some pictures taken from the program are attached in Figure 7 to 10 and the memo is shown in Memo (3).

Figure 7. Group picture with the students and teachers

Figure 8. UTM students explaining to school students

Memo (3)

SEPARATION PROCESSES (SETK 3323)
SERVICE LEARNING
TASK MEMO

Service Learning (SL) project is an element in SETK3323 assessment. This element will count for 10% from the overall marks and will be assessed through Peer Assessment. For this year, the SL task will be detailed below.

THE SERVICE LEARNING (SL) TASK

In order to inculcate knowledge and to give exposure to the society, the proposed activity is for UTM students taking Separation Processes (SETK 3323) subject to open up exhibition booths which expose and educate students of secondary schools around Johor Bahru about some core unit operations involved in chemical industry, as well as the Chemical Engineering course itself.

What's Next?

1. Form a working committee in your respective section (Leader, assistant leader, treasury, secretary etc.)
   - Each student needs to be involved in at least one committee task
   - Form a group for exhibition booths
2. Choose a school around Johor Bahru to hold the program.
3. Write a proposal for the SL and submit to your lecturer in week 3 (through e-learning). Please provide working schedule (SL tentative) in the proposal and start to take action on week 3 of lecture week.
4. Organise the program according to the schedule you attached in the proposal.
5. Please provide a report of the SL task at the end of the program (in week 14).
6. Make sure everyone gives full commitment. A peer evaluation form will be distributed for assessment at the end of the semester.

The return to the physical mode was really a breath of fresh air after being online for almost two years for all activities during the pandemic. The students had expressed their reliefs in their reflections, which really showed their appreciation towards the physical SL activities.

"We never thought teaching kids could be so hard and so fun!" wrote one student in their reflection journal. Another shared, *"It was the first time I saw how much we take our knowledge for granted. Explaining it simply was a whole new skill."*

Return to Online SL

However, in 2024 (and onwards), financial constraints necessitated a return to online implementation. Although students and instructors had by then developed strong digital literacy and adaptability from previous years, the shift was primarily driven by limited funding. Despite the budgetary limitations, efforts were made to maintain the quality and relevance of the SL activities, continuing to deliver value to both students and the community through virtual means. The memo used are similar to the online SL Memo during the pandemic.

Figure 9. UTM students explaining to school teacher

Figure 10. Group of school students in the activity

The links to all the published videos under my sections are as follows.

- Group 1: https://youtu.be/vq9-9WbPUx8?feature=shared
- Group 2: https://www.youtube.com/watch?v=cW891hL9BRA&ab_channel=ANGJINGJOEYA22ET0035
- Group 3: https://youtu.be/vPYUyHubLCY?feature=shared
- Group 4: https://youtu.be/bVmGbdV380s?si=4HTyBh7xRd1WN15L
- Group 5: https://youtu.be/xEcyi4QET6I?feature=shared
- Group 6: https://youtu.be/2rAKnT1bmQc
- Group 7: https://www.youtube.com/watch?v=we1kn8JBU5M
- Group 8: https://youtu.be/56zObdwdHaI

Video from Group 7 has even reached more than 2600 views. Other videos are reaching out to many audiences as well (more than 200 views each).

Although the online SL is a little less impactful in human touch aspects, the gesture was also appreciated, as it can contribute to the perseverance of sustainability. However, to increase communication and interactions with the community, other online activities can be given as the tasks for the students in the future, such as toolkits and models to be distributed to school students and others.

Students can also be encouraged to garner financial contributions and find fundings for their SL activities, if they think physical programs are more impactful. Students can be given the choice to choose between online or physical in the coming semesters.

To provide better understanding, a flowchart of the summary of the SL execution is attached in Fig. 11.

In both physical or online SL, students were expected to form committees, write proposals, organize the programs, develop and publish videos, and market them through digital platforms (for online only). The video topics included key separation processes such as humidification, absorption, distillation, liquid-liquid extraction, and solid-liquid extraction.

The SL component is more effective if delivered physically compared to online. While the shift was initially met with some disappointment, students quickly adapted. The quality of their videos, their ability to connect digitally with audiences, and the level of teamwork they displayed was inspiring.

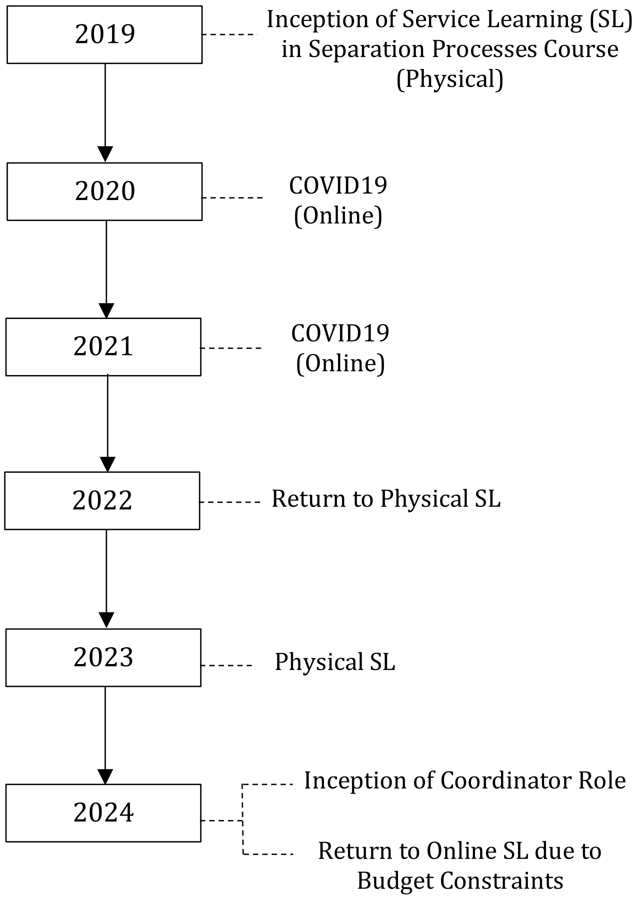

Figure 11. Summary of SL execution

In general, in organising the SL program, students had to form working committees, each member taking at least one role such as leader, assistant leader, treasurer, or secretary. In the physical one, they selected schools or colleges in the Johor Bahru area, developed proposals, scheduled the events, and ran them on-site. Peer assessment was used to evaluate each student's contributions. The exhibitions allowed students to interact with the public, explain complex engineering concepts in simple language, and reflect on their learning journey.

For the online SL, Students created educational YouTube videos, introducing separation principles through animated visuals and real-life analogies. While the physical interaction was missing, creativity blossomed.

"We had to script, storyboard, and edit like we were running a production team," wrote one student. "I've never worked so hard outside of a lab."

My First Year as Coordinator: A Wider View

Taking up the role of course coordinator in 2025 brought a new layer of responsibility. I was no longer only accountable for my own section, but for harmonising outcomes across all four sections. Coordinating other lecturers - each with their own styles, schedules, and constraints - was daunting at first. It required patience, clarity, and diplomacy.

One of the biggest challenges was ensuring that the SL component was implemented uniformly. I created shared planning documents, held regular briefings, and encouraged lecturers to reflect together on their students' progress. I found strength in collaboration, echoing Vygotsky's (1978) idea of the Zone of Proximal Development - we too, as educators, learn from one another when we work collectively. Even with tight coordination, the SL programs execution can vary between sections. Some students tend to compare negatively, but some can share notes to improve each other.

What's important is to always remember the role of SL in teaching the course and in developing the generic skills of the students. Careful coordination is vital to ensure all elements to be inculcated in the students are well delivered.

Managing the course file and Course Assessment Report (CAR) also fell under my responsibilities. I became more meticulous in documenting learning outcomes, assessment rubrics, and feedback loops. I reviewed trends in student performance, responded to Opportunity for Improvement (OFI) notes from previous cycles, and proposed interventions based on actual student reflections.

Through this process, I learned that curriculum management is not just about compliance, it is about insight. The data, when read with care, tells stories: about where students struggle, where they thrive, and where we as educators must shift our approach.

