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# Editorial Brief

The ASEAN Journal of Engineering Education (AJEE) celebrates a significant milestone with the publication of 12 insightful articles in this latest issue (Vol. 7, Issue 2). As an esteemed platform dedicated to fostering advancements in engineering education across ASEAN nations, AJEE consistently strives to contribute high-quality research and innovative pedagogical approaches. The latest collection of articles reflects the journal's commitment to enhancing educational practices, addressing contemporary challenges, and promoting scholarly discourse within the engineering education landscape.

The articles published in this issue encompass a diverse range of topics, showcasing a multifaceted exploration of engineering education. They delve into various dimensions of teaching methodologies, curriculum development, educational technological advancements, and pedagogical innovations relevant to the ever-evolving field of engineering education.

For this issue, AJEE published manuscripts that not only originates from Malaysia, but also from Singapore, Brunei and Nigeria. Each contribution offers valuable insights, innovative approaches, and critical discussions that can shape the future of engineering education, in each respective context. The journal remains committed to promoting excellence, fostering collaboration, and inspiring continual improvement in engineering pedagogy, aiming to propel the field forward in innovative and impactful ways.

Chief Editor

***Assoc. Prof. Ir. Ts. Dr. Zaki Yamani Zakaria***

# Editorial Boards

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# Work Stress Among Nigerian Electronic Technology Teachers: Exploring its Influence on Job Performance with Stress Beliefs as Moderator

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**Abstract**
Electronic technology teachers are among professionals who may face adverse effects of stress due to the nature of their job. This study explores the relationship between work stress and job performance among electronic technology teachers and investigates the role of stress beliefs in moderating this relationship. Purposive sampling was used to select 123 electronic technology teachers and 22 heads of departments in government-owned universities in Nigeria, who provided data for the study. Results indicate that work stress significantly predicts job performance among electronic technology teachers ($\beta$ = .60, $p < .001$). Additionally, stress beliefs were found to be a significant predictor of job performance ($\beta$ = .61, $p < .001$). Furthermore, stress beliefs were found to moderate the relationship between work stress and job performance. The findings suggest that teachers' job performance is influenced by both work stress and stress beliefs. Positive stress beliefs are associated with improved job performance, while negative stress beliefs may lead to decrements in performance. Understanding the interplay between work stress, stress beliefs, and job performance can inform interventions to improve the performance of electronic technology teachers and, subsequently, the skill acquisition of their students.

**Keywords**: Electronic Technology Teachers; Work Stress; Job Performance; Stress Beliefs

## Introduction

Electronic technology teachers belong to the group of professionals that may be adversely affected by stress due to the nature of their job. Stress can result whenever a situation is viewed as threatening, and one's options for handling it are regarded inadequate (Fischer et al., 2016). In addition, Lazarus (2006) defined stress as a relationship between an individual and their environment that is regarded as straining or exceeding their resources and jeopardizing their welfare. Stress at work is referred to as work stress. According to Carr et al. (2011), when the expectations of the workplace do not align with the employee's abilities, resources, and requirements, work stress is the unhealthy reactions that result. In other words, work stress is a harmful undesirable work environment that emanates when the job demands of electronic technology teachers outweigh their capabilities, resources, and needs.

The job demands of electronic technology teachers can be overwhelming. An electronic technology teacher, according to Watford UTC (2015), develops stimulating, enriching, and engaging lessons that encourage and nurture students' interest, enthusiasm, and skill acquisition while simultaneously responding to all curriculum changes and fostering a positive working relationship with co-workers and students. Similarly, Richmond (2017) stated that electronic technology teachers help students acquire skills by organizing and delivering high-quality instruction and creating course materials. Electronic technology teachers play a crucial role in facilitating requisite skills acquisition for self-reliance and gainful employment of learners. In the process of discharging their duties and meeting the demands of their job, electronic technology teachers often encounter a number of stressors which emanates from various factors such as adjusting to technological shifts and rapid changes in the field of electronics, troubleshooting of faults in complex systems of electronic appliances; sitting for long hours to detect faults; design and construction of circuits; prolonged visual inspection of miniature PCB components; working with fragile electronic components, and many others which may affect their job performance.

Job performance relates to the act of doing a job, such as teaching. Viswesvaran and Ones (2000) refer to job performance as quantifiable actions, behaviors, and results that employees engage in or direct toward corporate goals. Similarly, Jacobs (2013) viewed job performance as a means to reach a goal or set of goals within a job, role, or organization. In other words, job performance is the behaviour exhibited by the electronic technology teacher, which has an impact on the realization of the goals of electronic technology programmes. These behaviours and actions can be impacted by stress at work.

*Work Stress and Job Performance*

Perhaps, the greatest consequence of work stress, as it relates to education goals, is seen on workers performance and students' learning outcomes. Different studies have suggested or found an inverse relationship between work stress and performance (Arshadi & Damiri, 2003; Bakker & Demerouti, 2014; Farler & Broady-Preston, 2012; Mohammadi & Keshavarz, 2011; Ogbuanya et al., 2017). Thus, the stress-inducing job demands of electronic technology teachers implies that even the best and brightest among them may not be performing at an optimal level. Teachers work stress does not only affect their performance, it also has consequences for student skill acquisition. In connection with that, researchers have found that teachers' low job performance is an important aspect that affects student learning outcomes negatively (Rivkin et al., 2005) as well as outcomes later in life (Chetty et al., 2014). Therefore, rising unemployment rate among electronic technology graduates in Nigeria (National Bureau of Statistics, 2017), and unskilled services rendered by electronic technology workers (Nungse, 2015), can be attributed to decrement in job performance of electronic technology teachers. Based on the foregoing, we therefore hypothesize that:

*Hypothesis 1*: Work stress is a significant predictor of job performance of electronic technology teachers.

*Stress beliefs in Work stress - Job Performance Relationship*

Not all workers facing the same stressful situations at work exhibits decrements in job performance (Keller et al., 2012). Even while many employees may encounter stressful circumstances at work, not all of them will show a decline in work performance. Some employees perform better even when under the same stressor, while others get frazzled and less effective (Boyd, 2017; Lambert, 2005). The reason for this subjective reaction to work stress is unclear. However, an alternate possibility that needs to be researched is that this may be due to individuals' stress beliefs (Kilby & Sherman, 2016). Beliefs, according to Khoynezhad et al. (2012), can help people find meaning in their lives and influence their behavior. Also, Takarangi et al. (2017) discovered that optimistic beliefs had a favorable link with positive attributes that assist people overcome life's challenges.

Stress beliefs, according to Crum et al. (2013), are a set of beliefs about the good and bad aspects of the stress experience that are thought to influence how an individual experiences and responds to stressful events. Beliefs about stress, in particular, determine how information is extracted from difficult events, depending on whether the individual believes stress is debilitating or uplifting (Crum & Lyddy, 2013). Individuals who believe that stress is debilitating tend to focus on negative information from stressors that reinforces their negative beliefs, resulting in actions and behaviors that attempt to avoid anything that tax individual resources (Crum, Akinola, et al., 2017). Individuals who believe that stress is enhancing focus on positive information from stressors that reinforces their beliefs. Additionally, a person's collection of beliefs or way of thinking that influence their behavior and perspective is referred to as the mindset of such individual (Meyer, n.d.). However, according to stress mindset theory, when confronted with stressors, positive stress beliefs lead to positive consequences and vice versa (Crum, Leibowitz, et al., 2017).

Based on the foregoing, positive stress beliefs of electronic technology teachers are expected to lead to improved performance. Based on the foregoing, we therefore hypothesize that:

*Hypothesis 2*: Stress belief is a significant predictor of job performance of electronic technology teachers.

*Hypothesis 3*: The effect of work stress on job performance of electronic technology teachers will be moderated by stress beliefs.

Given that the level of skill acquired by electronics technology students is hinged on the degree of electronic technology teacher job performance, teachers cannot be exonerated from the dearth of skills noticeable in electronic technology graduates. At the same time, when thinking of performance improvements initiatives for teachers, the issue of work stress cannot be overlooked, considering its connection to decrements in job performance. As a result, the expanding literature suggesting that an individual's stress beliefs determine the extent to which stress creates negative consequences such as decreased job performance, needs to be examined. Gaining insight into the relationship between electronic technology teachers work stress, stress beliefs, and job performance would provide valuable information that can be used to improve teachers' performance.

A conceptual framework for the variables is provided in Figure 1 below. In the study, we investigated the relationship between three key variables: the independent variable, which is work stress, the dependent variable, which is job performance, and the moderator variable, which pertains to individuals' beliefs about stress.

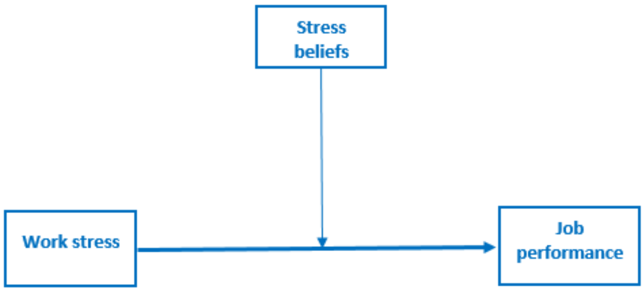



**Figure 1: Conceptual Framework**

## Methods

*Participants*

The participants of this study were all 123 electronic technology teachers and 22 heads of departments in the 22 government-owned universities that undertake electronic technology education programme in Nigeria. Electronic technology teachers and heads of departments in government-owned universities were purposively sampled.

*Measures*

Work stress: This is a 20-item scale adapted from the following measures: 4-item 'Assessment of Teacher Stress Questionnaire' (Kyriacou, 2001), 45-item 'Intensity of Stressful Events-at-Work Questionnaire' (Motowidlo et al., 1986), 10-item 'Perceived Stress Scale (Cohen et al., 1983), 5-item 'Job Stress Scale' (Lambert et al., 2006), and 22-item 'Workplace Stressor Assessment Questionnaire' (Mahmood et al., 2010). The Work stress scale assessed the degree to which electronic technology teachers consider their job conditions as stressful. Participants rated the extent to which their work conditions have been stressful, from 5 (*Not at all stressful*) to 1 (*Extremely stressful*), with lower scores indicating greater work stress.

Stress beliefs: This is a 23-item scale based on the 'Stress Beliefs Scale' (Laferton et al., 2018). On a 5-point Likert-type scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*), participants reported their thoughts about stress. Higher scores represented positive stress beliefs, whereas lower scores represented negative stress beliefs.

Job performance: To determine electronic technology teacher job performance, average of both supervisor/peer ratings and self-rating by the teacher were employed. Self-report measures of teachers' job performance in the past three months contain a 37-item scale which was adapted from the 47- item 'Individual Work Performance Questionnaire' (Koopmans et al., 2012). All items were on a 5-points rating scale. Rating scale labels were adapted to the specific items as follows: Items 1 and 2 was rated from (*insufficient*) to (*very good*), items 3 and 4 was rated from (*much worse*) to (*much better*), items 5 and 6 was rated from (*not at all*) to (*a great deal*), while items 7-37 were rated from (*seldom*) to (*always*). To measure supervisors' assessment of the teachers' job performance in the past three months, the wordings of the teacher self-report measures were modified for use as the supervisor-rating instrument to measure teacher performance. The scale for assessing job performance of electronic technology teachers by supervisors was administered only to the heads of departments. For both self-report and administrator rating of job performance instrument, a high score indicates a high job performance.

## Data Analysis

Frequency counts, percentages, means, standard deviations, correlational analyses, regression analyses, and moderation analysis were used to analyze the data. Statistical Package for Social Science (SPSS 22.0) was used to perform frequency counts, percentages mean, standard deviation, bivariate correlations, and regression analysis, while PROCESS Macro (Version 2.16.1) was used for the test of moderation. The decision rule for establishing correlation analyses was based on strength of correlation coefficients ($r$) ranging between ±0.00 to 0.19 for very weak relationship; ±0.20 to 0.39 for weak relationship; ±0.40 to 0.59 for moderate relationship; ±0.60 to 0.79 for strong relationship; and ±0.80 to 1.00 for very strong relationship (Evans, 1996).

To take a decision on regression analyses, if the p-value of the regression estimate *(β)* or F-value is less than or equal to 0.05, the regression estimate or F-value is significant (then reject the null hypothesis). To take a decision on moderation, when the $\Delta R^2$ increases (i.e. positive), the variable added in-between predictor and outcome variable is a possible moderator, but if $\Delta R^2$ is zero or negative, such variable is not a possible moderator. Additionally, if zero does not lay in-between the lower limit and upper limit of confidence intervals, then the moderation effect is significant.

## Results

Profile of respondents: Description of respondents based on gender, stress beliefs, work stress, and job performance indicated that more male respondents were involved in the study (93%). Majority of the electronic technology teachers are facing a high amount of work stress (54%), and about half of the teachers are not exhibiting professional standards of job performance (51%). Also, negative stress beliefs are common among the teachers (80%).

**Table 1. Mean, Standard Deviation, Cronbach's alpha, and Correlation among the Scales.**

| Variables | Mean | SD | 1 | 2 | 3 |
|---|---|---|---|---|---|
| Work Stress | 3.59 | 0.91 | (.871) | | |
| Job Performance | 3.64 | 1.06 | .596** | (.890) | |
| Stress Beliefs | 3.19 | 0.99 | .409* | .609** | (.824) |

Note. Cronbach's alpha values are in the diagonal. *p < .05, **p < .01.

We determined the mean and standard deviation, Cronbach's alpha, and correlation analysis for this study. The results presented in Table 1 shows that Cronbach's alpha values for the study variables are relatively large. In this study, the alpha values for work stress, job performance, and stress beliefs are .871, .890, and .824 respectively, which imply high measure of internal consistency. A closer look at Table 1 reveals that the correlations among the constructs are relatively moderate and significant.

*Hypothesis 1*: Work stress is a significant predictor of job performance of electronic technology teachers.

As shown in Table 2, a simple linear regression was calculated to predict the job performance of electronic technology teachers based on the amount of stress they experience at work. β = .60, t = 8.17, p < .001. A significant regression was found (F (1, 121) = 66.67, p < .001, with a regression square (R2) of .335 and an adjusted regression square (R2) of .350. The adjusted R2 value means that about 35% of the variance in the dependent variable (job performance of electronic technology lecturers) is explained by or can be predicted by the independent variable (work stress). Because of this, Hypothesis 1 is therefore accepted.

*Hypothesis 2*: Stress belief is a significant predictor of job performance of electronic technology teachers.

As shown in Table 3, a simple linear regression was calculated to predict the job performance of electronic technology teachers based on the belief they hold about stress. β = .61, t = 8.45, p < .001. A significant regression was found (F (1, 121) = 71.16, p < .001, with a regression square (R2) of .370 and an adjusted regression square (R2) of .365. The adjusted R2 value means that about 36% of the variance in the dependent variable (job performance of electronic technology lecturers) is explained by or can be predicted by the independent variable (stress beliefs). Because of this, Hypothesis 2 is therefore accepted.

*Hypothesis 3*: The effect of work stress on job performance of electronic technology teachers will be moderated by stress beliefs.