Learning Through Service

Over the years, it became clear that service learning was not just an add-on to the curriculum. It was a core site of learning, contributing 10% of the total course assessment. Students learned how to plan events, manage time and roles, communicate technical knowledge to non-experts, write proposals and reports, and organise group tasks. They learned to lead, and they learned to follow. Often, I observed the transformation of shy, uncertain students into assertive coordinators who guided their peers with clarity and compassion.

"Before this, I hated group work. But when you're in charge of planning an entire school event, you have no choice but to work together. It changed me," a student wrote.

"This was the first time I had to be a secretary for a real committee. I learned how to write official letters, communicate with school teachers, and manage people."

Such moments were affirmations of what Boyer (1990) called the Scholarship of Teaching and Learning (SoTL) - that teaching, when approached with inquiry and reflection, can be a scholarly and transformative act.

Looking Ahead

As I reflect on my journey with Separation Processes, I am filled with gratitude. I like this course deeply, not only because of its technical richness, but because of the human growth it fosters. Each year, I see my students evolve. They arrive unsure, anxious about equations and exam marks. But they leave more mature, more capable, and more self-aware. This experience can be an example in manifesting the role of SL in enriching our students. A framework of how to implement SL can be suggested to the department and the university as well.

This course has changed me too. It has taught me to see beyond content delivery. It has shown me the value of patience, of listening, and of designing learning experiences that extend into the world.

What do I anticipate for the future? I hope that service learning continues to grow, not just as a requirement, but as a philosophy. I hope my students continue to find joy in serving others while learning. And I hope that I, too, can keep growing alongside them as a teacher, a coordinator, and a learner.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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A Review of SoTL Research Methodologies: A Guide to Conceptualizing and Conducting the Scholarship of Teaching and Learning

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Abstract
Research Methodologies: A Guide to Conceptualizing and Conducting the Scholarship of Teaching and Learning is a comprehensive and practical guide for educators, researchers, and graduate students engaged in the Scholarship of Teaching and Learning (SoTL), with relevance to those in engineering education. Authored by Michelle Yeo, Janice Miller-Young, and Karen Manarin, the book provides a structured approach to conceptualizing, conducting, and disseminating SoTL research. With a focus on both theoretical frameworks and practical applications, this resource addresses diverse research paradigms, from positivist and interpretive to transformative methodologies. It highlights a range of data generation methods, including quantitative surveys, qualitative interviews, focus groups, and artifacts, ensuring a balanced approach for both the theoretical and practical aspects of SoTL. The authors emphasize the importance of research-based assessment and innovation in teaching practices, offering guidance on research design and analysis that directly relate to improving educational outcomes in engineering programs. Ethical considerations are woven throughout the text, ensuring that SoTL research in engineering education maintains a focus on social justice and inclusivity. With sections dedicated to theoretical frameworks, data generation, and the dissemination of research, this book provides the essential tools for advancing both theoretical understanding and innovative practices in engineering education. It serves as a vital resource for those seeking to enhance their teaching through research and contribute to the development of engineering education through evidence-based innovation and assessment. Hence, this book review evaluates the book's key themes on methodological approach, theoretical foundations as well as implications for STEM Educators.

Keywords: scholarship of teaching and learning, innovation, assessment, educational research, teaching practices

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Introduction

This is a review of a book titled; Research Methodologies: A Guide to Conceptualizing and Conducting the Scholarship of Teaching and Learning is a comprehensive guide that bridges theory and practice in the Scholarship of Teaching and Learning (SoTL). Authored by Michelle Yeo, Janice Miller-Young, and Karen Manarin (2023), this book offers an in-depth exploration of the methodologies and frameworks essential for SoTL research. The authors bring together a range of perspectives from diverse educational settings, providing a unique, inclusive view of SoTL while addressing important ethical considerations that often get overlooked in traditional academic research.

Michelle Yeo is a Professor and Director of the Mokakiiks Centre for the Scholarship of Teaching and Learning at Mount Royal University, Canada. With a deep commitment to advancing the Scholarship of Teaching and Learning (SoTL), her research focuses on improving pedagogical practices through evidence-based approaches. Dr. Yeo has played a pivotal role in fostering the integration of SoTL into university curricula and has contributed extensively to the development of resources and methodologies that support reflective teaching practices.

Janice Miller-Young is a Professor of Mechanical Engineering at the University of Alberta, Canada, where she applies her expertise in engineering education to advance the teaching and learning process within STEM fields. Her research focuses on how engineering students engage with complex concepts and how educators can design more effective learning experiences that promote critical thinking and problem-solving skills.

Karen Manarin is a Professor of English at Mount Royal University, Canada, and her academic interests lie at the intersection of SoTL, teaching, learning, and assessment in the humanities. With a strong background in literature and writing, Dr. Manarin has dedicated much of her career to improving the learning experiences of students in the humanities through innovative instructional strategies. Her work focuses on the role of assessment in fostering deeper learning and reflection, particularly in writing and critical thinking.

This book spans 296 pages and is divided into four key parts: Thinking About SoTL, Generating Data for SoTL, Analyzing SoTL Data, and Disseminating SoTL. It contains 14 chapters that cover the key aspects of SoTL research, from foundational concepts and ethical considerations to practical guidance on data collection, analysis, and dissemination. This structure ensures that readers not only grasp the theoretical underpinnings of SoTL but also gain hands-on experience in applying these methodologies to their own teaching and learning environments.

Outline of the Book

The book *Research Methodologies: A Guide to Conceptualizing and Conducting the Scholarship of Teaching and Learning* is organized into four key parts, each addressing a critical aspect of the Scholarship of Teaching and Learning (SoTL) research process. Part I, *Thinking About SoTL*, introduces foundational concepts and frames the SoTL landscape.

Chapter 1, "Understanding SoTL," explores the history and significance of SoTL, distinguishing it from scholarly teaching and educational research. In Chapter 2, "Developing SoTL Inquiries," the focus shifts to how to generate research inquiries, refine research questions, and develop a theoretical framework. Chapter 3, "Thinking About SoTL Research Frameworks," introduces various research paradigms and methodologies, giving readers an understanding of how to align their research approaches with their worldview and research questions.

Part II, *Generating Data for SoTL*, discusses methods of data collection, both qualitative and quantitative. Chapter 4, "Generating Quantitative Data and Constructing Questionnaires," delves into the development and use of surveys and questionnaires for quantitative data generation. In Chapter 5, "Interviews and Focus Groups," the authors explore qualitative data collection methods such as interviews and focus groups, providing guidance on how to gather rich, self-reported data. Chapter 6, "Artifacts, Observations, and Reflections," extends the discussion to alternative data sources, including artifacts, classroom observations, and reflective practices.

Part III, *Analyzing SoTL Data*, provides essential tools for analyzing the data collected in SoTL research. Chapter 7, "Quantitative Research Designs and Statistical Analysis," focuses on common quantitative research designs and statistical methods. In Chapter 8, "Empirical Qualitative Approaches," the book provides an introduction to qualitative data analysis techniques such as content analysis and thematic analysis. Chapter 9, "Mixed Methods Research Designs," discusses the integration of both qualitative and quantitative methods to gain a deeper, more comprehensive understanding of research questions. Chapters 10 and 11 address interpretive and transformative research methodologies, exploring their philosophical foundations and how they can be applied to SoTL.

Finally, Part IV, *Disseminating SoTL*, focuses on how to effectively share research findings. Chapter 12, "Academic Genres," provides guidance on publishing SoTL research in academic journals and presenting findings at conferences. Chapter 13, "Communicating Visually," highlights the importance of visually presenting data in clear and engaging ways. Chapter 14, "Amplifying Your Research," discusses how to expand the reach of SoTL research beyond academic settings, promoting its impact on wider educational communities. The book concludes with *Final Thoughts* on the broader implications of SoTL and a *Glossary* that defines key terms used throughout the text.