**Table 2. Regression Analysis Summary for Work Stress Predicting Job Performance**

| Variable | B | SEB | β | T | df | F | P | $R^2$ | Adjusted $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| Work Stress | .690 | .085 | .596 | 8.165 | 1,121 | 66.67 | .000[b] | .335 | .350 |
| Constant | 1.151 | .313 | | | | | | | |

a. Dependent Variable: job performance

**Table 3. Regression Analysis Summary for Stress Beliefs Predicting Job Performance**

| Variable | B | SEB | β | T | df | F | P | $R^2$ | Adjusted $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| Stress Beliefs | .649 | .077 | .609 | 8.436 | 1, 121 | 71.16 | .000[b] | .370 | .365 |
| Constant | 1.555 | .257 | | | | | | | |

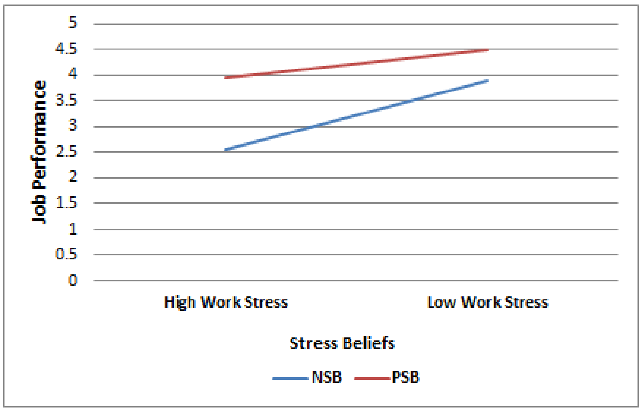
a. Dependent Variable: job performance

**Table 4. Overview of the Impact of work stress on job performance under the influence of stress beliefs**

| Outcome: Job Performance | | | | | |
|---|---|---|---|---|---|
| | **β** | **SE** | **T** | **LLCI** | **ULCI** |
| **Interactions** Work Stress X Stress Beliefs | -.2310 | .0866 | -2.67 | -.4024 | -.0596 |

The data shown in Table 4 reveals the moderating effects of stress beliefs on the relationship between work stress and job performance. The table shows significant interaction effects of work stress and stress beliefs on job performance ($\beta$ = -.231, *SE* = .0866, *LL* = -.4024, *UL* = -.0596), Thus, Hypothesis 3 is accepted. This means that stress beliefs significantly moderate the relationship between work stress and job performance of electronic technology teachers. Since the moderation is significant, a graph was produced from the data for visualizing the conditional effect of work stress (x) on job performance (y).

Figure 1 below therefore depicts the direction of the moderating role of stress beliefs on the relationship between work stress and job performance. The figure shows the impact of work stress on job performance under the influence of stress beliefs. As shown in the output of the graph generated on the conditional effect of x on y, electronic technology teachers who hold positive stress beliefs generally perform better on their job. However, the figure depicts a wide boost in performance for teachers working under high conditions of work stress.




**NSB:** Negative stress beliefs; **PSB:** Positive stress beliefs

**Figure 1. Impact of work stress on job performance under the influence of stress beliefs**

## Discussion

The specific purpose of this research is to investigate the relationship between work stress, stress beliefs, and job performance. With respect to hypothesis 1, our findings showed that work stress significantly predicts job performance of electronic technology teachers. The direction of relationship is such that job performance reduces as work stress increases. This finding validates the job demand-resource theory which suggested an inverse relationship between work stress and job performance. The finding is also in agreement with that of Atkinson (2004) and Mohammadi & Keshavarz (2011), who have linked work stress to decrements in job performance.

Findings on hypothesis 2 established that stress beliefs significantly predict job performance of electronic technology teachers. Specifically, 36% of the variance in their job performance can be predicted by a factor of whether they hold a stress-is-debilitating or stress-is-enhancing mindset. The direction of relationship is such that negative stress beliefs lead to decrements in job performance. This suggests that teachers who have positive stress beliefs are likely to maintain professional standards of job performance. This finding is in agreement with that of Aronson et al. (2002) and Blackwell et al. (2007) who noted that mindsets can significantly influence health and performance.

Furthermore, findings on hypothesis 3 revealed that stress beliefs significantly moderate the relationship between work stress and job performance of electronic technology teachers. The direction of the moderating role of stress beliefs on the relationship is such that under conditions of high work stress electronic technology teachers who hold negative stress beliefs are the ones who experience decrements in job performance. This means that the earlier finding that job performance reduces as work stress increases (Hypothesis 1) is only true for electronic technology teachers who belief that stress is harmful for them. This finding means that teachers who experience a lot of stress but do not belief that stress is harmful are no more likely to show decrements in job performance. This implies that the real obstacle to productivity of electronic technology teachers is not their stress-inducing job conditions, but the negative belief they have about stress. Keller et al. (2012) noted that when an individual under stressful situation views the experience as enhancing, his body is going to believe him, and his stress response will become healthier. In support of the findings, Keller et al. (2012) further noted that the mindset that one holds with respect to stress can alter and influence the effect of stress, thereby making the expected more likely. In other words, stress mindset becomes a self-fulfilling prophecy. Thus, the degree to which stress produces negative outcomes such as decrements in job performance depends largely on electronic technology teacher stress beliefs.

## Implication of the Study

The central finding of this study is that degree to which work stress leads to decrements in job performance in electronic technology teachers, depends largely on electronic technology teachers stress beliefs. Ordinarily, one may find it difficult to accept that the belief that one holds about stress has implications on one's job performance. However, the findings of this study when made available to teachers via anticipated publication will reveal the important role they play in determining the nature of their stress experience. This is because findings showed that inspite of stressful work conditions, teachers who hold positive stress beliefs still demonstrate positive outcomes. Through this information, teachers may be motivated to change their stress beliefs in order to replicate the same outcome in their own lives. Teachers will thereby tap into the positive side of stress to jump-start their adrenalin and motivate performance more quickly in response to impending deadlines, while having things under control. When teachers imbibe positive stress beliefs and thereby exhibit professional standards of job performance, it will contribute to their advancement and promotion on the job.

Because the information generated from this study have the potential of making teachers function at their best, it also has implication for the learners. Since teachers play a crucial role in facilitating skill acquisition for self-reliance and gainful employment of learners, when they function at an optimal level, this translates to high quality instruction and interaction between teacher and students. This provides better opportunity for skill acquisition and progress of learners.

The findings of this study also serve as an eye-opener to educational managers on the stress-inducing nature of electronic work and the need not to overlook the issue of work stress in their teacher performance improvement efforts. This will spur them to take appropriate actions, such as creating opportunities for professional development, provision of state-of-the-art equipment, and other measures to support and create an enabling work environment for electronic technology teachers. Since, the study revealed that teachers who hold positive stress beliefs do not experience decrements in job performance. This may lead to the design of intervention measures and packages for conducting intervention programmes, geared towards changing teachers stress beliefs, as part of measures to improve their performance.

## Conclusion

This study shed light on the relationship between work stress, stress beliefs, and job performance among electronic technology teachers. The findings provide valuable insights into the challenges faced by these educators and how their beliefs about stress play a pivotal role in determining their job performance. Firstly, the study established that work stress significantly predicts job performance among electronic technology teachers. This emphasizes the importance of addressing work-related stressors to enhance teacher performance. Furthermore, the study revealed that stress beliefs moderate the relationship between work stress and job performance. In other words, the impact of work stress on job performance is influenced by an individual's stress beliefs. These findings carry several implications for educators, educational managers, and policymakers. Teachers may benefit from interventions aimed at changing their stress beliefs, promoting a more positive outlook on stress, and equipping them to handle stress more effectively. Educational institutions and managers should also consider strategies to reduce workplace stressors, thereby supporting teachers in maintaining high job performance. Ultimately, the study highlights the role of stress beliefs in shaping the experiences and job performance of electronic technology teachers. Understanding and addressing these beliefs can lead to improved teacher performance, which, in turn, has the potential to positively impact the skill acquisition of students in Nigeria. This research contributes to the broader conversation on teacher well-being and performance in the education sector.

## Limitations of the Study

Our study is not without limitations, First, the study population is distinct, and of relatively small size. So, caution should be exercised in generalizing the findings of the survey to other fields of study. Second, this study employed a cross-sectional survey design, which does not ultimately allow causal inference to be made. We, therefore, recommend that longitudinal or experimental research be conducted in future research for improved and better results. Finally, there is no doubt that individuals may not be better assessors of their strengths and weaknesses; hence there may be relatively and unintentional insincere responses by the respondents of this study.

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# Promoting Cognitive Engagement using Technology Enhanced Book-End Method in Online Active Learning Strategies

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**Abstract**

This study aims to investigate the effectiveness of active learning methodologies and technology tools in enhancing cognitive engagement among students in an online learning environment. Traditional teaching methods may not be sufficient to be replicated to engage students in online learning, which may lead to lower levels of cognitive engagement and reduced learning outcomes. Thus, it is essential to explore how technology tools and active learning strategy can be used to enhance cognitive engagement in online learning. This study involves the implementation of book-end method in active learning strategy and the adoption of technology tools such as Mentimeter, Padlet, Zoom or Microsoft Teams with breakout function and Canva in online classes. The theory of constructive alignment, how people learn (HPL) framework and scaffolding strategies are employed to ensure a seamless harmony between the provided activities and assessments. The students had to reflect their experience in this online learning classes and thematic analysis was conducted deductively using pre-determined themes based on cognitive engagement theory to analyse whether the students were cognitively engaged during the online lessons. The findings of this study indicate that book-end approach in active learning using higher order thinking skills activities and technology tools can significantly enhance cognitive engagement among students in online learning. The use of recaps infused with Mentimeter and breakout sessions powered by Zoom or MS Teams and Canva as the intermittent discussions tools, contribute to improved cognitive engagement. In conclusion, this study highlights the importance of using active learning methodologies and technology tools to enhance cognitive engagement in online learning. The findings suggest that educators should incorporate these tools and methodologies into their teaching practices to improve learning outcomes in online classes.

**Keywords**: Cognitive engagement, Online Active Learning, Book-End Method, Educational Tools, and Technologies.

## Introduction

The global impact of Covid-19 has been severe, affecting lives, health, and reverberating through socio-economic and educational ecosystem. The shift to online teaching and learning began in early 2020 due to the imperative of maintaining physical distance. Despite this, many educators and students continue to grapple with the challenges posed by this change. Educators strive to maintain strong engagement during online instruction, often unaware that the shift from in-person to virtual classes requires a reimagining of approaches. It's crucial to recognise that strategies effective in physical classrooms cannot be seamlessly replicated in the online environment.

A persistent hurdle in online education is maintaining consistent student engagement within lessons and classes. As students navigate their learning journey from the comfort of their homes, without direct instructor supervision, they're susceptible to experiencing stress, burnout, and mental exhaustion due to the shifting landscape. Consequently, they might find themselves lacking motivation to sustain their learning momentum.

Chiu (2021) reported that among the reasons the students are not engaging in the online class are due to a lack of cognitive engagement. Yet, the instructors use a lot of behavioural engagement, while also lacking emotional attachment. Instead of feeling motivated to learn, students were forced to attend the class and underwent a rather boring session because it is entirely a lecture, with the only interaction taking place through questions such as, "Do you understand this?" or "Do you have any questions?"

Cognitive engagement refers to the active participation process within a class that stimulates students' motivation to delve deeper into subjects covered earlier, fostering the ability to connect the dots. This cognitive involvement leads students towards achieving a better understanding, moving beyond mere behavioural compliance, which primarily aims at enforcing discipline. In online education, behavioural engagement proves challenging as students occupy distinct spaces, disconnected from both peers and instructors. Hence, directives like "Attendances are mandatory for maintaining your coursework grade" or "Ensure timely submission of online assignments to avoid deductions" lose their efficacy, inadvertently stifling students' curiosity instead of nurturing it.

Redmond et. al. (2018) investigated the student participation in online learning. They assessed how the term 'engagement' is portrayed and understood across various scholarly articles, often finding its interpretation to be unclear or inconsistent. In response, a detailed structure, drawing from repeated themes discerned from the extensive research was introduced. Within this structured approach, they highlighted the various facets of online participation, placing significant emphasis on the concept of cognitive engagement. This form of engagement envelops a variety of educational components, including, but not limited to, critical analysis, self-reflection (metacognition), and a profound grasp of subject matter. Redmond et al. advocate that this structured approach serves a dual purpose. Not only does it provide a theoretical lens for academic discourse, but it also functions as a tangible roadmap for educators. This roadmap can assist teachers in critically assessing their existing online instructional strategies, prompting them to innovate and refine their techniques for the betterment of their students.

As to understand better, Redmond et.al. defines cognitive engagement pertains to the depth and quality of a student's mental involvement in their learning. It's characterized by a student's effort and determination to truly understand and process complex concepts, rather than merely memorizing information. When students are cognitively engaged, they often employ critical thinking, metacognition, and demonstrate a deep disciplinary understanding. These characteristics are vital as they enable learners to interact meaningfully with the content, ask relevant questions, and make connections between new information and prior knowledge. Redmond's study on online engagement highlighted the significance of these aspects in ensuring effective online education.

Meanwhile, earlier, Richardson and Newby (2006) explore the concept of cognitive engagement in online learning. Cognitive engagement refers to how students integrate their motivations and strategies into their learning. The authors argue that cognitive engagement is crucial for success in online learning, and that instructors and designers of online courses should focus on ways to encourage cognitive engagement among learners.

To engage online learners cognitively, Richardson and Newby suggested that the instructors and designers should focus on creating meaningful learning activities that encourage higher-order thinking, such as planning, predicting, and analyzing information. They should also provide opportunities for learners to take responsibility for their own learning, such as through self-assessment and reflection. Additionally, instructors and designers should consider learners' prior experience with online learning, as well as their motivations and strategies for learning. By focusing on cognitive engagement, instructors and designers can create online learning environments that are more effective and engaging for learners.

Fostering enhanced cognitive engagement can be effectively achieved through the application of active learning methodologies. Active learning stands as a pivotal student-centred strategy aimed at refining cognitive skills. Often, educators adopt the book-end model, as articulated by Felder and Brent (2009), encompassing diverse in-class activities like advance organizers, intermittent discussions, and closure sessions. Within these interactions, a spectrum of techniques can be harnessed, including Brainstorming, Focused Listing, Think-Pair-Share, Think Aloud Pairing Problem Solving (TAPPS), Reflection, Muddy Questions, and more. According to Felder and Brent's research, these active learning strategies facilitate the development of critical thinking, problem-solving, and collaboration skills among students.

Felder contributions to engineering education and active learning have had a significant impact on teaching methodologies. Their work emphasizes the importance of engaging students in the learning process by encouraging them to actively participate and interact with the subject matter. For instance, the book-end model proposed by Felder (2008) involves incorporating various active learning techniques at the beginning and end of a class session. This approach not only enhances cognitive engagement but also promotes deeper understanding of the material and its practical applications.

Incorporating active learning methodologies in the classroom involves a dynamic interplay of strategies that not only enhance cognitive engagement but also cultivate skills crucial for real-world applications. The combination of brainstorming, reflection, and collaborative problem-solving techniques recommended by Felder promotes a holistic approach to learning. This approach aligns with the growing consensus that students benefit greatly from hands-on experiences and opportunities to apply theoretical knowledge in practical scenarios.

In online education, the incorporation of engaging tools and technology stands as a pivotal catalyst in fostering dynamic and interactive learning experiences. These tools, such as Canva, Mentimeter, and Padlet but not limited to these, alongside versatile learning platforms like Zoom or Webex, play a crucial role in enhancing the level of student interaction and involvement. For instance, platforms like Zoom, Webex or Microsoft Teams offer features like breakout rooms that facilitate smaller group discussions, replicating the collaborative atmosphere of traditional classrooms.

Read et. al. (2022) discuss the implementation and impact of collaborative small group tasks conducted via breakout rooms in Microsoft Teams during the 2020/21 academic year. Their study reveal that a majority of students not only enjoyed these tasks but also believed that they significantly enhanced their learning experience during online sessions. The study emphasizes the effectiveness of collaborative documents in facilitating interactions among students and underscores the benefits of maintaining consistent groupings over time. While some students expressed concerns about technical issues and participation levels, the findings overall emphasize the value of online breakout rooms as a tool for enhancing student engagement, understanding, and collaboration in virtual learning environments.

In addition to the breakout rooms features, tools like Mentimeter and Padlet are also important to enable real-time participation, allowing students to contribute ideas, questions, and reflections anonymously, thereby creating an inclusive environment that encourages open expression without apprehension of judgment. The utilization of such engaging tools not only promotes active participation but also strengthens cognitive engagement, deepening the understanding of subjects through peer collaboration and instructor interaction. Ultimately, these technology-driven enhancements contribute significantly to enriching the online learning journey by enabling a more immersive and interactive educational experience.

In a study conducted by Mohin et al. (2022), the use of Mentimeter in online learning has been found to be effective in enhancing student engagement and participation. Mentimeter is a user-friendly and technologically sound tool that allows for anonymous feedback from students, which can help to boost morale and act as an incentive for participation. Students have reported that Mentimeter is enjoyable and helps them to pay attention in class, and it has been found to increase student attendance and improve teaching quality.

Moreover, in a study by Md Deni and Zainal (2018), Padlet was used as an educational tool to support students' learning of Communication Skills. The study found that the use of Padlet enabled learning to be more collaborative, with students having access to other students' work and the teacher's feedback. This aspect of Padlet use assisted students in their learning as they were able to learn from others' mistakes or good answers, how others answered questions, and from the given feedback. However, it is important to note that the use of Padlet must be based on sound pedagogical reasoning to ensure its effectiveness.

Yundayani, Susilawati, and Chairunissa (2019) investigated the effect of Canva on students' writing skills and found that incorporating visual media, such as Canva, significantly improved students' writing performance and helped them apply technology to language learning. The study was conducted with an experimental group that used Canva in their writing process, while the control group received no treatment. The results showed that the experimental group had a significant improvement in their writing performance compared to the control group. The study suggests that incorporating visual media, such as Canva, can be an effective way to improve writing skills in EFL students.

Amidst the pandemic-induced shift to online classes, the implementation of active learning remains viable, albeit with necessary adjustments. Consequently, this study intends to explore the integration of active learning methodologies using book-end model approach, supported by essential tools (apps and mechanisms), tailored to suit the virtual landscape. Its focus is on deciphering how this adapted approach can facilitate cognitive engagement among students during online lessons.

## Application Method

In this study, there were three batches of students learning chemical engineering investigated from two universities. Batch A comprised 2nd-year students with only 27 students (September Semester 2020). Batch B consisted of 82 second-year students from another university (March Semester 2021). Batch A students were taught Principles of Chemical Engineering, which is a material and energy balance-related subject, while Batch B learned Heat Transfer, respectively. All these batches were exposed to a similar strategy: online active learning.

The followings are the tools and apps being used for each batch:

**Table 1. Type of Apps & Tools used by both batches of students**

| Type of Apps/Tool | Batch A | Batch B |
|---|---|---|
| Online Platform | MS Teams with Breakout Function | Zoom with Breakout Function |
| Follow-up platform | Telegram | Telegram |
| Engagement Tool | Mentimeter & Padlet | Mentimeter & Padlet |
| Collaborativ e Tool | Microsoft Office (Docs & Power Point) | Canva |

In formulating the teaching and learning strategies, three foundational guiding principles were diligently embraced: the How People Learn (HPL) framework by Bransford (2000), Constructive Alignment proposed by Biggs (1999), and effective scaffolding strategies. To ensure comprehensive alignment with the HPL framework, the implementation of advanced organizers and closure were deemed essential to satisfy both knowledge-centred and learner-centred perspectives. For the latter, it became imperative to assess and address any preconceived misconceptions before introducing novel information. Furthermore, a learner-centric approach entailed delving into students' demographics, enabling the thoughtful curation of activities and tools that resonate with their diverse needs. Given the pandemic-induced shift to remote learning, the accessibility and affordability challenges of internet connectivity emerged. Consequently, camera usage wasn't mandated throughout classes, and a Telegram group was created to allow the students to access materials using low-bandwidth internet. This digital ecosystem, complemented by Canva and the online platform with breakout functionalities, bolstered a sense of communal engagement, fostering collaboration and mutual support among students. The strategic integration of Mentimeter and Padlet, as a recurring formative assessment tool, sustained active student participation and upheld the assessment-centred lens, offering real-time engagement during live sessions.

In addition to fostering cognitive engagement through thoughtfully crafted activities, the framework of constructive alignment is employed to ensure a seamless harmony between the provided activities and assessments. Recognizing the pivotal role of assessments in shaping learning trajectories, it's imperative to acknowledge that students acquire knowledge through the lens of assessments. As the desired outcome revolves around nurturing cognitive engagement, coupled with meticulously designed in-class activities that embrace this objective, assessments—both formative and summative—primarily embrace open-ended formats. This approach veers away from rote drilling, which involves rigorous exercises culled directly from textbooks and tutorials.

A consistent practice was carried out involves scaffolding students regularly. For instance, if students are unfamiliar with Canva, they are offered a tutorial before utilizing it as a collaborative tool. Similarly, if they are new to online collaboration within breakout rooms, instructors traverse these virtual spaces to reiterate instructions, facilitate discussions, and extend additional time to help them acclimate. This approach aids students in becoming comfortable as they engage in solving assigned tasks, case studies, or problems collectively.

A class is usually conducted employing the Book End Model approach. Within a 2-hour session, the customary activities unfold as follows:

**Table 2. Typical activities in an active learning class for 2 hours**

| Duration | Activities |
|---|---|
| Initial 10 minutes of the class | Commence with a Recap via Mentimeter or Initiate Brief Discussion Questions |
| 10 to 15 minutes into the lecture | Engage in a Mentimeter Activity |
| After 45 minutes of the lecture | Participate in a 10-minute Breakout Session (using Canva) – Team-Based Activity |
| After 1 hour of the lesson | Pause for a 5-minute Break |
| After 1.5 hours of the lesson | Take part in a 10 to 15-minute Breakout Session – Team-Based Exercise |
| 5 minutes before the class concludes | Conduct a Reflection or Initiate a Quiz using Mentimeter |

Furthermore, as an additional component, students were assigned biweekly tasks involving reflective writing through the application of the Gibbs Reflective Cycle Template. These reflections were then shared on Padlet using the provided links. Additionally, students frequently engaged in the practice of composing succinct reflections via Mentimeter. While participation in reflection writing was optional, students were regularly encouraged to recognize the benefits of consistently documenting their reflections to enhance their memory retention and learning experiences. The Gibbs Reflective Cycle (Gibbs, 1988), a robust framework, facilitated introspection of their learning journeys.

In order to assess the presence of cognitive engagement within the learning process, a thematic analysis was conducted in deductive way, and the themes were pre-determined, drawn from the research on cognitive engagement presence of Rotgan and Schmidt (2011), who expanded upon the works of Csikszentmihalyi (1975), Krapp and Lewalter (2001), Prenzel (1992), and Schraw et al. (2001). This contextual cognitive engagement encompasses three core facets: (1) involvement with the current task (item: "I was engaged with the topic at hand"), (2) dedication and perseverance (item: "I invested significant effort"; "I desired to continue working for a while longer"), and (3) the experience of flow, complete absorption in the activity (item: "I was so engrossed that the surroundings faded away"). These components are succinctly captured by the following keywords: (1) ENGAGEMENT WITH TASK, (2) EFFORT & PERSISTENCE, and (3) ABSORBED WITH ACTIVITY.

The following sentences in Table 3 are some of possible sentences that came from the students' reflections, which can fall under these three keywords.

**Table 3. Possible Sentences from Students Reflections Indicating Cognitive Engagement Presence**

| Keywords | Activities |
|---|---|
| Engagement with Task | "I found the topic to be really interesting and wanted to learn more about it." |

| | |
|---|---|
| | "I was curious to explore different aspects of the task and was eager to start working on it." "The assignment was challenging but it captured my attention because it related to real-world problems." |
| Effort & Persistence | "Even though I encountered obstacles, I kept trying different approaches until I found a solution." "I dedicated extra time to practice and understand the difficult parts of the lesson." "I refused to give up on the problem and kept searching for alternative methods to solve it." |
| Absorbed with Activity | "I lost track of time while working on the project because I was so immersed in it." "I was so focused on the task that I didn't realize how quickly time passed." "I found myself completely absorbed in the activity, forgetting about everything else around me." |

**Findings and Discussions**

Frequently, a considerable portion, approximately 40-50%, of students consistently engaged in writing and sharing their reflections across all batches. This percentage remained consistent unless reinforced with multiple reminders or some gamification strategies such as rewards, points or in the form of marks. Presented in Table 4 and 5 are excerpts from the reflections spanning different batches.

**Table 4. Excerpts of Reflections from Batch A and B Students**

| Exhibit | Reflection's Snippet Batch A | Reflection's Snippet Batch B |
|---|---|---|
| 1 | I really like *to communicate via mentimeter* as I can say my opinions without any worries **Keyword: ENGAGEMENT WITH TASK** | Thank you sir for your "unique" teaching ! I totally enjoyed it as currently do not have any lecturer doing these kind of breakout rooms and *make us think* instead of spoon feeding us. **Keyword: EFFORT & PERSISTENCE** |
| 2 | I really like to communicate via mentimeter as *I can say my opinions* without any hesitation and I no need to scare of people judging the opinions. I really like that idea. I also appreciate sir to sacrifice your precious time to create video on mass balance to make students understand deeply and apply the knowledge in solving problems regarding mass balance. The videos make me more recognize the topic. **Keyword: ENGAGEMENT WITH TASK** | At first I really find it difficult to adapt with the teaching method of Dr because it was new to join in breakouts and interact with other classmate . Later, I feel *energetic* to join heat transfer class because dr really motivate us to learn new things and I get to know the important of skills like *critical thinking* for an engineer. I learned how problems in the engineering world would be. Especially the assignments done using Canva was very fun, I realized *I can be creative, I realized my potential.* **Keyword: EFFORT & PERSISTENCE** |
| 3 | Other than that sir also gave us a lot of quiz and activity with teams or menti meter or kahoot and I think that *really really help me to engage better with the lesson* and I thank sir for that **Keyword: ENGAGEMENT WITH TASK** | The teaching style of Dr is very interesting for me. The lecture notes are very creative and the cartoons are very cute. Dr's teaching method is the best because *students are actively involved in the discussion and discussions are always lively and to the point.* **Keyword: ABSORBED WITH ACTIVITY** |
| 4 | In my opinion, this experience was good because I had to *think hard.* For example, we had to do a mass balance for each stream, even though there was only one column (evaporator). I understood bypass process better when sir explained it, it uses the same | Dr's teaching styles are way more different which requires us to *think and figure out why things happen* instead of just following a formula and getting the answer without understanding why things happen as they do. To be honest, this is the way how |

| | | |
|---|---|---|
| | concept as what we learnt before such as input is always equal to input. So, I figured as long as I hold on to the concept input = output, I just have to read the question thoroughly and I will have no problem trying to solve the question.<br>**Keyword: EFFORT & PERSISTENCE** | engineering would be in future I guess. In my opinion, this is what students are gonna face in the outer world when they get graduated.<br>**Keyword: EFFORT & PERSISTENCE** |
| 5 | I have been learning Material & Energy Balance for 5 weeks, and I was really satisfied with it. I did *a lot of team works together* with the other students, for example, discussing the lecture slides together, getting some questions and so on. It was really a fun and exciting course for us to learn throughout the semester.<br>**Keyword: ENGAGEMENT WITH TASK** | I was initially unsure and scared that I could not cope with it, but it changed due to project which I completed that enabled me to understand the subject and link it to our daily lives and to how I would use it in the future. I believe that the assignment and task provided by Dr. enabled me to *gain a better understanding of the issue.*<br>**Keyword: EFFORT & PERSISTENCE** |
| 6 | The videos can help me to understand better rather than just reading from the lecture slides. Then, we also have done some *class activity during lecture.* This is quite interesting for me to *learn through the activities.*<br>**Keyword: ENGAGEMENT WITH TASK** | Since Dr take over the class I feel scared sometimes to join the class because I am the type of student that don't like to interact much during the class but after that I feel that the way Dr used is actually help me a lot *to improve my thinking skill.*<br>**Keyword: EFFORT & PERSISTENCE** |

Table 4 presents the snippets of reflections from both Batch A and B, respectively. Upon careful examination, minimal disparities emerge between the two cohorts in terms of their reflections, emotions, and perceptions of the conducted online activities. Interestingly, while certain students embrace the breakout room exercises with enthusiasm, others harbour reservations, possibly due to social apprehensions even within the virtual setting. Notably, for both Batch A and B, the breakout activities served as novel experiences, uncharted territory in their online learning journey.

A majority of students found Mentimeter particularly appealing due to its anonymous nature, which is similar to the finding made by Mohen et. al. (2022). This platform allows students to freely contribute ideas, pose questions, and share their sentiments without fearing judgment. Furthermore, students engaged in reciprocal interaction, responding to posed questions, fostering a dynamic learning environment. In Figure 1, a compilation of reflections from a Heat Transfer lesson with Batch B is showcased. While students were instructed to provide brief reflections on their learning, they utilized this opportunity not only for self-reflection but also to seek clarification, contemplate their newfound knowledge, and express their thoughts.

Other researchers have also delved into the intricate landscape of cognitive engagement, uncovering its multifaceted effects on various learning scenarios. The findings from studies such as those conducted by Liu et al. (2023) shed light on the intertwined nature of social and cognitive engagement in online discussions. These studies explore how students' interactions within virtual spaces contribute not only to cognitive processes but also to the establishment of a collaborative and participatory learning environment. This resonates with the observed phenomenon where students in this study embraced the breakout room exercises and engaged in reciprocal interactions, creating a dynamic learning atmosphere. The students' reflections are also similar to the findings shared by Redmond et. al. (2018) and Richardson and Newby (2006), of which suggesting that they are cognitively engaged when they are higher order thinking skills (HOTS) activities conducted during the lessons.

In the context of online learning platforms, Xiao and Hew (2023) conducted research on the effects of tangible rewards in gamified environments. Their investigation goes beyond traditional notions of cognitive engagement to explore the intricate connections between intrinsic motivation, behavioural engagement, cognitive engagement, and learning performance. Their findings highlight the complexity of motivating learners and enhancing their engagement, touching upon aspects such as gamification strategies and their impact on cognitive involvement. Similarly here, when the students were given opportunity to be in breakout session with some gamified experience among the teams, they are excited and heavily engaged in the discussion to ensure their team wins.

Moreover, the research by Kumar, Vrontis, and Pallonetto (2023) ventures into AI-enabled technologies and their impact on cognitive engagement. By examining factors that foster cognitive engagement in the context of AI, their study draws attention to the evolving dynamics between learners and technologies. This aligns with the novel experiences the students encountered in using platforms like Mentimeter. Notably, the observation that students found anonymity appealing on Mentimeter resonates with the concept of cognitive engagement, as individuals are more likely to engage in meaningful discourse when they feel safe and uninhibited. This is also fulfilling the framework of community centred based on How People Learn (HPL) framework by Bransford (2000), for which the students feel they are in a secure learning environment and be able to express their own thoughts freely.

The insights from these studies collectively reinforce the notion that cognitive engagement is not isolated but intertwined with various factors, ranging from social interactions and gamification to technological platforms. As it was observed in this study, the willingness to explore novel experiences and the utilization of platforms that provide anonymity can foster cognitive engagement, leading to more active participation and deeper learning outcomes.

Table 5 depicts the categorisation of Batch B's final reflection using Gibbs Reflective cycle, and to map whether the provided reflections from students reflecting on their learning experiences matched with the Rotgan and Schmidt (2011)'s framework. Out of three main criteria, it can be seen that from 24 submissions of the reflections, either one or two or all the themes based on this framework appeared in the reflections. Another category, OTHERS, is related to their gratitude and appreciation to the instructor.

**Table 5. Classification of Students' Final Reflection from Batch B into Cognitive Engagement (Rotgan & Schmidt, 2011) Themes**

| Themes | Frequency |
|---|---|
| ENGAGEMENT WITH TASK | 16 |
| EFFORT & PERSISTENCE | 14 |
| ABSORBED WITH ACTIVITY | 16 |
| Others | 11 |

As previously stated, thematic analysis was employed to categorise these reflections into distinct themes. This process allowed to identify recurring patterns, emotions, and concerns that emerged across the responses. According to Gibbs Reflective Cycle, which is often utilized to explore personal experiences and facilitate self-improvement (Gibbs, 1988), these themes can shed light on the different stages of the learning process and students' responses to them.