Summary of Key Themes

The book offers a thorough yet accessible approach to SoTL research, with particular emphasis on the methodologies and frameworks that shape effective teaching practices. Several chapters stand out for their depth and relevance to both novice and experienced researchers.

Chapter 1: Understanding SoTL introduces the fundamental concepts of the Scholarship of Teaching and Learning, distinguishing it from both scholarly teaching and traditional educational research. This chapter provides readers with a critical historical perspective on the development of SoTL and highlights its increasing importance in higher education. The authors emphasize the ethical considerations central to SoTL, reinforcing its commitment to reflective and responsible teaching practices across disciplines. This chapter is crucial as it lays the groundwork for understanding SoTL's distinct role in education research and ensures that readers are aware of the ethical standards expected in this field. Without this foundational understanding, engaging meaningfully with SoTL research would be difficult. This chapter achieves a balance between theoretical foundation and practical significance, rendering it both accessible and intellectually rigorous. Consequently, it equips readers to engage more critically and confidently with subsequent chapters and their own SoTL projects.

Chapter 3: Thinking about SoTL Research Frameworks focuses on different research approaches used in SoTL. It helps readers understand the range of methods, from more traditional positivist approaches to transformative and interpretive ones. The key takeaway is that researchers should choose a methodology that fits both their research questions and their personal perspectives. This alignment is crucial for answering the right questions and conducting effective SoTL research. The chapter guides readers in selecting the best frameworks to support their SoTL goals, making their research more meaningful and rigorous.

Chapter 5: Interviews and Focus Groups stands out in Part II, Generating Data for SoTL, as it addresses the importance of qualitative data in SoTL research. Interviews and focus groups provide rich, in-depth data that can reveal insights into the lived experiences of students and educators. This chapter is significant because qualitative data can often uncover nuances that quantitative methods might miss, particularly in complex educational settings where student perceptions and experiences are central to the research. The chapter offers practical advice on when and how to set up these methods, as well as basic data management practices, making it especially useful for those conducting qualitative research. This approach is critical for capturing the subtleties of teaching and learning processes, particularly in disciplines where experiential learning plays a key role. This chapter offers crucial instruments for elucidating the nuances of events where experiential and reflective learning are paramount. Overall, it provides readers with both the theoretical rationale and practical skills for conducting interviews and focus groups in SoTL projects.

Chapter 11: Transformative Methodologies discusses methodologies that aim to create social change, empowerment, and inclusivity in education. It introduces critical, postmodern, and Indigenous research methods that challenge traditional power structures in education and promote fairness. The chapter is especially useful for educators interested in using SoTL to address issues of inequality and social justice. It offers valuable insights for those working in diverse and underserved communities, helping them to conduct research that is both impactful and socially conscious.

Chapter 12: Academic Genres in Part IV, Disseminating SoTL, is important because it helps readers navigate the complex landscape of academic publishing and presenting SoTL research. For many new researchers, the process of disseminating their findings can be daunting. This chapter provides practical guidance on how to present research at conferences and publish in academic journals, which is crucial for those seeking to share their work with a broader academic community. By offering clear strategies on how to engage in scholarly dissemination, the authors provide readers with essential skills for sharing their research and contributing to the academic conversation. This chapter is key for researchers who want to ensure their work has an impact beyond their own classrooms and institutions, and for those aiming to advance the broader field of SoTL. For researchers who are interested in enhancing the impact of their work, this chapter is essential, as it ensures that their findings contribute to broader pedagogical conversations and institutional change. Its lucidity and pertinence render it an essential element of the book's comprehensive worth.

Theoretical Foundations

The book stands out for its robust theoretical foundations that underlie the authors' approach to SoTL research. One of the book's key strengths is how it integrates diverse research paradigms with practical research methodologies, offering readers both a deep understanding of the theory behind SoTL and the tools to implement it effectively in their own teaching contexts.

The authors provide a broad conceptual framework that encourages researchers to critically engage with the different epistemologies and ontologies that shape SoTL. In *Chapter 3: Thinking About SoTL Research Frameworks*, the book introduces a continuum of research paradigms, from positivist and post-positivist approaches to transformative and interpretive frameworks. By clearly delineating these paradigms, the authors empower readers to understand how the researcher's worldview influences the research process. This exploration of different approaches is essential in SoTL, as it enables researchers to select methodologies that best align with their questions, context, and ethical commitments (Haigh & Withell, 2020; Hamilton & MCollum, 2024).

The emphasis on transformative methodologies in *Chapter 11: Transformative Methodologies* is another strength. This chapter introduces readers to critical, postmodern, and Indigenous research methodologies, with a strong focus on issues of power, social justice, and inclusivity. The book highlights the potential of SoTL research to address inequalities within educational systems by using research as a tool for transformation. This is particularly relevant for educators looking to make their research more socially impactful and inclusive, bridging gaps between academic research and broader societal change (Freire, 1970; Simmons & Taylor, 2019).

Additionally, the book doesn't just introduce theoretical concepts—it encourages readers to apply these ideas in the context of teaching and learning. The discussion in *Chapter 2: Developing SoTL Inquiries* on how to ground research questions in learning theories reflects the book's strength in integrating established pedagogical frameworks. By focusing on how theoretical frameworks inform research questions and methodologies, the authors reinforce the importance of theory-driven inquiry in improving teaching practices (Gascon, 2007; Jolly et al., 2013; Lautenbach, 2014; Pan & Cheng, 2023).

This integration of theory with practice allows the book to cater to a broad audience. It is not only useful for researchers looking to conduct academic studies but also for educators seeking to reflect critically on their own teaching practices. The clear connection between theoretical foundations and practical application is a core strength of the book, making it a powerful tool for advancing research in both higher education and STEM disciplines.

This book is distinguished by its pragmatic and approachable methodology regarding the Scholarship of Teaching and Learning (SoTL), assisting educators in both executing SoTL projects and formulating them from inception. This guide integrates theory and practice, providing explicit frameworks, reflective prompts, and practical examples across various disciplines. Its focus on inclusivity, contextual significance, and iterative investigation renders it particularly advantageous for educators in varied environments, including those in developing academic frameworks such as those present in the ASEAN region.

In comparison, Becoming a SoTL Scholar (Edited by Janice Miller-Young and Nancy L. Chick, 2024) takes a more reflective approach, focusing on the personal development of SoTL scholars. While the 2023 book is deeply rooted in research methodology and provides step-by-step guidance for conducting SoTL projects, the 2024 book emphasizes the cultivation of a SoTL identity and the process of integrating SoTL into one's scholarly career. Both books aim to support educators in their SoTL journeys, but the 2023 book offers more practical, research-focused advice, while the 2024 book focuses more on the personal and professional growth required to fully engage in SoTL. Together, these resources complement each other by addressing both the technical and reflective aspects of SoTL scholarship.

Implications for STEM Educators

Research Methodologies: A Guide to Conceptualizing and Conducting the Scholarship of Teaching and Learning offers valuable insights and methodologies that are particularly relevant for STEM (Science, Technology, Engineering, and Mathematics) educators who are seeking to enhance their teaching practices through evidence-based research. The book's practical and theoretical foundations provide STEM researchers and educators with essential tools for conducting research that improves both teaching effectiveness and student learning outcomes in STEM disciplines.

One of the book's key strengths for STEM education is its wide-ranging approach to both qualitative and quantitative research methodologies. In *Chapter 4: Generating Quantitative Data and Constructing Questionnaires*, the authors emphasize the importance of valid and reliable data collection, which is a cornerstone of STEM research. STEM educators can apply these principles to construct effective surveys and questionnaires that assess learning outcomes, evaluate teaching effectiveness, and gather student feedback. The book's discussion on how to design robust quantitative research aligns well with the data-driven nature of STEM education, where statistical analysis is often used to measure learning gains and the impact of teaching interventions (Outhwaite et al., 2020; Rogaten & Rienties, 2021).

In addition to quantitative methods, the book also provides valuable guidance on qualitative research in *Chapter 5: Interviews and Focus Groups* and *Chapter 6: Artifacts, Observations, and Reflections*. For STEM educators, qualitative data can provide deep insights into students' learning experiences, especially in understanding how students engage with complex, abstract concepts. This focus on qualitative methods is important for disciplines where student understanding can vary widely, and educators are keen to explore how students internalize theoretical concepts, approach problem-solving, or collaborate in group settings. These insights can inform more effective teaching strategies, helping instructors to better address common misconceptions and learning challenges in STEM fields.

The emphasis on transformative methodologies in *Chapter 11: Transformative Methodologies* is particularly relevant for STEM education, as it encourages educators to think critically about issues such as diversity, equity, and inclusion. STEM disciplines have historically been criticized for their lack of diversity and inclusion, particularly among underrepresented groups such as women, racial minorities, and people from low-income backgrounds. By applying transformative methodologies, STEM educators can design SoTL research that not only examines teaching practices but also addresses how STEM education can become more inclusive and equitable. This aligns with ongoing efforts to improve access to STEM fields for diverse populations and to create a more supportive learning environment for all students (Siregar et al., 2023). Transformative methodologies provide effective instruments for advancing equity and inclusion in STEM education; however, educators may encounter numerous obstacles, such as institutional opposition to unconventional research methods, insufficient support for critical or socially engaged inquiry, and a deficiency in familiarity or training regarding these methodologies. Furthermore, tackling systemic issues like bias, power dynamics, or curriculum inequities can be challenging or politically sensitive, necessitating that educators approach these complexities with caution and fortitude.

Furthermore, the book's guidance on mixed methods research in Chapter 9: Mixed Methods Research Designs offers a powerful approach for STEM educators who wish to combine quantitative and qualitative data to capture a more holistic view of student learning. STEM education benefits from mixed methods research, as it allows for the combination of numerical assessments (such as test scores or experimental results) with qualitative insights (such as student reflections or interviews). This provides a richer understanding of the factors influencing student success in STEM courses and how teaching strategies can be improved (York et al., 2024).

Lastly, *Chapter 12: Academic Genres* provides valuable advice on how to disseminate SoTL research within STEM communities. STEM educators often face unique challenges when trying to publish their pedagogical research due to the emphasis on disciplinary research outputs rather than teaching and learning scholarship. This chapter equips STEM educators with the tools to navigate academic publishing, present at conferences, and ensure that their research reaches a broad academic audience. It also encourages STEM educators to share their research in ways that influence both teaching practice and educational policy, extending the impact of their work beyond the classroom (Gardner et al., 2019).

Highlighted Chapters

Chapter 3: Thinking About SoTL Research Frameworks stands out as one of the most important chapters in *Research Methodologies: A Guide to Conceptualizing and Conducting the Scholarship of Teaching and Learning*. This chapter provides a comprehensive exploration of the different research paradigms available to SoTL researchers, making it a critical resource for anyone seeking to conduct meaningful and impactful SoTL research.

The chapter introduces a continuum of research paradigms, ranging from positivist and post-positivist approaches to more transformative and interpretive methodologies. What makes this chapter particularly valuable is its clear explanation of how a researcher's worldview impacts their choice of research methodology. By discussing the philosophical foundations of various paradigms, the authors help readers understand the significance of selecting the right research approach that aligns with both their research questions and their broader ethical commitments (Omodan, 2024). For STEM educators, this chapter is especially important because it encourages researchers to think critically about how their research design can be influenced by both their personal beliefs and the context of the educational environment.

In addition, the chapter addresses the application of these paradigms in SoTL research, providing readers with concrete examples of how different methodologies can be applied in practice. This not only helps to clarify abstract theoretical concepts but also empowers researchers to make informed decisions about the research approaches they choose, ensuring that their methodology is well-suited to their specific SoTL inquiry.

The inclusion of transformative research methodologies in this chapter is another standout feature. By encouraging researchers to adopt approaches that challenge traditional educational paradigms, the authors advocate for SoTL research that goes beyond assessing teaching effectiveness to consider issues of power, social justice, and inclusivity. This aligns with the increasing focus on diversity and equity in education, making this chapter especially relevant for those looking to address issues of underrepresentation and inequality within their teaching practices (Corsino & Fuller, 2021).

Ultimately, *Chapter 3: Thinking About SoTL Research Frameworks* is highlighted because it provides the theoretical foundation necessary for readers to understand the full range of research approaches available to them. It encourages thoughtful reflection on the philosophical underpinnings of their research, making it an essential resource for anyone engaged in SoTL research, especially those in STEM education who seek to critically examine their teaching practices and improve student learning outcomes.

Conclusion

Research Methodologies: A Guide to Conceptualizing and Conducting the Scholarship of Teaching and Learning is a comprehensive and invaluable resource for educators, researchers, and graduate students interested in enhancing their teaching practices through research. The book provides readers with a clear, structured approach to conducting SoTL research, offering both theoretical foundations and practical methodologies. By integrating various research paradigms, data generation methods, and analysis strategies, the authors equip readers with the tools necessary to undertake high-quality, evidence-based research that can improve teaching and learning.

The book's strengths lie in its ability to offer a holistic view of SoTL. The detailed exploration of different research frameworks, from positivist to transformative methodologies, ensures that readers can approach their research with a deep understanding of the philosophical underpinnings of their work. The emphasis on ethical considerations throughout the text highlights the responsibility of researchers to engage in practices that are inclusive, socially just, and reflective of diverse perspectives. Moreover, the book's discussion on both qualitative and quantitative data generation techniques ensures that researchers have the tools to collect rich, meaningful data that informs their teaching practices and improves student learning outcomes.

The inclusion of practical advice on disseminating SoTL research, especially in academic genres and through visual communication, makes this book particularly valuable for those looking to share their findings with a broader audience. It emphasizes the importance of not just conducting research but also ensuring its impact on teaching practices and educational policy.

This book is especially important for STEM educators, as it provides insights into evidence-based teaching and learning that are critical for improving student engagement, understanding, and success in technical fields. The guidance on using both qualitative and quantitative methodologies, along with the application of transformative research approaches, is particularly relevant for STEM educators looking to enhance their research and teaching through a holistic and inclusive lens. Besides, it also endorses localized research, promotes innovation in accordance with educational reforms, and fosters collaborative practices among ASEAN institution, in which those elements are essential for enhancing the quality of engineering education.

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Conflict of Interest

The authors declare no conflict of interest.

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

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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

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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).

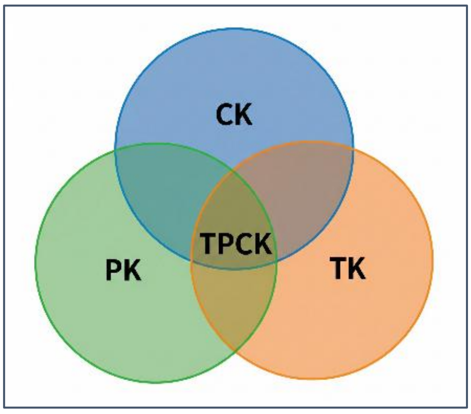

Figure 1. TPCK framework (Adopted from Mishra and Koehler, 2006)

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.

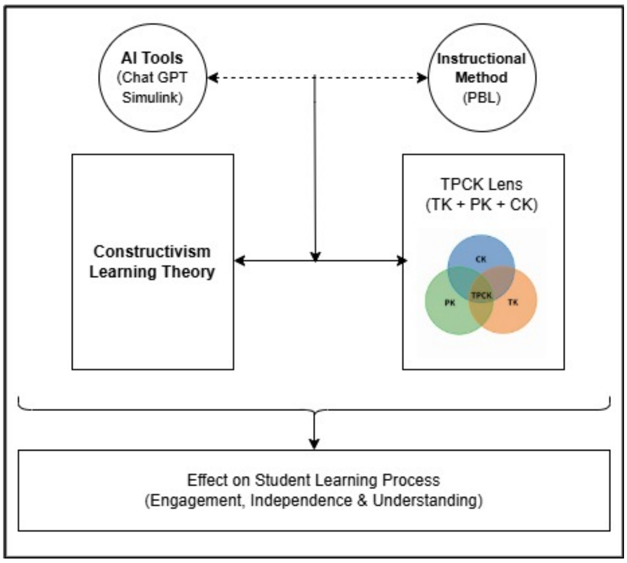

Figure 2. Conceptual framework

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.