One prevalent theme is "Engagement with Task." This theme encapsulates students' expressions of how the instructor's unique teaching methods captured their attention and encouraged them to grapple with the course material. Many students noted their initial surprise and uncertainty about this approach but subsequently acknowledged its effectiveness. As an example, a student acknowledged that the instructor's teaching was "unique," Furthermore, this theme often involves identifying challenges and subsequent efforts to overcome them, as exemplified by another student's statement about the difficulty of adapting to the new learning style.

The theme of "Effort & Persistence" underscores the importance of dedicating time and energy to mastering the subject. Several reflections express the struggles encountered while analyzing questions and managing time during tests. As for instance, one student reveals her initial uncertainty about question interpretation and subsequent adjustments in her approach. Furthermore, other reflections emphasize the need to recognise and rectify mistakes for future learning.

The theme of "Absorbed with Activity" highlights the immersive nature of the learning process, especially in relation to specific test questions and classroom activities. These reflections often mention the students' experiences during tests and their perception of time allocation. A student expresses surprise at the unexpected nature of the exam questions, leading to a realisation about the need for better preparation.

The theme of "Gratitude & Self-Improvement" for OTHERS category emphasizes students' appreciation for the instructor's teaching methods, acknowledging their evolution in learning, and expressing a commitment to self-improvement. These reflections often emphasize personal growth and a realization of the value of skills gained. A student's reflection showcases this theme by expressing gratitude, appreciating the learning process, and planning for better decision-making in the future.

Although online learning during pandemic is hassle that requires greater preparation time, the students can readily be engaged with some activities that were designed that require their active participation. Active learning strategies play a pivotal role in enhancing cognitive engagement among students in various educational settings. These strategies involve interactive and participatory methods that require students to actively process and apply course material, fostering deeper understanding and critical thinking. Students' reflections on their learning experiences highlight the positive impact of active learning on engagement and learning outcomes.

Active learning methods encourage collaborative activities and group discussions. Students find value in team-based interactions, quizzes, and other collaborative tasks that require them to actively apply their knowledge and engage with peers. This collaborative approach aligns with the principles of active learning, which emphasize hands-on, student-centered approaches to enhance learning (Patiño et al., 2023). These interactions stimulate critical thinking and foster a deeper understanding of the subject matter.

Moreover, active learning methods bridge the gap between theoretical learning and practical application. Students appreciate assignments that enable them to apply their knowledge to real-world scenarios. This practical application not only enhances cognitive engagement but also promotes a better understanding of the subject matter's relevance (Mou, 2023). Students' reflections highlight how active learning methods contribute to meaningful and applicable learning experiences.

In conclusion, the reflections provided by students underscore the positive impact of active learning on cognitive engagement. The integration of interactive tools, collaborative activities, problem-solving tasks, and practical applications collectively contribute to fostering a deeper understanding of the content and encouraging critical thinking. Research findings support the notion that active learning strategies significantly enhance cognitive engagement, leading to more effective learning outcomes (Prestridge & Cox, 2023).

## Conclusion

In the challenging transition to online learning necessitated by the Covid-19 pandemic, this study underscores the pivotal role of active learning methodologies in fostering cognitive engagement among students. The global shift to virtual classrooms, brought to light the imperative of reimagining traditional instructional approaches for the digital sphere. The integration of engaging tools like Mentimeter and Padlet, which facilitate real-time, anonymous participation, has emerged as a significant strategy to sustain student engagement and foster an inclusive environment that encourages open expression.

The findings reveal that not only does the thoughtful incorporation of such interactive tools and collaborative activities enhance active and cognitive engagement, but instructor support also plays a crucial role in guiding students through the online learning journey. Insights from reflective writing activities and tool-assisted interactive sessions suggest that the tailored application of active learning strategies, coupled with supportive technological platforms and guided social interactions, can indeed navigate the challenges posed by online education.

This confluence of strategies not only enriches the learning experience by promoting deeper understanding and critical thinking but also holds the potential to enhance learning outcomes in the virtual domain. Thus, the research affirms that with strategic integrations of active learning methodologies, technological tools, and instructor-led guidance, educators can sculpt impactful and cognitively engaging online learning experiences, even amidst the unprecedented challenges in a virtual learning environment.

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# Developing Structural and Civil Engineering (SCE) Curriculum in sub-Sahara African Nations on the Foundation of the Developed Nations, in Training, Practices and Technology – Nigeria as Case Study

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## Abstract

The training and practice of structural and civil engineering (SCE) education in developing nations, especially the sub-Sahara African nations, are not as robust and dynamic when compared to what are operating in the developed Nations of the World. Available resources in the public domain show strong evidence of a sustained fundamental link of SCE training and practice of the developed nations to the classical training of the ancient Caesar's Rome. This paper looks into the training and practice of structural and civil engineering about 2000 years ago in the imperial Caesar's Rome. The data used were collected from the information available from the public domain. The results showed that: (i) the curriculum for SCE education was very wide and deep and it is in partnership with the State (ii) the training together with the attendant skill development program/schemes began early at Roman home, (iii) SCE is deeply connected to Latin and Greek languages, and (iv) a heavy dependence on classical philosophical studies existed. It is thus concluded that the curriculum for SCE engineering in developing nations be tied to these foundations.

**Keywords**: Caesar, Civil engineering, Curriculum Education, Nigeria, Practice, Sudan, Sub-sahara Africa, Training.

## Introduction

The structural and civil engineering (SCE) and technology capabilities of developed nations continue to advance robustly and to be a major driver of the economies of those nations. The same cannot be said of the developing nations especially sub-Sahara Africa where there is a lot of expectations from Nigeria to take the leadership role. But sadly, this has not been. While many foreign companies are daily making major inroads into Nigeria's construction industry, the same cannot be said of a Nigerian company winning a major construction job in another country. The situation seemed to be so bad that Nigeria now imports technicians and artisans. This is a result of a wrong policy by the Nigerian Government that phased out trade centres without putting in place appropriate commensurate institutions. This trend has not escaped the notice of the Council for the Regulation of Engineering in the Country (COREN) and has described the scenario as shameful (COREN, 2021). In an attempt to resolve this, it is thus necessary to look beyond the surface and try to find out if Nigeria SCE engineering industries are operating from the same foundation as those of the developed nations, especially the United States of America (USA) and the United Kingdom (UK). It is an open fact, and it is well documented that SCE training and practice in the USA, UK, and European countries are founded on principles and practices that dated into the ancient Rome, especially the Caesar's era (Bianco, 2023). These nations, as former colonies of the Roman Empire, inherited massive SCE works and other structures that are still standing and functioning. It is very glaring that these nations have not only held firmly to and sustained the principles from which these structures emerged, but have also continued to draw inspiration from these inherited structures. Further, these Caesar-era Roman structures have become the subject of study for Engineers and materials scientists (Fox, 2021). The influence of Roman structural themes on modern-day structural constructions is glaring, as many structural forms like domes, vaults, arches, and many others, that are being used in structures were developed by the Romans over two thousand years ago. In addition, the wordings in the ICE and ASCE, as will be shown later in this work, contained expressions that are deeply rooted in

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Caesar's time. In the field of SCE, the strategies for selection of the materials and the methodology to produce mortar have remained substantially unchanged not even with the introduction of the ordinary Portland cement (D'Ambrosio, 2015).

*Problem Statement*

The structural and civil engineering education in Sub-Saharan African countries seemed to lag behind that of their counterpart in the developing Nations. Many approaches have been proffered as ways to improve engineering education, especially in the sub-Sahara African nations including, increased funding, welfare for teachers, arrest of brain drain, and so on. Lately, the encouragement of STEM education has also become an added strategy to improve engineering education (Gladstone et al., 2022). All these are noble ideas. But are these ideas built on the correct foundation? According to Goldberg and Somerville (2016), continuous improvement will require a cultural attitude and commitment with the attendant humility to admit that learning from outside our community enhances such improvement. In this case, improvement from the learning schemes founded on ancient Rome SCE principles and practices cannot even be considered as an outsider to the African nations. As noted by Bianco (2023), Roman architecture and the building science of the time are an integral part of today's heritage; and belong to all. Structural engineering practices in sub-Saharan African nations should connect to and maintain a firm grip on this foundation. Thus the purpose of this paper is to underscore the need of sub-Sahara African nations, especially Nigeria, for the development of structural and civil Engineering (SCE) curriculum on the foundation of Caesar's Rome of classical times in terms of educational training, practices, and technology. The time frame considered spanned the times of Julius and his Son, Augustus Caesar when the Roman engineering feat reached a sublime height. The primary source of information about structural engineering and construction works of the time is Emperor Caesar's Engineer, Vitruvius, described as the Chief Engineer of the civilized World (Bruner, 2007). Vitruvius treatise *De Architectura Libri Decem* (Ten Books on Architecture), written after 2. B.C (Fapohunda, 2023a and Fapohunda, 2023b), is a seminal comprehensive work that is a revelation of the structural engineering history and theories of the Classical Roman antiquity. It was a publication that was addressed to Augustus Caesar, the Emperor of Rome (and to the Roman world at the time, which included the whole of Africa) that has survived to the present day.

*Some definitions*

It is necessary to study the two Greek words that combined to form the word "architecture", so that the thought behind it can be grasped. This word is according to equation 1.

$$\text{architecture} = \text{arch}\d{e} + \text{tekton} \quad \textbf{(1)}$$

This is expedient so that the full depth and expanse of the meaning, in the classical imperial period can be captured, as we progress in the curriculum development. The first word "*arche*", in the language of the period means the governmental authority or position or a Principality or the State Personified; and the person sitting on it was called "archon" (Prince) to whom all the people owed subjection and into whose hands the power of overall governmental administration fell and who also has the power to punish evil doers (Paul, 2014a). This was the person of both Julius and Augustus Caesar at the time. The second word "*tekton*" means simply a builder or to construct. This word is elastically wide and deep in the treatise of Vitruvius. For example, a builder can build with concrete, stone, wood, glass, bricks, gold, silver, iron, bronze, and so on. Also, what a builder builds is many and diverse in the treatise of Vitruvius. It could be housing of all types for different people, or temples of Gods, palaces, towns, cities, towers, bridges, water-carriers (aqueducts), sewage systems, water-supply systems for a city/town, construction machines, military equipment, institutional structures, roads, and ships (military and merchant ships) so on. All these and many more are included in the Vitruvius concept of building. Each of these types of constructions, no doubt, will require different structural systems, different construction techniques, different construction materials, different safety measures, different technical associations, different administrative styles, and so on. All these happened to be the war times and peace-time activities of both Julius and Augustus Caesar, and Vitruvius was there, as their *numero uno* Engineer. In addition, a builder can build for their own citizens (or *civilis* in Latin, the root of the word "civilians") or for strangers. Those who are bound together by the common defence, legislature, and temple are regarded as citizens in the understanding of the time. Both Julius and Augustus Caesar built structures for their own citizens (or *civilis*) as their Prince (*arche*). It is then understandable that Vitruvius directed his work to Augustus Caesar, who as the Prince of Roman citizenship, represented the Roman state at the time, and thus the "Prince-Builder". The "arche" and "tekton" Equation 1 can now be interpreted to mean:

architecture = arche + tekton =

Prince-Builder/ Civil Engineer/ Citizens Engineer (2)

Thus, Prince-builder or Civil engineer (ing) – within the context of citizenship engineer (ing) - will be used interchangeably in this work and this is our mindset; and hence-forth used as to the scope of structural engineering in the attempt to link its curriculum development to its imperial Roman roots and foundation. Structural engineering, in our view, is wider than civil engineering (which history tells, is the engineering after peace was established). This is because structural engineering was behind the war time structures wars were fought at the time to establish peace. Structural and Civil engineering are thus linked to the persons who established peace. This was Augustus Caesar at the time (Houston, 2016 and Augustus, 2021). That is not to say that the authors are advocating a career in the military as a prerequisite for the practice of structural engineering. Rather, it is to be understood in the philosophical sense. According to Keener (1993), philosophers used to describe their conflict with wicked and bad ideas (or actions, conduct, etc.) or principles as wrestling in an athletic contest or a war. What are used in this conflict, according to him, are virtues – listed in Table 2 and not fists or missiles, or any violent means. Structural and civil engineers will have to deploy all these virtues to solve multifaceted human problems in the practice of the profession. This is the equivalent of the modern-day recognition of the need for the development of "soft skills" or interpersonal skills, or such phrases among engineers.

## Methodology

*(i) Sources of Information*

The approach adopted for this work is to gather all available information in the public domain around the time frame under reference. This information, obtained from internet sources, Universities repositories, textbooks, commentaries, and so on, dealt with numerous construction projects. Also, political events that generated construction activities of the time, of which structural engineering was pivotal, were studied and analysed. But the primary source of information is the Morgan's translation of the Ten Books on Architecture by Vitruvius (1914). All others are supportive. The materials collected from the public domain for the purpose of this work were grouped and analyzed around four themes on the basis of relevance to aim of the study. These are: (i) preparatory and early education, (ii) Basic Education (iii) Post-basic Education (iv) the content of the curriculum.

## Results and Discussion

*(i) Preparatory Education and Early Education*

The substance of the Roman curriculum up to the high school level is presented in Table 1. It can be seen in Table 1 that training of Roman children began at home with an emphasis on behaviour, behaviour with respect to the Roman Constitution and to participate in the worship of the Gods for peace sake of all men. Thus, it was the parental duty at home, to lay s solid foundation for their children for the development of Roman character, Roman Faith, and to be submissive to the concept of the Divine or Providence. The practical expression of this faith and concept produces some elements that are essential to the formation of Roman character. These elements were expanded by Barrow (1953) and Miliken (1958), and it is presented in the original Latin words in Table 2. The issue of moral or character as foundational to education is also recognized by the Nigerian Education Research and Development Council (NERDC, 2013).

The syllabus for Nigerians according to section 2 of the National Policy on Education released by NERDC (2013) is presented in Table 3. From observing Table 1 and Table 3, it can be deducted that the three divisions of stages of education are approximately similar. It can be observed from the comparison of both Tables that while the Roman placed the responsibility of early education of children squarely at home, the Nigerian counterpart placed it squarely in the hands of private operators. The substance of education at home is with reference to the development of good character and the study of Roman law (or in modern terms, the Constitution) and divine appreciation. That is, familiarity with the Constitution started early at home for Roman citizens. The Constitution was and still is what is common to all the citizens. In Nigeria, this is not so. Not many people have it, not to say able to comprehend it for the purpose of practicing it. The importance of this early instruction on Constitutional matters resulted in what is later known as Jurisprudent developed by the Jurists, which is to be part of the curriculum for Civil engineers recommended by Vitruvius as will be observed later (Table 4). In his Institutes, Justinian (2023) summarized the Roman jurisprudence as to live honestly, to injure no one, and to give everyone his due. To injure none is the whole goal of structural engineering in all ramifications. From this *maxim* arose many construction laws that are used in developed Nations, which govern the construction process, construction safety and performance as well serve as a basis for apportioning construction risks (Bruner, 2007).

**Table 1: Expected Syllabus content up to High School (Milliken, 1958)**

| S/No | Stages | Some of the contents of the Syllabus |
|---|---|---|
| 1 | Early years home-training (less than 7 years old) | • Education and Training in<br>- Discreet behaviour<br>- Modesty in speech<br>- Respectful behaviour<br>- Roman Law, summarized as " to live honestly, to injure no one and to give everyone his due" (Justinian, 2023)<br>- In home-based Roman Religion meant to procure the "Peace of the God" to mankind. |
| 2 | Elementary school (7 – 12 years old) | • Great attention paid to reading and writing in Latin and Greek<br>• Training in Arithmetic<br>• Training of memory through learning by heart Greek and Latin prose and poetry |
| 3 | High school (12 – 19 years old) | Training and education in the followings:<br>• Grammar (in Greek and Latin)<br>• Dialectic (the art of critical enquiry by discussion)<br>• Geometry<br>• Astronomy<br>• Music<br>• Medicine<br>• Civil engineering<br>• Public speaking |

**Table 2: Character development (Barrow, 1953 and Miliken, 1958)**

| | Latin Words | Description |
|---|---|---|
| 1 | *Pietas* | The proper submission to all the established institutions, and a sense of duty to the immortal Gods and one's parents, that is, the habit of obedience to divine authority |
| 2 | *Simplicitas* | This is the quality in a man to sees things clearly and see them as they are, that is, keeping one's feet planted firmly on the ground |
| 3 | *Frugalitas* | To have simple tastes |
| 4 | *Gravitas* | Serious sense of responsibility which made even the smallest affairs of life seem too things too great to be trifled with |
| 5 | *Humanitas* | Respect for human personality and relationship. A sense of the dignity of one's own human personality, which is unique and which must be cared for and developed to the full, . . . . . and the recognition of the personality of others and their right to care for their own personalities, . . . and this recognition implies self-restraint. Respect for human personalities and relationships |
| 6 | *Virtus* | Manliness and energy |
| 7 | *Disciplina* | The training (at home and public) which produces steadiness of character |
| 8 | *Industria* | Hard work |
| 9 | *Constantia* | Firmness of purpose , . . tenacity of purpose |
| 10 | *Clementia* | The willingness to forgo one's rights for common goals |
| 11 | *Comitas* | Good humour |
| 12 | *Libertas* | Maintenance of freedom of individual |
| 13 | *Fidas* | Respect for pledged words and the expressed intention |
| 14 | *Mores* | Holding fast to what has been handed down as containing accumulated wisdom, which no moment or man can supply |

It is difficult to practice structural/civil engineering in an unstable environment where there is no stable human character, stable institutional and good legal framework that guides relations amongst citizens at every contact encountered in all human endeavours during practice be it the government at all levels, or government agencies, or institutions, individuals, and so on. It is also noteworthy in Table 1 that the development of peace issues, as essential component of human personality formed part of early years of education, and this training resided at the average Roman home. Inclusion of the concept of peace issues at the early stage of human development, inadvertently prepared the framework of peace and harmony that are necessary for the practice of SCE A structural and civil engineer needs a lot of skills in the art of practical peace-making to manage the diversity of human natures in forms of character, conduct, cultures, ethnicity, belief, legal systems, citizenship, etc., that must be resolved; first to create enabling working environment for peace and harmony, and secondly for safe and sound structural judgement during the whole period of the construction work. However, peace issues, ultimately fall under the jurisdiction of the statesmen who are empowered to punish violators of public or societal peace, which was a sin-qua-non for the practice of civil engineering. Placing the early educational development of Nigerian citizens in the hands of private operators, with no guidance or basis (as the Roman counterpart anchored Roman Law), and with no well-developed character sets as in Table 2 (as for the Roman), portend danger to the society. Nigerians trained by private operators who are unknown and amorphous and subject to the whims of just any wind of doctrine, cannot produce the stable and resilient character as well as peaceful disposition required to practice structural engineering in the long run.

*(ii) Basic Education*

The elementary school in ancient times, from Table 1, is approximately equal to Nigeria's basic education as can be seen in Table 3. The substance of the curriculum for elementary school in the classical times is basically arithmetic and language studies in Latin and Greek literature poetry, history, oratory, and so on. Although the concept of what constitutes arithmetic may have varied in terminology over times, the centrality of the study of Latin and Greek languages to the Basic education in the times under reference is unmistakable. The centrality of a common language in a community as a vehicle of growth, development and specially building activities for civilization, was recognized a long time ago. Moses (2014) document showed that, but for the intervention of the Divinity in ancient times, the whole humanity would have succeeded in their efforts to build a city and a tower that was to reach the Heavens because of the common language at the time. The present stage of human civilisation seemed to be firmly established on the taught-forms and though-precepts that were either Latin or Greek or both combined together. While the classical Greek language is today's language of universal learning and education; Latin, the language of the Romans is the medium of Caesar's imperial law (constitution), and still the basis of several national legislations (Bianco, 2023). Nigeria basic education also recognizes the importance of Languages by including a minimum of 3 (three) languages, namely English language, French language, and one Nigerian; as well as Arabic language which is optional. The inclusion of these languages was well-intended but may not provide the necessary link to the language of classical Caesar's times on which structural and civil engineering practices were founded. The link is necessary to gain access to resources that is necessary for robustness and dynamism in the practice of the profession so as to make meaningful contributions to human development.

*(iii) Post-Basic Education*

The contents of the curriculum of post-basic education by NERDC (2013) are shown in Table 3. This is approximately equivalent to the High school in Caesar's Rome of the 1st century as shown in Table 1. The NERDC (2013) contents contain five (blocks) and within each block are courses. The courses in the first block are compulsory and five other subjects are to be added in other blocks. In the technology block, there is building construction. Building construction here, using the language of Caesar's time was simply Civil engineering as earlier adverted to. In Caesar's time, the scope of activities of Civil engineering, according to Augustus (2021) and Fapohunda (2023b) encompassed the construction activities enumerated in Table 4. The learning of civil engineering began at High school. With the exception of structures for private individuals, most construction works were undertaken by the reigning Emperor or Magistrate, including temples or worship centres. They are thus what can be termed "institutional construction". On the other hand, what constitutes Building construction in the Nigerian environment, though not compulsory, was not disclosed by the NERDC (2013), but the practice is not as wide as the Caesar's Rome counterpart as can be observed in Table 4. Also, the practice in Nigeria is not institutional in outlook.

**Table 3: Expected Syllabus Content in Nigerian Schools (NERDC, 2013)**

<table>
<tr><th>S/no</th><th>Stages</th><th colspan="2">Some of the content of the Syllabus</th></tr>
<tr><td>1</td><td>Early child care Development Education (ECCDE) - Up to 4 years old (in daycare centres,- fully in the hands of private sector, social development services)</td><td colspan="2">• Teachings to:<br>- Inculcate social, moral norms and values<br>- Inculcate in the child spirit of enquiry and creativity through the exploration of nature and the environment, art, music,<br>- Develop sense of cooperation and team spirit<br>- Stimulate good habits in child and good health habits<br>- Rudiments of numbers, letters, colour, shapes, forms, etc. through play</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">5 - 15 years old (Basic Education)<br>-</td><td>Pre-Primary – 1 year</td><td>The same as in ECCDE at daycare centres</td></tr>
<tr><td>Primary Education – 6 years</td><td>There is a specific curriculum consisting of:<br>- English studies<br>- One Nigerian Language<br>- Mathematics<br>- Basic Science and Technology (Basic Science, Basic Technology, Information Technology and Physical and Health Education)<br>- Religious and National values (Christian Religious Studies, Islamic Studies, Social Studies, Civil Education, Security Education)<br>- Cultural and creative arts<br>- Arabic (Optional)</td></tr>
<tr><td>Junior Secondary Education – 3 years</td><td>There is a specific curriculum; and it is as in Primary Education (above) in addition to<br>- Pre-Vocational studies (Home Economics, Agriculture)<br>- French language<br>- Business Studies</td></tr>
<tr><td>3</td><td>Post-Basic Education (> 15 years old)</td><td colspan="2">• Compulsory and Cross-cutting Subjects (English Language, Mathematics, Trade and Civic Education)<br>• Science and Mathematics (Biology, Chemistry, Physics, Further Mathematics, Health Education, Agriculture, Physical Education, Computer Studies)<br>- Technology (Technical Drawing, General Metal Work, Basic Electricity, Electronics, Auto Mechanics, Building Construction, Woodwork, Home Management and Food and Nutrition.<br>• Humanities (Christian Religious Studies, Islamic Studies, Visual Arts, Music, History, Geography, Government, Economics, Literature-in-English, French, Arabic, Any Nigerian Language with Curriculum.)<br>• Business studies (Stores Management, Accounting, Commerce, Office Practice, Insurance)<br>• Trade and Entrepreneurships Subject. (34 subjects are listed)</td></tr>
</table>

**Table 4: The Scope of Civil engineering in the Caesar's time**

| S/No | **Civil Engineering** | **Types** | **Divisions** | **Descriptions** |
|---|---|---|---|---|
| 1 | The art of Civil Engineering | Construction of Fortified Towns/Cities | NA | NA |
| | | Construction of Public buildings | Defensive | Planning of Walls |
| | | | | Towers |
| | | | | Gates |
| | | | | Devices for resisting hostile attacks |
| | | | Religious | Erection Fanes |
| | | | | Erection of Temples to Immortal Gods |
| | | | Utilitarian | • Erection of meeting places for public use<br>• Harbour<br>• Markets<br>• Colonnades<br>• Baths (but were a place for social life, news, gossip, lectures, and games (board games, exercise, games with balls).<br>• Theatres (a place for entertainment)<br>• Amphitheatres (modern day Stadium)<br>• Promenade<br>• Bridges<br>• Roads<br>• Aqueducts (water carriers)<br>• Forum (a central **open space** used as a meeting place, market, or gathering place for political discussion or demonstration, a central city location critical for communicating ideas and news. It also comprised of several public buildings that included courts, jails, and government facilities).<br>• Circuses (for horse and chariot racing)<br>• Basilica (Basilicas were halls of justice and commercial marketplaces |
| | | Structures for private individual | In the city | NA |
| | | | In the countryside | NA |
| 2 | Making of time-pieces | Sundials, water clocks, | NA | For measuring time |
| 3 | Construction of machinery | For military purpose | NA | Catapults, ballistae, siege machines, tortoise, towers, amongst others |
| | | For non-military purposes | NA | Hoisting machines, engines for raising water, water wheels, water mills, water screws, pump, odometer, amongst others. |

An institutional or community-centred orientation of the training of civil engineers will make some courses in humanity, social sciences, philosophy, and law reasonable as will be seen shortly in the curriculum of civil engineers in the Caesar's Rome. This is because institutions exist for a community; and all the elements in it must meet and learn how to interact peacefully.

It is the human beings in the community that is important as a whole, not in part; before the practice of the profession. Presently, an average Nigerian civil engineer does not think that his/her profession has anything to do with Law, or Social sciences, or Philosophy, etc., or the development of ethical issues as a condition for communal interactions that engineering infrastructures and construction promote. The character development for good neighbourliness begins at home, and the home is the subset of the whole society. Romans thus located this in the formative years of the early life of the Roman citizens at home as can be seen in Table 1 to nurture and develop the character in Table 2 out of which many curriculum features of civil engineering in the time of Caesar developed. For example, from item 13 of Table 2 (respect for pledged words), the Roman civil engineers exercise great care in contracting because the Roman legal doctrine of *pacta sunt servanda* ("contracts must be honored") imposed strict contractual liability unless non-performance was excused under the doctrine of *rebus sic stantibus* ("provided the circumstances remain unchanged") (Bruner, 2007). These ancient principles undergird the modern law of contract and its legal doctrines of sanctity of contract, force majeure, and impracticability. This learning began at Roman home (Bruner, 2007).

*(iv) The Content of Civil Engineering Curriculum in Caesar's Time*

Against the background of the foundation laid by going through the curriculum contents of Table 1, the curriculum for civil engineering, arranged into nine (9) groups in Caesar times is presented in Table 5. Looking at the contents of Table 5, the contents of the curriculum may seem strange in Nigeria, especially when observed that the construction of machines and engines are included as part of the curriculum, but it is not strange to the United Kingdom and European Nations. For example, in 1828, the Institution of Civil Engineers (ICE) was established through Royal Charter (ICE, 2014).

**Table 5: Breakdown of the curriculum of Civil engineering according to Vitruvius's (Fapohunda, 2023; Bianco, 2023)**

| S/no | Knowledge Required | Relevance to the Profession |
|---|---|---|
| 1 | Skillfulness with pencil | a) Enables ability to sketch the appearances of work being proposed |
| 2 | Knowledge of Geometry | a) This impacts ability to use of ruler and compass required for making plans of buildings on the ground.<br>b) Necessary for the right application of square, the level instrument and the plummet.<br>c) To learn Optics in Geometry enable light to the building to be drawn from fixed quarters of the Heaven.<br>d) The arithmetical part of geometry enables the cost of the building to be calculated and measurement to be computed.<br>e) Geometrical theories and methods allow symmetrical problems to be solved. |
| 3 | Knowledge of Political History | a) This is necessary to be able to preserve or repair the society and her infrastructures. |
| 4 | Knowledge of Philosophy | a) This is to make the **Civil Engineer** not to be self-assuming, but make him courteous, just, honest and without avariciousness.<br>b) Necessary for Civil Engineer to be honest and incorruptible.<br>c) To learn Physics and its fundamentals, which is taught under Philosophy so as to be able handle numerous construction works. |
| 5 | Knowledge of Music | a) To acquire knowledge of canonical and mathematical theory.<br>b) To enables the tuning of ballistae, catapult and scorpions to proper key.<br>c) To impact the skill necessary to make water organs and objects which resemble them. |

| | | |
|---|---|---|
| 6 | Knowledge of Medicine | a) To settle the issues of climate, air, healthiness or otherwise of sites and the use of different waters to ensure healthiness of dwellings. |
| 7 | Know opinion of Jurists | a) To ensure that in the drawing up contracts, interests of both the employer and contractor are safely guarded.<br>b) To impact understanding of laws governing some elements of building, for example, drains, windows, water supplies, etc. |
| 8 | Knowledge of Astronomy | a) For the location East, West, South and North.<br>b) To acquire the knowledge of Constellations and Stars. |
| 9 | Theory of Heavens | a) For finding equinox, solstice, course of stars and revolution of the firmament.<br>b) To be able to understand the Theory of Heavens.<br>c) To give the skills necessary to construct machines and engines. |

In the definition, mechanical science and construction of machinery were part of what constituted civil engineering. An excerpt from that charter says:

> "*. . . . Thomas Telford, of Abingdon Street, in the City of Westminster, Esquire, a fellow of the Royal Societies of London and Edinburgh, and others, had formed themselves into a Society for the general advancement of Mechanical Science, and more particularly for promoting the acquisition of that species of knowledge which constitutes the profession of a Civil Engineer, being the art of directing the great sources of power in Nature for the use and convenience of man, as the means of production and of traffic in states both for external and internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation, and docks, for internal intercourse and exchange, and in the construction of ports, harbours, moles, breakwaters, and lighthouses, and in the art of navigation by artificial power for the purposes of commerce, and in the construction and adaptation of machinery, and in the drainage of cities and towns . . .":*

It can be observed that many of the construction works listed in Table 4 – practised in Caesar's time - are included in this Charter. Times and development have not changed this definition of civil engineering, as the current amended charter which came into effect in 2022, as other amended charters in 2015, 2018 still retain this definition (ICE, 2022). The phrase "the powers in Nature" was expressed in chapters 9 and 10 of the "Ten Books on Architecture". Thus, the ICE (2022) definition of civil engineering had inputs from knowledge and practices that dated to the time of Caesar's Imperial Rome. By contrast, the Nigeria's Institution of Civil Engineers (NICE, 2023) defined civil engineering as:

> "A professional service engineering practice that applies the knowledge of mathematics and the physical sciences to design, construct and maintain the physical and naturally built environment for the benefit of man and the environment".