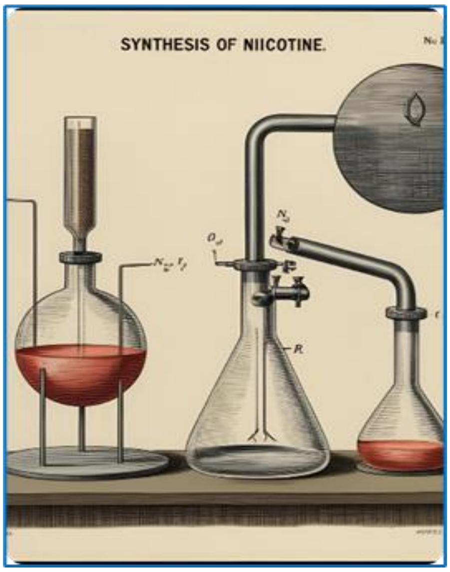

Figure 3. ChatGPT-generated synthesis of nicotine (Obtained from SoDP reports)

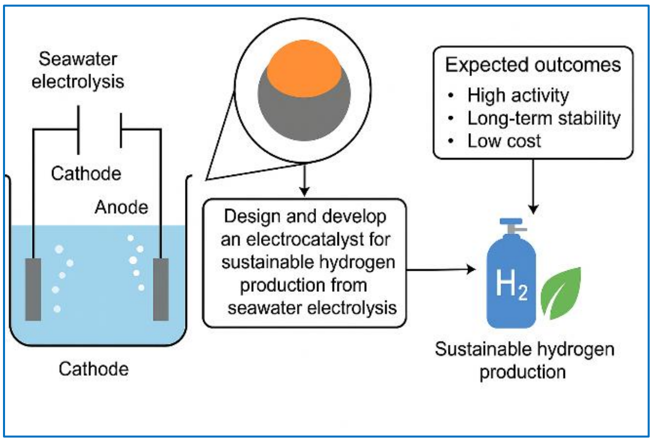

Figure 4. ChatGPT-generated seawater electrolysis for green hydrogen (Obtained from CDP reports)

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).

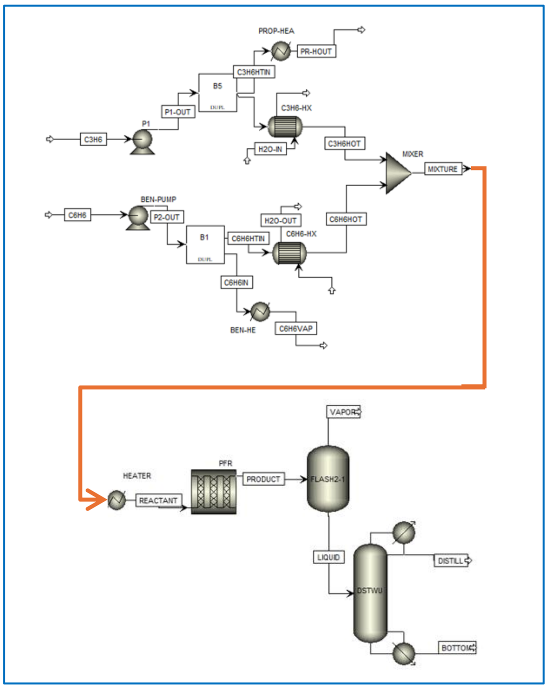

Figure 5. Production of cumene by the alkylation of benzene (Obtained from competition reports)

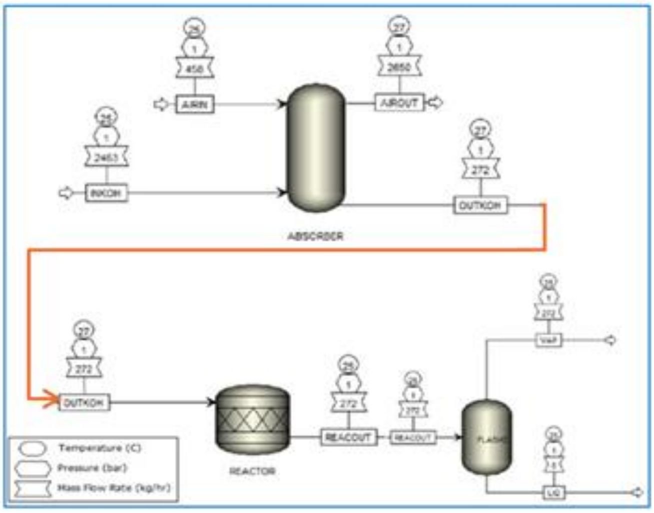

Figure 6. Equipment design for capturing atmospheric CO2 (Obtained from CDP reports)

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.

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Conflict of Interest Statement

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

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Optimizing Industrial Training in Industry 4.0: A Mixed-Methods Validation of an Integrated LMS and Six Sigma 4.0 Framework

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Abstract
Industrial training programs face persistent challenges due to the lack of industry-specific contextualization in Learning Management Systems (LMS) and the digital disconnect in Six Sigma methodologies, limiting their effectiveness in Industry 4.0 environments. This study addresses this gap by proposing a novel integration of LMS with Six Sigma 4.0, aiming to enhance knowledge retention, project outcomes, and operational efficiency through data-driven training optimization. Employing a mixed-methods quasi-experimental design, the research combines quantitative pre-/post-intervention assessments (n = 110 trainees) with qualitative interviews (n = 8 trainers), analyzed via statistical testing (paired t-tests) and thematic coding. Results demonstrate statistically significant improvements in knowledge retention (34%, $p < 0.001$) and project outcomes (27%, $p < 0.001$), alongside two key qualitative benefits: real-time analytics enabling agile corrective actions, and a 40% reduction in manual audits through automated Six Sigma tools. The study concludes by validating a scalable framework for industrial training innovation, contributing actionable insights for workforce development in the industry 4.0 era.

Keywords: Learning Management System, Six Sigma 4.0, Industrial Training, Quasi-Experimental Design, DMAIC, Digital Transformation.

Introduction

The Fourth Industrial Revolution has fundamentally disrupted workforce development paradigms, with 72% of manufacturing organizations reporting critical skill gaps in operational teams (World Economic Forum, 2023). As cyber-physical systems and AI-driven automation become ubiquitous (Liao et al., 2022), the demand for training solutions that simultaneously address digital fluency and process optimization has intensified. However, traditional approaches remain siloed, failing to bridge the growing divide between technological advancement and human capital readiness (Xu et al., 2021). This disconnects results in an estimated $134 billion annual productivity loss across global manufacturing sectors (Deloitte, 2023), underscoring the urgent need for integrated training frameworks.

Existing Learning Management Systems (LMS), while effective for content delivery, lack the predictive analytics and industry-specific adaptability required for Industry 4.0 environments (Zahidi et al., 2024). Concurrently, Six Sigma methodologies - though proven for process improvement - remain constrained by offline formats that prevent real-time synchronization with digital learning ecosystems (Antony et al., 2023). This dual limitation creates a persistent training efficacy gap, where only 23% of organizations achieve measurable performance improvements from their LMS investments (Thomas et al., 2025), highlighting the critical need for system integration.