The NICE definition has a limited scope in application compared to the ICE definition (2015 – 2022). It may be tempting to argue that the categories of disciplines in Table 5 are not nowadays required in structural and civil engineering education. They are definitely relevant and their lack is evident in its practice, especially in sub-Sahara African Nations like Nigeria. The subjects in categories 3 (history), 4 (philosophy), and 5 (Law or Jurisprudence), are no doubt progression from education in the early years depicted Table 1; placed at home in the Caesar's Rome but in the hand of private operators in Nigeria. Vitruvius seemed to be saying that without the training that impacts citizenship consciousness and values, civil engineering does not exist. As can be seen in Table 5, the inclusion of philosophy and associated studies renders a professional "just and honest without avariciousness, According to Vitruvius, for no work can be rightly done without honesty and incorruptibility". Home is the beginning of the training for true philosophical development in a child. The ancient Romans held fast to the sayings of Solomon (2014) that when children are trained in the way they should go, they will not depart from it. This is now termed professional conduct, an important dimension enshrined in national legislations and endorsed worldwide by professional chambers. In addition, the study of physics, the bedrock of engineering, according to Table 5 must be learnt from platform of philosophy. The modern practice does not see any relationship between philosophy and construction works. And by that, he meant the Greek philosophies of Plato, Socrates, Epicureans, and so on. It may be necessary to introduce philosophical studies into the Postgraduate curriculum, especially at the Doctoral level, when the minds of candidates are now mature. This will make the title "Doctor of Philosophy" meaningful. Jurisprudence is important to be able to draw and comprehend contractual duties and obligations. Faithfulness to pledge words is a precursor to faithfulness to written agreement and contract (Table 1 – 2). The study of astrology and concept of the theory of Heaven in the Table 5 are insight that the present space agencies/stations/explorations and all the associated national infrastructures of the developed Nations had root in the Caesars's Rome. This underscores the earlier conclusion that civil engineering, as practiced in the Caesar's Rome was the profession of (or in partnership with) the state. It is in this domain that the phrase "power in the nature" was derived and clues on how machineries were constructed was given. After setting forth that the principles governing machines (*mẹchanẹ)* and engines (*organon*) are different from each other, Vitruvius in Book X, Chapter 1, No. 4, he says:

> " . . ***All machinery*** is derived from nature, and is founded on the teaching and instruction of the revolution of the firmament. Let us but consider the connected revolutions of the sun, the moon, and the five planets, without the revolution of which, due to mechanism, we should not have had the alternation of day and night, nor the ripening of fruits. Thus, when our ancestors had seen that this was so, they took *their* ***models from nature***, and by imitating them were led on by divine facts, until they perfected the contrivances which are so serviceable in our life. Some things, with a view to greater convenience, they worked out by means of ***machines*** and their revolutions, others by means of ***engines*,** and so, whatever they found to be useful for investigations, for the arts, and for established practices, they took care to improve step by step on scientific principles.

It is obvious the invention of structural element that they called "*arche*" and domes was by observation and imitation of the visual shape of the sky above. This portion of the treatise needs to be studied for the development of engineering infrastructure which is impossible without equipment. The inclusion of medicine as part of the curriculum is also reasonable since most civil engineering works are carried out in the open field, and thus, civil engineers must be educated in health and sanitary issues that are not found on sites.

*(v) The Final Comments*

It was earlier said in the opening sentence that structural and civil engineering (SCE) practice are not as dynamic and robust when compared to the developed Nations. This paper looked at the foundations of SCE in sub-Sahara Africa using Nigeria as case study and that of the United Kingdom. From the available information in the public domain, strong and sustained link to SCE training and practices to ancient Caesar's Rome in the training of SCE in UK were established. Although grounded in the practice and technology of ancient Caesar's Rome, the principles put forward in *De Architectura* remain valid today for effective, sustainable structural and civil engineering design based on rigorous education and a good knowledge of structural engineering materials and construction. This is the reason why they form the bedrock of the definition of civil engineering by ICE (2022. The education that Vitruvius advocated was not academic, but pragmatic. He called for civil engineers to lay good foundation for a wide and deep "wholistic" education so as to be able to address the well-being of all in their work. He intended that civil engineering issues be comprehended through interdisciplinary but integrated education, beginning from tender years so as to recognize interconnectivity between all studies and thus able to comprehend how and when to apply them (Bianco, 2023).

## Conclusions and Recommendations

From the analysis of the data obtained from this investigation, the following conclusions are made.

i. Structural and Civil engineering (SCE) training and practices in the United Kingdom are linked to the training and practices of SCE in the classical Caesar's imperial Rome.
ii. The profession of SCE is closely linked to the State.
iii. Structural and Civil engineering (SCE) training and practices in the classical Caesar's imperial Rome had a very wide and deep foundation that encompassed many branches of learning.
iv. The ICE curriculum of SCE had as part of its contents, a module dealing with the development and construction of SCE equipment and machinery, just like the curriculum contents of SCE in the Caesar's time.
v. The development and construction of SCE equipment and machinery are linked to the space studies.
vi. Latin and Greek languages seem to be the language of SCE and vehicle for the conveyance of SCE educational resources.

Based on the findings from this study, the followings are recommended.

i. The policy of placing early education into the hands of private operators should be reviewed.
ii. The study of developmental languages of Greek and Latin should be encouraged at all levels of education for access to thought forms and precepts that form the bedrock of SCE knowledge and understanding.
iii. Philosophical studies should be introduced as part of the curriculum contents of graduate programs.
iv. The Government of the developing Nations should establish and adequately fund space

research program, which seems to be the domain from which to tap the resources necessary for the development and construction of engineering equipment and machinery.

v. Also, the definition of civil engineering should be re-worded and be in line with ICE definition, for dynamism and robustness in structural and civil engineering training and practices from generation to generation.

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# Empowering Higher Education through a Micro-Credential Program in Power Electronics Course

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**Abstract**

In line with the global and national shifts towards enhancing educational accessibility, flexibility, and quality, Malaysia has embarked on a transformative journey with the implementation of the Malaysian Education Blueprint 2015–2025 (Higher Education) and E-Learning Guidelines for Malaysian Higher Education Institutes. This strategic initiative acknowledges the pivotal role of e-learning in shaping the future of education by enabling greater access to knowledge and skills. The COVID-19 pandemic has further accelerated the growth of e-learning, emphasizing the need for innovative educational approaches. This paper presents a micro-credential program in the field of power electronics, aligned with Malaysia's commitment to advancing higher education through technology-driven solutions. The curriculum, which is tailored to meet the needs of a wide range of learners, covers all the fundamentals of power electronics and leaves participants with specific knowledge and abilities. This micro-credential program is designed to empower professionals and students, supporting their career objectives in the dynamic power electronics industry, by emphasizing accessibility, flexibility, and high-quality learning experiences.

**Keywords:** Micro-credentials, Power Electronics, Online Learning, Lifelong Learning, Massive Open Online Courses

## Introduction

In 2014 and 2015, the Ministry of Education Malaysia established the e-Learning Guidelines for Malaysian Higher Education Institutions (HEIs) and Malaysian Education Blueprint 2015–2025 (Higher Education) to provide guidance for the transformation of the nation's education system. It encompasses a complete framework designed to address various aspects of education in Malaysia, outlining clear objectives and strategies to enhance the quality of education at all levels, from early childhood education to higher education, and to drive the e-Learning environments in the Malaysia education system (Ministry of Education Malaysia, 2014, 2015).

Ten shifts have been identified by the Ministry in the Education Blueprint to transform higher education in Malaysia, as shown in Figure 1 (Ministry of Education Malaysia, 2015). It addresses key performance issues within the system, specifically focusing on quality and efficiency aspects. It also considers the global trends that are causing disruptions in the higher education landscape. The third shift, which is Nation of Lifelong Learners, serves the purpose of equipping individuals with the necessary skills to adapt to the evolving demands of a high-income economy. Additionally, it aims to unlock the full potential of individuals outside the workforce through reskilling and upskilling initiatives. For the ninth shift, which is globalized online learning, blended learning models are anticipated to become a prevalent educational strategy in higher learning institutions (HLIs). The implementation of a strong cyber infrastructure that capable of supporting technologies such as video conferencing, live streaming, and Massive Open Online Courses (MOOCs) will benefit lots of students. Thus, Malaysian HLIs were urged to explore and actively engage with these online learning platforms to extend their global outreach.

The COVID-19 pandemic has further accelerated the growth of e-learning, as it has a significant impact on the global education and employment sectors. The situation demanded a reassessment of conventional pedagogical approaches by educational institutions, forcing them to consider the use of hybrid or online learning options for the future. Many businesses also accelerated their digital transformation efforts to adapt to the new normal. This led to increased demand for tech-related jobs. As the job market shifted, employees and job seekers focused on acquiring new skills and competencies to remain competitive in the changing employment landscape (Shanahan & Organ, 2022).

N. Jaalam, M. S. Bakar, A. Z. Ahmad, S. Ab Ghani, N. Saad, N. W. Arshad (2023), Empowering Higher Education through a Micro-Credential Program in Power Electronics Course, *ASEAN Journal of Engineering Education*, 7(2), 28-32.


**Figure 1. The 10 shifts to transform higher education system in Malaysia** (Ministry of Education Malaysia, 2015)

As for Malaysia, in response to the new normal due to the pandemic, Malaysian HEIs have taken proactive measures to embrace e-learning approaches specifically Open and Distance Learning (ODL) practices. ODL has emerged as a prominent trend in providing access to high-quality education, fostering lifelong learning possibilities, offering flexible learning techniques, and creating a conducive learning atmosphere for individuals. Students engaged in several forms of online educational activities, including attending virtual lectures, participating in online tutorials, and engaging in self-directed learning through online platforms such as Zoom, Google Meet, Google Classroom, Flipped Classroom, etc. In contrast to traditional physical examination practice, online assessments and assignments offer the advantage of providing students with immediate access to their grades and constructive feedback, enabling them to enhance their performance in subsequent evaluations.

To support these transformations, the Ministry has introduced the Data Plan and Device Package initiative in 2021, targeting the B40 group. Approximately 200,000 data plans and 4000 gadgets have been distributed to facilitate remote learning for students within this demographic. In the same year, a budget allocation of RM50 million had been approved for upgrading the Malaysian Research and Education Network to ensure students get better and faster internet access and connectivity (*Higher Education Institutions Must Adapt to Digital Changes Post-Covid-19*, n.d.).

Consequently, the concept of Micro-Credentials which enable individuals to take short courses at their own convenience and pace, is gaining more attentions (Chukowry et al., 2021). According to Malaysia Qualifications Agency (MQA), a Micro-Credential refers to a formal recognition of evaluated learning outcomes achieved via the completion of one or more specific courses. Its purpose is to equip learners with specific knowledge, values, skills, and competencies (Malaysia Qualifications Agency, 2020). Certain Micro-Credentials may be referred to as digital badges, online certificates, licenses, alternative credentials, endorsements, nano-degrees, or micro-masters (Malaysia Qualifications Agency, 2020; Shanahan & Organ, 2022).

This paper will present the implementation of Micro-Credentials for the Power Electronics course at Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA). A brief overview of Micro-Credentials of all around the world as well as in Malaysia will be given first. Next, it will discuss the development of Micro-Credential of Power Electronics course followed by the assessments. Finally, general recommendations will be given to enhance the implementation of this Micro-Credential.

## Overview of Micro-Credentials Around the World

The post-pandemic period has seen numerous governments all over the world adopting Micro-Credentials as a means to facilitate the reintegration of individuals into the workforce through training and reskilling initiatives. In pursuit of this objective, governments are allocating substantial financial resources. For example, the Australian Federal Government announced a $4.3 million fund in 2020 to build a micro-credential market to assist re-employment initiatives. Similarly, in the same year, the Irish Government's Human Capital Initiative (HCI) allocated a noteworthy €12.3 million to provide funding for seven universities in support of their micro-credential projects. The governments of Alberta and Ontario, Canada have also demonstrated their commitment by investing a total of $65.1 million in Micro-Credential development and awareness programs.

As for Malaysia, Universiti Sains Malaysia (USM) has led the way with the establishment of Micro-credential@USM, a program designed to assist professionals from all organizations and industries, educators, and lifelong learners (CDAE, 2018). Following this are Universiti Malaya (UM), Universiti Putra Malaysia (UPM), and Universiti Teknologi Mara (UiTM) Pulau Pinang branch (UiTMCPP), which have all started the move since 2019 (Academic Development and Enhancement Centre (ADEC), 2019; Pusat Pembangunan dan Kecemerlangan Kepimpinan Akademik, 2019). A series of seminars and workshops have been conducted to train the module developers to design their modules (Ahmat et al., 2021). Nowadays, many public universities have taken part in offering this kind of learning such as Universiti Kebangsaan Malaysia (UKM), Universiti Teknologi Malaysia (UTM), Universiti Utara Malaysia (UUM), Universiti Islam Antarabangsa (UIA), Universiti Malaysia Sarawak (UNIMAS), and UMPSA.

*Micro-Credentials at UMPSA*

UMPSA has offers three distinct categories of Micro-Credentials namely Micro-Credentials (MC), Stand-Alone Micro-Credentials (SAMC), and Micro-Credentials Industry (MCI) (CIReL, 2022). Figure 2 illustrates the fundamental framework of MC in UMPSA, where each MC course carries a weight of 3 credit hours, contributing to a cumulative total of 120 Students Learning Time (SLT). This MC can be split into three modules, each having its own set of Course Learning Outcomes (CLO), which may be either identical or varied. Each module is also designed to be completed within a one credit hour timeframe, which corresponds to 40 SLT. It was suggested to have a maximum 3 chapters only for each module and they can have their own Learning Material (LM), Learning Activity (LA) and Learning Assessments (LS).

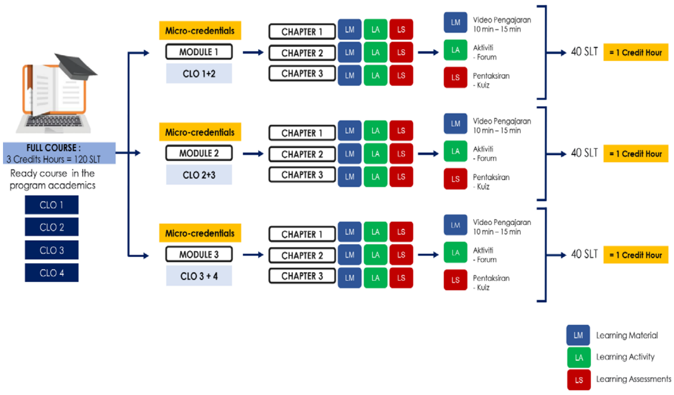


**Figure 2. Micro-Credentials structure at UMPSA** (CIReL, 2022)

Figure 3 depicts a flow chart outlining the process of MC development and registration at UMPSA. Initially, the course developer needs to identify and gather all the necessary details pertaining to the course and thereafter develop a comprehensive teaching plan including the delivery mode and assessments. Subsequently, the digital content shall be created in accordance with the e-learning content quality guidelines (GPKKeP) established by the Centre of Instructional Resources and e-learning (PSPe) at UMPSA before it can be uploaded to the designated platforms.

## MC 01: Introduction to Power Electronics

For Power Electronics Course, it is under MC category where it is further divided into three modules: MC 01, MC 02, and MC 03 entitled Introduction to Power Electronics, DC Power Supplies and AC Power Supplies respectively as shown in Figure 4. Each module has its own Course Learning Outcome (CLO) and was allocated a total of 40 hours of Students Learning Time (SLT). For time being, only MC 01 has been established while MC 02 and MC 03 are still in progress. Figure 5 presents the synopsis and CLO pertaining to MC 01.