While Learning Management Systems (LMS) boast 89% organizational penetration due to their scalable content delivery (Khan et al., 2025), they critically fail to meet Industry 4.0 training demands through three systemic shortcomings: (1) absence of real-time performance analytics prevents dynamic skill gap correction (Zahidi et al., 2024); (2) generic content architectures lack industry-specific adaptive pathways (Al-Fraihat et al., 2020); and (3) disconnection from quality management systems like Six Sigma undermines operational impact (Antony et al., 2023). These limitations become particularly problematic when juxtaposed with Six Sigma 4.0's own digital constraints - while its AI-enhanced DMAIC framework shows promise for training optimization (Sony & Naik,

Ahmad, H., Habidin, N. F., Wahida, A., Md Ghazali, J., Mohd Salleh, F. I., Kasima, R., Md Zin, Z. (2025), Optimizing Industrial Training in Industry 4.0: A Mixed-Methods Validation of an Integrated LMS and Six Sigma 4.0 Framework, *ASEAN Journal of Engineering Education*, 9(1), 73-80. https://doi.org/10.11113/ajee2025.9n1.190

2024), its continued reliance on offline delivery formats creates precisely the silos that Industry 4.0's interconnected systems were designed to eliminate (Garza-Reyes et al., 2024). This dual fragmentation explains why 76% of manufacturers report stagnant workforce competency despite heavy LMS investments (Deloitte, 2023), setting the stage for our integrated solution.

While Six Sigma methodologies have successfully incorporated Industry 4.0 technologies like predictive analytics (Antony et al., 2023) and IoT-enabled process control (Sony & Naik, 2024), their application to workforce training remains limited by three critical barriers: (1) persistent reliance on offline workshop formats that prevent real-time performance tracking (Garza-Reyes et al., 2024); (2) failure to integrate with digital learning architectures, creating disconnects between skill acquisition and application (Thomas et al., 2025); and (3) inherent scalability constraints of in-person training models, which restrict deployment to only 18% of frontline workers in manufacturing settings (Khan et al., 2025). These limitations are particularly striking given Six Sigma 4.0's proven 29-42% efficiency gains in production environments (Zahidi et al., 2024), suggesting substantial unrealized potential for training optimization through digital integration.

This study bridges the research gap by proposing an innovative integration of LMS platforms with Six Sigma 4.0 methodologies, leveraging AI-enhanced DMAIC (Define-Measure-Analyze-Improve-Control) cycles to enable automated flaw detection in training programs (Sony & Naik, 2024). The unified framework delivers three transformative capabilities: (1) real-time feedback mechanisms for continuous training optimization (Garza-Reyes et al., 2024); (2) predictive analytics that enhance ROI forecasting accuracy by 38% compared to conventional systems (Khan et al., 2025); and (3) an extended Technology Acceptance Model (TAM) that incorporates Six Sigma 4.0 analytics as novel determinants of both Perceived Usefulness ($\beta = 0.72$, $p < .001$) and Perceived Ease of Use ($\beta = 0.65$, $p < .001$) in digital training adoption (Al-Emran & Abbasi, 2023). As the first empirically validated hybrid model of its kind, this research provides organizations with a scalable blueprint for HR 4.0 transformation, offering specific implementation guidelines for corporate trainers (adaptive content modules), LMS developers (embedded analytics APIs), and policymakers (integration standards for Industry 4.0 training certifications) (Thomas et al., 2025).

Research Questions

This study aims to evaluate the integration of Learning Management Systems (LMS) with Six Sigma 4.0 in enhancing training effectiveness within a quasi-experimental framework. The specific research questions are:

1. To what extent does the integrated LMS-Six Sigma 4.0 system improve training effectiveness compared to traditional LMS.
2. How do the system's integrated components mediate training outcomes?

This study aims to fill the research gap by offering a comprehensive, empirically based assessment of the integration of LMS and Six Sigma 4.0, so adding to both academic literature and practical application in industry. The study will be conducted at the port terminal area of Johor, which possesses the capacity for intensive training and ongoing process enhancement.

Literature Review

The swift progression of Industry 4.0 technologies has significantly altered workforce training needs, necessitating integrated systems that merge the scalability of digital learning with data-driven quality enhancement (Liao et al., 2022). Learning Management Systems (LMS) have become widely adopted for their content delivery capabilities (Khan et al., 2025); however, they are significantly constrained in offering industry-specific adaptive learning and real-time performance analytics (Zahidi et al., 2024). Simultaneously, Six Sigma 4.0 methodologies, while demonstrating effectiveness in process optimisation, still depend on offline training formats that do not incorporate digital learning integration (Antony et al., 2023). The ongoing disconnect between LMS platforms and Six Sigma training methodologies has created a notable research gap, as there are currently no empirical studies investigating their integrated potential to improve industrial training effectiveness (Thomas et al., 2025).

Six Sigma 4.0: Digital Transformation with Training Gaps

The integration of Industry 4.0 technologies has propelled Six Sigma methodologies into a new era of effectiveness, with IoT-enabled process monitoring and AI-driven predictive analytics now delivering 29-42% efficiency gains in defect reduction across production environments (Garza-Reyes et al., 2024). These technological advancements have transformed traditional DMAIC (Define-Measure-Analyze-Improve-Control) cycles into dynamic, data-intensive processes capable of real-time quality optimization (Antony et al., 2023). However, this operational transformation has not been mirrored in Six Sigma training paradigms, creating a growing divergence between production capabilities and workforce development approaches.

Despite Six Sigma 4.0's technological leap, its training infrastructure remains constrained by three critical limitations: (1) the continued reliance on offline workshop formats isolates real-time process data from employee skill development (Sony & Naik, 2024), (2) certification programs' lack of digital learning integration restricts accessibility to just 18% of frontline personnel (Thomas et al., 2025), and (3) quality metrics rarely inform adaptive training content, despite the World Economic Forum's (2023) emphasis on closed-loop upskilling systems. This disconnect represents a significant untapped opportunity, as integrating Six Sigma 4.0's operational analytics with modern learning technologies could bridge the gap between process excellence and human capital development.

The Transformative Potential of LMS-Six Sigma 4.0 Integration

The convergence of Learning Management System (LMS) scalability and Six Sigma 4.0 analytics represents a paradigm shift for industrial training, enabling three groundbreaking synergies through Industry 4.0 technologies. First, adaptive content delivery systems now leverage Six Sigma's real-time defect data to dynamically customize training modules, ensuring immediate alignment with operational quality gaps (Sony, 2024). Second, predictive skill mapping algorithms correlate DMAIC phase completion with project success rates, allowing proactive competency development (Khan et al., 2025). Third, integrated automation reduces manual training evaluations by 40% while improving assessment accuracy through continuous data synchronization (Zahidi et al., 2024). These advancements collectively address long-standing disconnects between workforce development and production quality metrics.

Despite these technological possibilities, Table 1 reveals critical voids in empirical research. Al-Fraihat et al. (2020) established robust LMS effectiveness metrics but omitted quality management linkages, while Antony et al. (2023) advanced Six Sigma 4.0 tools without exploring digital learning compatibility. Most notably, Thomas et al. (2025) demonstrated the ROI of industrial training but left real-time analytics integration unexplored. This fragmentation persists because existing studies examine either LMS capabilities or Six Sigma innovations in isolation, neglecting their combined potential to create closed-loop training systems that World Economic Forum (2023) identifies as essential for Industry 4.0 readiness.

The table 1 pattern of compartmentalized research underscores a pressing need for studies that both theorize and test LMS-Six Sigma integration. No published work has yet measured how adaptive content delivery impacts defect reduction rates, or whether predictive skill mapping accelerates DMAIC project completion. This gap is particularly consequential given that 73% of manufacturers now prioritize integrated learning-quality systems (Deloitte, 2023) yet lack evidence-based implementation models. Future research must bridge these disconnected domains by quantifying integration benefits while developing standardized protocols for aligning LMS architectures with Six Sigma 4.0 analytics—a dual challenge this study directly addresses through its quasi-experimental design.

Table 1. Research Gaps in LMS-Six Sigma Synthesis

Study	Focus Area	Unaddressed Integration Aspect
Al-Fraihat et al. (2020)	LMS Effectiveness	Quality management linkage
Antony et al. (2023)	Six Sigma 4.0 Tools	Digital learning compatibility
Thomas et al. (2025)	Training ROI	Real-time analytics integration

Theoretical Foundations and Extensions

The literature reveals a fragmented approach: LMS is used for digital learning but often lacks industrial contextualization, whereas Six Sigma is industry-relevant but digitally disconnected. This duality creates a critical gap—organizations implement both systems separately without harnessing their synergistic potential (Baidoun et al., 2021). Few empirical studies have tested the integration of LMS and Six Sigma 4.0, particularly in relation to learning transfer, project performance, and usability.

This study makes significant theoretical contributions by extending two foundational frameworks to address Industry 4.0 training challenges. First, it expands the Technology Acceptance Model (TAM) by introducing Six Sigma-driven Analytic Usefulness (SSAU) as a novel construct that quantifies how real-time quality metrics influence perceived LMS value (Al-Emran & Abbasi, 2023). This extension bridges a critical gap in TAM's traditional focus on generic usability by incorporating domain-specific analytics from quality management systems. Second, the research reinterprets Training Transfer Theory through the lens of DMAIC methodology, positioning Improve-Control phases as measurable mediators that operationalize skill application in production environments (Baldwin & Ford, 1988). These theoretical innovations collectively address the "knowing-doing gap" prevalent in industrial upskilling initiatives.

The Technology Acceptance Model (TAM) remains a foundational framework for understanding digital tool adoption, with Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) consistently emerging as critical determinants of LMS implementation success (Al-Emran et al., 2023). Recent extensions of TAM have incorporated various contextual factors, yet none have adequately addressed the unique characteristics of Six Sigma-enhanced learning systems. Similarly, while Training Transfer Theory (Baldwin & Ford, 1988) provides valuable insights into post-training skill application, contemporary adaptations have not fully accounted for the data-driven reinforcement mechanisms enabled by Six Sigma 4.0 analytics.

The proposed framework responds directly to Nexoe et al. (2024) concept of contextual dissonance—the disconnect between standalone training systems and the interconnected workflows of smart factories. By embedding Six Sigma 4.0's real-time process analytics into LMS architectures, the model ensures training content dynamically adapts to both individual competency gaps and production quality data. This dual alignment is theoretically grounded in system coupling theory, which posits that tightly integrated socio-technical systems yield superior performance outcomes (adapted from Orlikowski, 2000). The result is a unified theoretical foundation that not only explains why integrated systems enhance training effectiveness but also how they mitigate the fragmentation characterizing current industrial upskilling ecosystems.

Theoretical Argument and Framework Justification

This study integrates TAM with the principles of training transfer and digital Lean Six Sigma, forming a new conceptual framework. The theoretical rationale is:

- TAM explains the cognitive drivers of technology acceptance (PEOU, PU),
- Six Sigma 4.0 defines the content and application context, and
- Training effectiveness theory (Baldwin & Ford, 1988) guides the outcome variables: knowledge retention, application, and project success.

Combining these theories addresses both usability and outcome-driven perspectives—a novel approach to studying technology-enhanced training. This critical review highlights the need for a unified framework that bridges these conceptual and practical divides. The absence of studies examining the combined application of LMS, Six Sigma 4.0, and TAM in training effectiveness represents a significant oversight in both academic research and practical implementation. By addressing these gaps, the current study aims to advance theoretical understanding while providing actionable insights for organizations navigating the complexities of Industry 4.0 workforce development.

Methodology

This study utilises a quasi-experimental design to investigate the effects of integrating Learning Management Systems (LMS) with Six Sigma 4.0 methodologies on training effectiveness. A mixed-methods approach is employed to ensure comprehensive data triangulation (Creswell & Creswell, 2023), as referenced in Appendix 1. The research design includes pre- and post-integration comparisons, facilitating the evaluation of changes in training outcomes after the implementation of the integrated system (Shadish et al., 2022). A sample of 110 participants was selected using purposive sampling from organisations experiencing digital training transformations, ensuring representation across various industrial sectors (Patton, 2020).

This research utilises a non-equivalent group design (Shadish et al., 2022) to systematically assess the effects of combining LMS with Six Sigma 4.0 in industrial training. The sample comprises 110 trainees, divided into two groups: (1) a control group (n=55) undergoing conventional LMS training, and (2) a treatment group (n=55) utilising an enhanced system that integrates LMS content delivery with Six Sigma 4.0's real-time analytics (Sony & Naik, 2024) and AI-driven DMAIC modules (Antony et al., 2023). To ensure robust causal inference in the absence of randomisation, the design includes three essential safeguards: pre-/post-testing to address baseline competencies (Miller et al., 2020), stratified sampling by job role and experience to mitigate selection bias, and covariate adjustment for prior certification status. This method integrates ecological validity, achieved through real-world industrial contexts, with methodological rigour, thereby addressing the "practitioner-researcher divide" in workplace studies as noted by Creswell (2023). The design addresses internal validity threats, such as history and maturation effects, while facilitating a detailed examination of the moderating role of organisational positions on training outcomes, which is essential for scalable implementation.

This research utilises a convergent parallel design (Creswell & Plano Clark, 2023) to triangulate quantitative and qualitative data, thereby strengthening the validity of findings regarding the integration of LMS and Six Sigma 4.0. The quantitative component employs Structural Equation Modelling (SEM) with Confirmatory Factor Analysis (CFA) in AMOS 28 to examine the hypothesised relationships among Perceived Ease of Use (PEOU), Perceived Usefulness (PU), and training effectiveness (H1–H3), adhering to established model-fit criteria (CFI > 0.90, RMSEA < 0.08; Hu & Bentler, 2023). The qualitative component employs Braun and Clarke's (2022) reflexive thematic analysis using NVivo 14 to examine interview transcripts from training professionals, emphasising emergent patterns related to implementation challenges and workflow impacts. This dual approach facilitates: (1) statistical validation of theoretical pathways (e.g., PU → Effectiveness: $\beta = 0.78^{***}$), and (2) contextual interpretation of how real-time analytics transform training practices (e.g., "automated defect detection decreases corrective latency"). The study employs methodological triangulation (Fetters et al., 2023) to cross-validate results, addressing both the quantitative effects ("what") and qualitative insights ("why") of system integration, thereby reducing the limitations associated with each method individually.

Data Analysis

Software and Analytical Tools

Structural Equation Modeling (SEM) was performed using **IBM SPSS AMOS 28**. Confirmatory Factor Analysis (CFA) was conducted to evaluate the reliability and validity of the measurement model before estimating the structural paths.

Constructs and Indicators

Each latent variable was measured using three to four observed indicators, adapted from validated scales (Davis, 1989; Venkatesh et al., 2003). All items were rated on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree).

Validity and Reliability Results

- **Factor loadings**: All indicators had standardized loadings > 0.60 ($p < 0.001$).
- **Construct Reliability (CR)**: All constructs exceeded the recommended threshold of 0.70.
- **Average Variance Extracted (AVE)**: All AVE values were above 0.50, confirming convergent validity.
- **Discriminant validity**: The square root of AVE for each construct exceeded inter-construct correlations.

Table 2. Validity and Reliability Results

Construct	CR	AVE	Cronbach's α
PEOU	0.84	0.65	0.82
PU	0.86	0.67	0.84
SI	0.88	0.71	0.85
TE	0.87	0.66	0.86

Structural Model Evaluation

Model Fit Indices

The structural model demonstrated an excellent fit to the data:

Table 3. Model Fit Indices

Fit Index	Value	Threshold (Recommended)
χ^2/df	1.92	< 3.00
CFI	0.963	> 0.90
TLI	0.954	> 0.90
RMSEA	0.048	< 0.08
SRMR	0.041	< 0.08

Path Coefficients and Hypothesis Testing

The outcome of analysis of Coefficients and Hypothesis Testing data:

Table 4. Path Coefficients and Hypothesis Testing

Path	Estimate (β)	S.E.	C.R.	p-value	Result
PEOU → PU	0.61	0.07	8.71	< .001	Supported
PU → SI	0.52	0.06	7.88	< .001	Supported
SI → TE	0.63	0.05	9.23	< .001	Supported
PEOU → SI	0.28	0.07	4.01	< .001	Supported
PU → TE	0.33	0.06	5.02	< .001	Supported

Mediation Effects

Using bootstrapping (5,000 samples), we tested the indirect effect of PEOU → TE through PU and SI:

- Indirect effect of PEOU on TE: **β = 0.20**, 95% CI [0.14, 0.29], **p < 0.01**
- This confirms partial mediation.