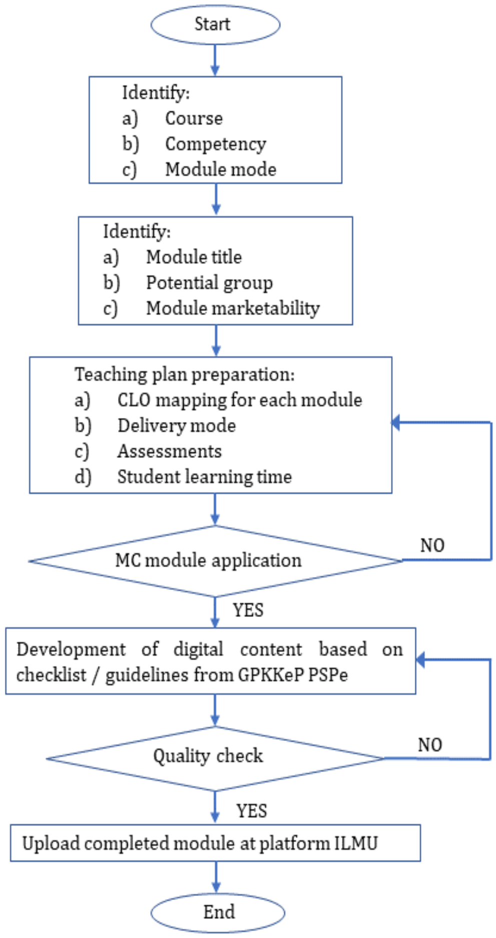


**Figure 3. Flow chart for Micro-Credentials development and registration at UMPSA** (CIReL, 2022)

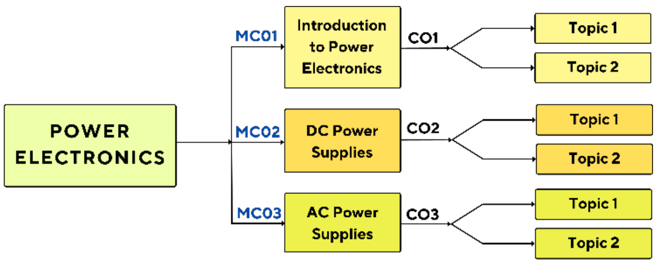


**Figure 4. Micro-credential structure for power electronics course.**

**Synopsis:**
This module presents a foundation of knowledge, understanding, analysis and design of power electronics circuits for a conversion and control of electrical energy.

**Course Learning Outcome:**
Describe the operating principles and the switching characteristics of a power electronics converter.

**Figure 5. The synopsis and course learning outcome for MC 01.**

*The Development of e-content*

Module MC 01 consists solely of two chapters, entitled "Fundamentals of Power Electronics" and "Rectifier". The topic of Fundamentals of Power

Electronics will encompass the study of electrical switches and their applications in power electronics. On the other hand, the later topic will explore both uncontrolled and controlled rectifiers. This module is designed to provide 40 hours of SLT which involves lectures, learning activities, and assessments. The laboratory activity will primarily be conducted using simulation methods. Thus, students are required to install the LTspice software to simulate the behaviour of the rectifiers.

The module's delivery employs a cutting-edge approach that incorporated the use of Green Screen technique as shown in Figure 6 and the Lightboard technology as demonstrated in Figure 7. Both recording sessions were taking place in the EduCreator Studio located at the Faculty of Electrical and Electronics Technology, UMPSA. Once the e-contents have undergone quality checks, they will be uploaded on the TINTA and iLMU platforms. The TINTA system is a digital self-paced learning platform that is accessible solely to staff and students of UMPSA. In contrast, iLMU is an Integrated Learning Management System for Universality that can be assessed by the external community.

**Figure 6. e-content development using Green Screen technique.**

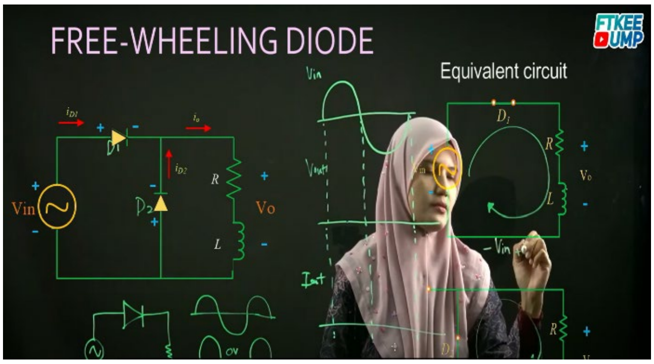


**Figure 7. e-content development using Lightboard technology.**

*Assessments*

In this module, students will undergo evaluation through a series of assessments, including one test, one lab report, and two quizzes. These assessments will contribute to the overall grade with respective weightings of 50%, 40%, and 10% as tabulated in Table 1. All assessments will be conducted online via the Moodle platform which employed a range of question formats such as multiple choices and embedded answers (Cloze). Figure 8 shows an example of the question using the Cloze method. Students are required to fill in the blank with the correct answer and it will be automatically graded.

**Table 1: Assessment's List**

| Assessment | Percentage |
|---|---|
| Quiz | 10 % |
| Lab report | 40 % |
| Test | 50 % |

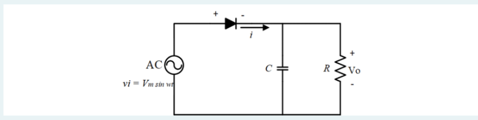

Figure 1

**Figure 1** shows a rectifier circuit that has an input voltage of 230 V, 50Hz with 47 Ω load resistor and 96 μF capacitor. If the diode turns off angle, θ is estimated at 125 degree, determine:

i) The diode turns on angle, α if the ripple voltage is 102 V

α = ____ radian

ii) The expression of output voltage,

ωRC = ____ radian

Vθ = ____ V

*For the final expression, just upload your pdf file at the end of this test.

iii) The new capacitor, C for the ripple output voltage of 55 V

C = ____ mF

iv) The new power diode turns on angle, α for the new capacitor value

New α = ____ radian

v) The new peak diode current,

$I_{Dpeak}$ = ____ A

**Figure 8. Sample questions using embedded answers (Cloze) method.**

## Recommendations

For the successful implementation of the Micro-Credentials programs, it is crucial to focus on several key strategies including raising awareness, providing incentives, and promoting Micro-Credentials in an effective manner. To accomplish this objective, universities need to proactively establish meaningful connections with relevant stakeholders, to gather valuable insights and secure their support, as well as to outreach potential learners. Simultaneously, it is imperative to provide incentives to the module developers to boost their motivation and commitment, while for the learners, scholarships can be offered to encourage their participation in the program. Finally, the establishment of a dedicated website or platform is essential in order to provide detailed information for this program. It is also possible to use a variety of platforms, such as social media, webinars, workshops, and industry events to promote awareness of this program. Social media, webinars, workshops, and industry events can also be utilized to enhance the visibility and recognition of this program.

## Conclusion

The development of micro-credentials in power electronics is essential to meet the growing demand for specialist knowledge in this field. However, it requires a comprehensive approach involving a well-structured module, the utilization of advanced technology for content delivery, and designing a suitable assessment. This program holds the potential to bridge the knowledge gap, enhance skill sets, and make education more accessible. As the demand for specialized expertise in this field continues to grow, these credentials can serve as a vital tool for career advancement and industry competitiveness, benefiting both individuals and the broader workforce.

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# Gender and Diversity in a Problem and Project Based Learning Environment: A Book Review

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**Abstract**
"Gender and Diversity in a Problem and Project Based Learning Environment" by Xiangyun Du is a pioneering exploration of the intersection between pedagogical innovation and gender diversity in engineering education. This book expertly navigates the challenges of achieving gender inclusivity in male-dominated disciplines while showcasing the transformative potential of Problem-Based Learning (PBL) methodologies. Through insightful case studies, critical analyses, and a rich synthesis of research findings, Du presents a compelling argument for the effectiveness of PBL as a catalyst for fostering diversity and equity in engineering education. Her work not only informs but also inspires positive change, making it an indispensable resource for educators, researchers, and policymakers striving to create more inclusive and equitable engineering education.

**Keywords**: diversity, gender equality, inclusivity, pedagogy, women empowerment.

Du, X. Y. (2022). Gender and Diversity in a Problem and Project Based Learning Environment. New York: CRC Press. ISBN: 9781003338260

## Introduction

*Gender and Diversity in a Problem and Project Based Learning Environment* is authored by Xiangyun Du, Professor from the Department of Learning and Philosophy; and also, a Director at UNESCO Centre for Problem and Project-based Learning, Aalborg University, Denmark. Having earned her academic degrees in engineering education (master's degrees at Linköping University, Sweden, and Roskilde University, Denmark, and a PhD degree at Aalborg University, Denmark), she has been committed to research in educational transformation through pedagogical change using Problem-Based and Project-Based Learning methodology) – in diverse social, cultural, and educational contexts. Having worked in fields of development ranging from engineering, STEM, teaching preparation, language teaching, business to health (medicine, dental, and public health sciences) education, etc.), her research topics included change from an inter/cross-cultural perspective, curriculum and pedagogy development, faculty/staff/ teacher development, intercultural learning and teaching, and gender studies.

Based on her expertise in PBL, in this book, Du's main argument revolves around the pivotal question of whether PBL can serve as a viable solution to the prevalent issue of a dearth of university students pursuing engineering and technology studies, particularly focusing on the underrepresentation of women in these fields. At the core of her book is the exploration of how the PBL environment, implemented in engineering education, can foster gender diversity and inclusivity. Through a comprehensive examination of learning experiences among engineering students in Denmark, Du delves into the intricate interplay between PBL methodologies and their potential to create a more welcoming and supportive space for diverse groups, with a particular emphasis on women.

The larger point of this book extends beyond a mere exploration of pedagogical techniques; it seeks to shed light on the broader implications of gender diversity in engineering education. By analyzing the various dimensions of PBL, Du aims to contribute valuable insights into transforming not only teaching methodologies but also the overall culture within engineering disciplines. The book underscores the importance of creating an environment that accommodates diverse learning styles and perspectives, ultimately making a compelling case for the integration of PBL as a means to address the gender disparity prevalent in engineering and technology fields.

Readers should care about this book because it offers a nuanced perspective on a critical issue within higher education. In an era where diversity and inclusion are paramount, Du's work serves as a guide for educators, policymakers, and anyone interested in fostering equitable opportunities in STEM fields. The comprehensive research and ethnographical study presented in the book provide practical insights and evidence-based strategies for creating an educational landscape that not only attracts but also nurtures a diverse cohort of engineering students. Ultimately, Du invites readers to contemplate the transformative potential of PBL in shaping the future of engineering education by breaking down barriers and encouraging participation from individuals of all backgrounds and genders.

This book has 326 pages and contains 10 chapters consisting of Introduction; PBL Environment for Gender Diversity in Engineering Education; Understanding Learning; Gender Understanding; Gendered Ways of Learning in Engineering Education; Research on Gender Diversity in Engineering Education; Studying Electrical and Electronics Engineering; Studying Architecture and Design Engineering; Gender and Learning in Engineering Education; and Conclusion: Is PBL a Recipe to Gender Diversity?

**Summary and opinions**

The book unfolds a series of key arguments that collectively lead to its overarching view. Du begins by positioning PBL as a potential pedagogical solution to the prevalent issue of low enrolment in engineering and technology programs. She intricately examines the dynamics of learning within the PBL framework, shedding light on how this methodology influences students' engagement and understanding in engineering education. The exploration of gender understanding and the identification of gendered ways of learning contribute to a deeper understanding of diversity within this educational context. Building upon existing research on gender diversity in engineering education, Du conducts an ethnographical study of engineering students in Denmark, providing rich qualitative data as evidence. Furthermore, specific case studies in electrical and electronics engineering, and architecture and design engineering offer nuanced insights into how gender dynamics manifest in these disciplines. The evidence supporting these arguments ranges from statistical data on enrolment trends to interviews and surveys capturing diverse perspectives. The concluding chapter weaves these threads together, culminating in the central question: Is PBL a recipe for gender diversity in engineering education? In essence, the book presents a comprehensive and well-supported exploration of the transformative potential of PBL in addressing the broader issue of gender representation in engineering fields.

In the first chapter of this book, readers gain the idea which sets the stage for the book's central inquiry and the context in which the research was conducted. The second chapter, PBL Environment for Gender Diversity in Engineering Education, is instrumental in setting the stage for the book's central theme and exploring the implications of PBL for promoting gender diversity in engineering education. It outlines the key principles and characteristics of PBL and establishes its relevance in addressing issues of gender diversity within engineering programs. The chapter defines PBL as an instructional approach that centers on students' active engagement in solving real-world problems. Students work collaboratively, applying their knowledge and critical thinking skills to address complex, authentic challenges. The PBL environment is characterized by its emphasis on student-centered learning and problem-solving (Hmelo-Silver, 2004).

The chapter also acknowledges the persistent gender gap in engineering and technology fields. It recognizes that women and other underrepresented groups are often underrepresented in engineering programs, and this lack of diversity has implications for both the workforce and societal equity.

The highlighted key themes:

- Collaborative Learning: The chapter underscores how PBL encourages collaborative learning, where students work together in small groups to tackle complex problems. This collaborative approach can promote diversity and inclusivity by valuing the contributions of all students and fostering a sense of belonging (Peña & de les Valls, 2023).
- Active Learning: PBL places a strong emphasis on active, hands-on learning. This can be particularly empowering for female students, as it allows them to engage with the subject matter directly and build confidence in their problem-solving abilities (Felder & Brent, 2007).
- Real-World Relevance: PBL often involves real-world, authentic problems. By connecting learning to practical applications, it can make engineering education more appealing and relevant to a diverse range of students (Chen et al., 2023).
- Student-Centered Approach: The student-centered nature of PBL acknowledges and values the individual experiences and perspectives of learners. This approach can help address implicit biases and create an equitable learning environment (Gray, 2023).

The third and fourth chapter, Understanding Learning and Gender Understanding explores the foundations of learning theory and its application in PBL settings, provides a critical theoretical foundation for the book's exploration of gender diversity in engineering education within the context of PBL. By examining established learning theories and their applicability to PBL, the chapter highlights the potential for PBL to create an inclusive and equitable learning environment. This understanding is vital in addressing the gender gap in engineering education and ensuring that all students have equal opportunities for success. By its nature, PBL challenges traditional teaching methods and stereotypes associated with gender roles. Female students, as well as their male counterparts, are given equal opportunities to take on various roles within the problem-solving process, challenging preconceived notions about gender-specific capabilities in engineering (Bellamy, 2023). The chapter starts by defining and discussing various learning theories, including behaviourism, constructivism, and socio-cultural theories. These theories provide the foundation for understanding how individuals acquire knowledge, skills, and attitudes (Crawley, 2014). The chapter sets the stage for later discussions by demonstrating how an understanding of learning theories can inform the design of PBL activities that are sensitive to gender differences in learning styles. It hints at the potential for tailored PBL experiences that can engage and support all students, regardless of their gender.

Chapter 5, 6 and 9 explores the existing literature and research findings regarding gender differences in learning styles and preferences; and investigates how gender can influence learning approaches and behaviours within the engineering context; and highlighting the gaps and challenges. It examines how societal expectations and stereotypes can shape students' approaches to learning, particularly in male-dominated fields like engineering. The chapter delves into the cultural and social factors that contribute to gendered ways of learning. It considers how societal norms and expectations, as well as the prevailing engineering culture, can influence the learning experiences of female students. By investigating how gender influences learning approaches, the chapter uncovers both the challenges that female students may face in engineering education and the opportunities to create more inclusive learning environments. It discusses strategies to address these challenges and promote diversity.

Chapter 7 and 8 present case studies on Electrical and Electronics Engineering; and Architecture and Design Engineering where it shows how PBL can be tailored to meet the needs of students in different engineering subfields, offering insights that can be applied in various educational settings. The chapters underline the adaptability and efficacy of PBL and Project based learning (PjBL) in promoting gender diversity and inclusivity within engineering, including traditionally male-dominated subfields. Architecture and design fields emphasize creativity, collaboration, and problem-solving. The chapter explores how these aspects can create an inclusive environment and align with PBL principles. It also showcases practical applications of PBL in architecture and design engineering programs, illustrating how these methodologies can foster a more diverse and inclusive cohort of students. Moreover, the chapter addresses the unique challenges that female students may face in these creative fields and the opportunities for innovation and pedagogical change.

Final chapter, Conclusion: Is PBL a Recipe to Gender Diversity?, has the shortest pages among the rest. It wraps up the book's core arguments and addresses the pivotal question of whether PBL can facilitate gender diversity in engineering and technology education. The chapter revisits the key arguments and themes explored throughout the book, including the role of PBL in promoting gender diversity, the impact of gender on learning approaches, and the practical applications of these concepts in specific engineering subfields. It synthesizes the research insights and findings presented in earlier chapters, emphasizing the contributions of PBL to creating more inclusive and equitable learning environments. The chapter critically evaluates the evidence presented and considers the strengths and limitations of PBL as a strategy for achieving gender diversity. It acknowledges the complexities and nuances involved in addressing this issue. While drawing conclusions, the chapter looks forward and considers the future of gender diversity in engineering and technology education. It may offer recommendations for future research, policy, and pedagogical practices.