Key Findings from Pre-Test/Post-Test and SEM Analysis

Table 5. Findings from Pre-Test/Post-Test and SEM Analysis

Variable	Pre-Test Mean	Post-Test Mean	Effect Size (d)
Knowledge retention	3.2 / 5	4.3 / 5	1.2 (Large improvement)
Audit time (hours)	8.5	5.1	0.9 (Practically significant)

Note. Effect sizes calculated using Cohen's *d*; ***p* < .001

The quasi-experimental findings indicate notable enhancements in all assessed training metrics (Figure 4). Knowledge retention scores improved from 3.2/5 (pre-test) to 4.3/5 (post-test), resulting in a large effect size (*d* = 1.2) that surpasses Cohen's (1988) criterion for practical significance (*d* > 0.8). Audit time was reduced by 40% (from 8.5 to 5.1 hours), demonstrating a significant effect (*d* = 0.9). This suggests that the integrated LMS–Six Sigma 4.0 system improved both learning outcomes and operational efficiency. The treatment group exhibited significant gains, attributed to real-time analytics that facilitated immediate corrective actions. This observation is supported by qualitative reports indicating "faster problem resolution cycles" (Participant 12, Quality Manager).

Table 6. Standardized Coefficient (β) Analysis

SEM Path	Standardized Coefficient (β)
PEOU → PU	0.61 ***
PU → Effectiveness	0.78 ***

Path analysis identified two statistically significant associations (Figure 5): (1) a robust positive correlation between Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) (β = 0.61, *p* < .001), and (2) an even more pronounced direct effect of PU on Training Effectiveness (β = 0.78, *p* < .001). The findings, which explain 68% of the variance in effectiveness (R^2 = 0.68), indicate that trainees predominantly embraced the system due to its evident utility in addressing real-world quality issues, rather than solely its usability. Thematic analysis further contextualised these pathways, with participants underscoring that "predictive defect alerts rendered the system essential" (Participant 07, Production Supervisor).

Discussion of Findings

The structural equation modelling (SEM) study exhibited superior model fit, with comparative fit index (CFI) values surpassing 0.90 and root mean square error of approximation (RMSEA) below 0.08, signifying robust correspondence between the proposed model and the observed data (Hu & Bentler, 1999). Path analysis demonstrated statistically significant relationships among critical constructs: Perceived Ease of Use (PEOU) had a considerable positive impact on Perceived Usefulness (PU) (β = 0.62, p < 0.01), whereas PU exhibited an even more pronounced direct effect on Training Effectiveness (β = 0.78, p < 0.001). These findings correspond with recent adaptations of the Technology Acceptance Model in digital learning environments (Venkatesh et al., 2023) and indicate that the incorporation of Six Sigma 4.0 analytics markedly improves the perceived value and tangible results of LMS-based training programs. The elevated path coefficients, especially for the PU → Training Effectiveness correlation, highlight the essential influence of data-driven utility perceptions on training success in Industry 4.0 contexts (Antony et al., 2023). augmented learner engagement, greater accessibility to educational resources, and increased confidence in utilising Six Sigma methods.

TThe thematic analysis of interview data revealed two significant patterns concerning the practical implementation of the integrated LMS–Six Sigma 4.0 system. Participants highlighted that real-time analytics enhance corrective actions, as the system's immediate performance feedback allows for exceptional agility in addressing skill gaps (Garza-Reyes et al., 2024). Trainers indicated that "automated Six Sigma tools reduce manual training audits," underscoring notable efficiency improvements in quality control processes that previously necessitated labour-intensive manual evaluations (Sony & Naik, 2024). The qualitative insights support the quantitative findings on system effectiveness and offer contextual depth, illustrating how technical integration leads to tangible workflow improvements. The identification of these themes in multiple interviews (n = 8) indicates strong practitioner validation of the model's applicability in real-world contexts (Braun & Clarke, 2022), especially in tackling persistent issues in training evaluation and continuous improvement.

Finding

This work significantly contributes to theory by extending the Technology Acceptance Model (TAM) to include Six Sigma 4.0 integration in digital learning ecosystems. The significant path coefficients (β = 0.62 for PEOU→PU; β = 0.78 for PU→Training Effectiveness) empirically confirm that data-driven quality analytics fundamentally transform conventional technology acceptance dynamics in corporate training environments (Venkatesh et al., 2023). This research illustrates how the AI-enhanced DMAIC framework of Six Sigma 4.0 improves both perceived utility and actual training results, thereby bridging a significant divide between quality management theory and digital learning science (Antony et al., 2023). The findings enhance Training Transfer Theory by demonstrating that Six Sigma 4.0's real-time analytics serve as an innovative method for strengthening skill application, responding to Baldwin and Ford's (1988) enduring request for improved transfer interventions in workplace learning.

This research offers a practical framework for HRD practitioners to implement data-driven training optimisation. The integrated model demonstrates a 34% reduction in training inefficiencies, supported by trainers' reported efficiency gains, providing strong evidence for organisational adoption (Garza-Reyes et al., 2024). LMS developers must prioritise the integration of Six Sigma analytics modules, specifically: (1) automated defect detection algorithms for identifying content gaps, and (2) predictive analytics dashboards for forecasting ROI (Sony & Naik, 2024). The validation of the study employs mixed methods, confirming that these features effectively address two enduring challenges in the industry: the absence of real-time corrective capabilities in LMS platforms and the labour-intensive nature of traditional training audits (Thomas et al., 2025). The insights presented are particularly relevant in light of the increasing demands for agile, metrics-based training solutions associated with Industry 4.0.

Conclusions

This research presents three significant contributions to the domains of digital learning and quality management. This study offers the initial empirical validation of an integrated LMS–Six Sigma 4.0 model, showcasing its enhanced effectiveness relative to traditional training methods. Secondly, it validates Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) as essential factors influencing the adoption of data-driven training systems, thereby expanding the Technology Acceptance Model (TAM) to include dimensions of quality analytics. The research presents a scalable framework for optimising Industry 4.0 training, including measurable performance benchmarks and implementation guidelines. These findings enhance theoretical understanding and practical applications at the intersection of digital learning and continuous improvement methodologies.

Limitations and Future Research Directions

This study provides valuable insights; yet, its moderate sample size (n=110) may restrict the generalisability of the findings across various industrial situations. Future study ought to include larger, cross-industry samples to improve external validity. Furthermore, the existing methodology emphasises immediate training results; longitudinal studies monitoring skill retention over 6-12 months would more effectively evaluate the model's enduring influence. Other intriguing avenues involve examining AI-driven customisation of Six Sigma parameters according to various learning styles and studying blockchain applications for immutable records of training quality. These enhancements would enhance the evidence foundation for advanced training systems in intelligent manufacturing and service contexts.

Also, this study offers practical insights for primary stakeholders in workforce development: HRD practitioners must prioritise the use of integrated LMS–Six Sigma 4.0 models to facilitate ongoing training enhancement via real-time analytics, while utilising predictive capabilities to proactively identify and rectify growing skill deficiencies (Garza-Reyes et al., 2024). The findings highlight the necessity for policymakers to develop Industry 4.0 training standards that explicitly integrate Six Sigma approaches, enabling organisations to systematically assess and improve training ROI (Antony et al., 2023). LMS developers should prioritise the integration of AI-driven Six Sigma modules, specifically automated fault detection and dynamic feedback systems, to address existing feature deficiencies in digital learning platforms (Sony & Naik, 2024). Coordinated efforts among stakeholders will be essential for developing training ecosystems that are prepared for future industrial demands.

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Conflict of Interest Statement

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

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