This book has left an indelible impact on me, primarily owing to its compelling exploration of the transformative role of PBL in addressing gender diversity in engineering education. Du's adept ability to seamlessly blend theoretical concepts with real-world applications was a standout feature, creating a narrative that marries academic rigor with practical insights. The depth of her ethnographical study, centered on engineering students in Denmark, not only illuminated the challenges within the PBL framework but also offered a nuanced understanding of the opportunities it presents. Du's examination of gendered ways of learning presented a revolutionary argument that challenges conventional perspectives, suggesting that innovative pedagogical approaches can effectively break down gender barriers in STEM fields (Duo, 2023). The inclusion of specific case studies, statistical data, and interviews enhanced the overall persuasiveness of her overarching argument, making it more convincing and applicable. Despite these strengths, it is worth noting that a more explicit acknowledgment of potential limitations or alternative viewpoints could have added nuance to the narrative. Nevertheless, Du's work emerges as an innovative and thought-provoking contribution to the discourse on gender diversity in STEM, offering tangible solutions and inspiring hope for a more inclusive future in engineering education.

## Conclusion

This book holds significant implications for educational researchers, policymakers, and educators. This comprehensive work successfully combines two vital areas of educational research and practice: the application of PBL and the promotion of gender diversity within engineering and technology education. Throughout the book, Du meticulously explores the intersection of pedagogical methods and gender inclusivity. She addresses the central question of whether PBL can serve as a recipe for achieving gender diversity in engineering education. Through well-researched chapters, Du not only presents a strong theoretical foundation but also offers practical insights and case studies from specific engineering subfields. The book takes an interdisciplinary approach, drawing from the fields of education, gender studies, and engineering, to provide a well-rounded perspective. It identifies the challenges and barriers that female students often face in male-dominated disciplines and emphasizes the importance of creating an inclusive learning environment. The book serves as a valuable resource for educators, researchers, and policymakers seeking to enhance gender diversity in engineering education. It offers practical strategies and recommendations for implementing PBL methodologies and tailoring them to address the unique needs of diverse student populations.

In conclusion, "Gender and Diversity in a Problem and Project Based Learning Environment" is a well-structured and informative book that tackles an important issue in engineering education. By examining the potential of PBL to bridge the gender gap in engineering and technology fields, Du's work not only informs but also inspires positive change. This book is an essential read for anyone dedicated to fostering diversity and inclusivity in engineering education and serves as a beacon of hope for a more equitable future in these critical fields.

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# Experiential Learning in Engineering Education: A Book Review

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**Abstract**
"Experiential Learning in Engineering Education" by Alan L. Steele offers an in-depth exploration of experiential learning (EL) within engineering education, uniquely enriched by global research, case studies, and the author's extensive experience and theoretical grounding. Steele's work stands out for its comprehensive coverage of EL applications, addressing the evolving landscape of post-pandemic education and emphasizing the expansive nature of EL. The book is invaluable for faculties, educators, and researchers, providing practical strategies, insights, and a solid theoretical foundation. Its eleven chapters are grounded in educational theories like Kolb's Cycle and reflective practice, and are enriched by Steele's extensive experience in education and practical application. The book particularly stands out for its incorporation of evident-based EL strategies, including innovative laboratory methods, flipped classrooms and best practices from cross-disciplines. However, it could benefit from a more balanced chapter depth, a broader narrative perspective, clearer guidance on student reflection, and addressing the implications of AI tools in assessments. Future editions should aim for a more equitable exploration across chapters, inclusion of diverse stakeholder perspectives, and enhanced visual content. By addressing these areas, the book has the potential to solidify its position as a pivotal resource in engineering education, shaping future generations of engineering educators.

**Keywords**: Experiential learning, engineering education, situated learning, reflection, education post-COVID

## Introduction

Experiential learning (EL) has established itself as a crucial component in engineering education, recognized for its significant contributions to enhancing students' critical thinking, problem-solving abilities, and practical skills over an extended period (Hernández-de-Menéndez et al., 2019).

Alan L. Steele's 'Experiential Learning in Engineering Education' published in 2023 breaks new ground, extending the traditional boundaries of EL in engineering education, and offering a diverse array of strategies for integrating EL into undergraduate programs. Steele challenges engineering faculties to broaden their pedagogical horizons and adopt innovative teaching practices.

Steele's work serves as both a practical guide and a catalyst for change in engineering education including the adaptation to the evolving landscape of education post-COVID-19 pandemic which other books on EL do not offer. He seamlessly integrates 'learning by doing' and 'reflecting on work' into the book's narrative, emphasizing the development of deep technical knowledge, essential soft skills, and the cultivation of the right attitudes through genuine and engaging EL activities.

The book comprises of 11 chapters, each offering in-depth insights into integrating EL within the engineering curriculum. The following section presents summaries of these chapters, providing a comprehensive overview.

This review aims to present a balanced evaluation of Steele's work, acknowledging its considerable contributions to the field of EL in engineering education while identifying areas for potential further development. The goal is to provide readers with an in-depth and sophisticated perspective on the book's merits and its potential to influence the field of engineering education.

## Chapter Summaries

This book consists of 11 chapters where each chapter is further dissected into subchapters. The summary of each chapter is as follows:

Raja Rosli, R.M.K., Techanamurthy, U., Zakaria, A.F. (2023), Experiential Learning in Engineering Education: A Book Review, *ASEAN Journal of Engineering Education*, 7(2), 37-41.

**Table 1. Summary of Chapter**

| Chapter | Summary |
|---|---|
| Chapter 1: Introduction | The chapter sets the context for EL within engineering education by defining EL, builds reader interest by highlighting the growing trend of EL and its relevance, and establishing continuity by providing teaser of the book features, chapter-by-chapter. |
| Chapter 2: Education Theory and Experiential Learning | This chapter primarily explores the connection between educational theories and frameworks that underpin EL. This established theoretical foundation sets the stage for in-depth discussions in each of the subsequent chapters. |
| Chapter 3: Laboratories | The chapter leads readers to understand the vital role of laboratory work in education, offering a critical comparison between structured 'cookbook' labs and more exploratory 'open' labs. It emphasizes the importance of designing learning spaces that foster creativity and innovation, and it covers the shift toward online learning, a transition accelerated by the post-COVID-19 era. |
| Chapter 4: In-class Experiential Learning | The chapter critiques traditional lecture-based in-class learning while introducing innovative in-class EL methods, such as flipped classrooms and peer instruction. Additionally, it underscores the role of technology and classroom design in supporting these approaches. |
| Chapter 5: Problem-Based Learning, CDIO and Project-Based Learning | From theoretical to practical perspectives, this chapter offers a broad implementation overview of popular EL approaches in engineering education, specifically problem-based learning (PBL), Conceiving-Designing-Implementing-Operating (CDIO), project-based learning (PjBL), and challenge-based learning (CBL). |
| Chapter 6: Projects | This chapter goes deeper into the crucial role of PjBL in engineering education, exploring a variety of project formats including capstone and design courses, and highlighting their unique impacts on student learning. It offers insights into implementation strategies, features the distinctive learning experiences that projects provide, and discusses advanced approaches to assessment. |
| Chapter 7: Cooperative Education | The chapter provides an in-depth exploration of cooperative education in engineering, revealing its integral role in EL and highlighting the reciprocal gains for both students and employers. Additionally, it vividly illustrates students' learning experiences during co-op placements through the lens of the situated learning framework. |
| Chapter 8: Beyond the Curriculum. Undergraduate Research and Student Societies | This chapter explores EL beyond the formal curriculum in engineering, emphasizing the vital role of faculty advisors in guiding students through research, societies, and competitions. It highlights the benefits of engagement, including enhanced technical skills, leadership, and practical experience, while addressing the challenges and need for adequate support. |
| Chapter 9: Lesson from Other Professional Programs | The chapter explores EL practices in medicine, business, and social work, showcasing unique approaches like role-reversal, performance-based assessments, and immersive simulations. It suggests these innovative strategies could enrich EL in engineering education, advocating for a collaborative exchange of educational strategies to benefit students in all professional fields. |
| Chapter 10: Engineering and Society | This chapter addresses the intersection of engineering and society, emphasizing the importance of integrating societal challenges related to diversity, indigenous contributions, and ethics into EL. It underscores the necessity of embedding these themes within EL activities, aiming to cultivate a generation of engineers who are not only technically proficient but also socially conscious and ethically grounded. |
| Chapter 11: Final Pieces and Conclusion | This final chapter synthesizes various aspects of EL in engineering education, zooming at key topics like assessment, accreditation, and learning models. It emphasizes the need for continuous adaptation and innovation in EL practices, notably considering recent global encounters like the COVID-19 pandemic. The chapter also underlines the |

| | |
|---|---|
| | importance of faculty support and resource allocation in fostering EL, and it envisions a future where EL is more integrated, interdisciplinary, and aligned with societal needs and ethical standards. |

**Strengths and Highlights of the Book**

'Experiential Learning in Engineering Education' by Alan L. Steele offers a range of unique strengths from which readers stand to gain significantly. Below are the primary highlights, among others:

*Author's Background and Expertise*

The author's diverse experiences, encompassing roles as an administrator, curricular designer, educator, supervisor, and former engineering student, brings a wealth of experience and expertise to the table, not just in theory but also in practical application, ensuring that the content is enriched with personal anecdotes and insights, making the book relatable and consumable to readers from various backgrounds. For instance, on pages 218-219, the author shares his personal invaluable best practices for supervising student group projects, highlighting the importance of evaluation rubrics. This section not only demonstrates the author's commitment to effective teaching and assessment in EL but also provides educator readers with practical strategies for immediate application.

*Solid Theoretical Foundation*

Chapter 2 stands out as the book's core, thoroughly discussing and linking educational theories to EL. The author provides a robust theoretical foundation, incorporating established frameworks like Kolb's (1984) Cycle, situated learning (Lave & Wenger, 1991), and Schön's (1983) Reflective Practice, ensuring academic soundness and practical relevance. This positions Steele's work as a valuable guide and catalyst for innovation in engineering education. Particularly noteworthy is Subchapter 2.7, which introduces varied student learning approaches, highlighting the need for adaptable group work guidelines. Additionally, Chapter 2 serves as an invaluable asset for researchers in engineering education, showcasing exemplary synthesis of theories, and setting a high standard for academic rigor and comprehensive analysis.

*Evidence-Based Practical Strategies*

The book stands out for its provision of Evidence-Based Practical Strategies, masterfully integrating theory with actionable advice for implementing EL. Drawing upon a wealth of experience, extensive reference, and worldwide universities visits, the author offers a pragmatic approach. A standout section is Subchapter 4.3 on Flipped Classrooms, where the author highlights, "The previously mentioned paper by Furse and Ziegenfuss (2020), can be a good starting point for anyone wanting to move a class to a flipped approach. There are practical details and advice given, including move over to a flipped approach in stages. One example they suggest works around splitting a term into three parts and starting in the first term with active learning approaches in class. In the second term video examples could be provided and in the final third video lectures can be provided". This citation underscores a strategic method for transitioning from traditional to flipped classrooms, emphasizing a gradual shift to foster effective learning environments in an engineering context.

*Post Pandemic Insights*

According to Badiru (2020), the challenges posed by the COVID-19 pandemic have demanded fresh, innovative approaches and creative solutions in the field of engineering education. Steele responds to this urgent need in his book, weaving this critical theme throughout his narrative. Particularly in Chapter 3, "Laboratories", Steele examines the emerging opportunities post-pandemic, discussing a variety of laboratory formats including remote, virtual, recorded, and simulation-based labs. He meticulously evaluates their pros and cons, offering tangible deliveries for their integration into EL. Beyond this chapter, Steele consistently highlights the role of technology in adapting to the post-pandemic era, emphasizing the utilization of online video meeting and conferencing (Chapter 6 and 7), digital access to course materials (Chapter 4 & 5), and online file sharing facilities (Chapter 11).

*Comprehensive Coverage*

The book offers an extensive examination of EL in engineering education, covering a wide array of topics and incorporating diverse case studies from both engineering and non-engineering disciplines. This ensures its relevance and applicability across various contexts, making it a valuable resource for numerous stakeholders. Faculty members dealing with the resource demands of EL, course designers working to integrate EL principles, educators looking for practical implementation tips, researchers exploring theoretical foundations, and students aiming to understand their educational journey will all find this book beneficial. Industry professionals can also gain insights into the advantages of EL for workforce development. Chapter 10 stands out as it covers the societal aspects of engineering, challenging the typical technical perspective and offering valuable considerations for minority groups, indigenous communities, and ethical philosophers.

## Opportunities for Enhancement

While 'Experiential Learning in Engineering Education' by Alan L. Steele presents numerous strengths, there are areas that could benefit from improvement. The following sections outline key areas that could be improved upon:

*Inconsistent Depth Across Chapters*

While the book offers a rich overview of EL in engineering education, there is a noticeable disparity in the depth of coverage across different chapters. Some sections provide extensive, in-depth discussions, while others only skim the surface of the topic at hand. The author occasionally directs readers to external resources for further reading, which, while helpful, highlights the uneven distribution of content within the book itself. This inconsistency might leave readers seeking a more balanced and uniformly detailed exploration of EL. This contrast is noticeable when comparing the detailed exploration of laboratories in Chapter 3 to the succinct overview of PBL, CDIO, and PjBL, which are all swiftly addressed within Chapter 5, which might hinder a full appreciation of these approaches.

*Narrative Bias Towards Educators*

The book aims to cater to a diverse audience, but the narrative predominantly favours educators, focusing extensively on the implementation of EL and the challenges educators might face. While other stakeholders are mentioned, their needs and perspectives are not explored in as much detail. This bias could potentially limit the book's appeal and utility for a broader audience, such as students, industry professionals, and others who might be interested in EL from different viewpoints. Addressing these areas would not only enhance the book's comprehensiveness but also its applicability across various audiences.

*Insufficient Guidance on Student Reflection*

Reflective practice is highlighted as a crucial element in EL, and while the book acknowledges the challenges associated with encouraging students to reflect deeply, it falls short of providing concrete strategies, such as in the work of Veine et al. (2020), to address these issues. Additionally, it lacks the inclusion of student perspectives, which are crucial for a holistic understanding of the reflection process in EL. The scattered mentions of incorporating reflection into EL assessments and activities throughout the book do not coalesce into a clear, actionable framework for educators. Given the importance of reflection in EL, a more focused and detailed discussion on this topic would have strengthened the book.

*Potential Treat of Artificial Intelligence (AI)*

While the book explores the role of technology in EL, especially in light of the COVID-19 pandemic, it does not adequately address the implications of the Fourth Industrial Revolution (4IR) in Engineering Education, such as additive manufacturing, 3D printing and particularly the rising use of AI tools such as ChatGPT. There is a looming threat of students potentially misusing AI tools in EL assessments, especially in written reflections, which poses a significant challenge for educators (Rahman & Watanobe, 2023). The book could have seized the opportunity to discuss these issues and offer strategies to ensure assessment integrity and effectiveness, but this aspect remains unexplored.

*Technical Errors and Need for More Visuals*

The presence of technical errors, as described in Table 2, and the need for more visual content in the book, while minor, should not be overlooked. These issues could pose challenges, particularly for non-native English speakers (Brooks et al., 2021), and might detract from the overall learning experience. A more rigorous proofreading process for future editions is recommended to eliminate these errors. Additionally, incorporating a greater variety of visual aids such as infographics, diagrams, and charts could significantly enhance the book's accessibility and appeal, especially for visual learners. This is crucial in today's educational landscape, where learners are increasingly drawn to visual content (Guo et al, 2020). By addressing these aspects, the book could maintain its relevance and competitiveness amidst a plethora of multimedia educational resources.

**Table 2. Example of Technical Errors**

| Technical Error | Page |
|---|---|
| Original: "The also found that the impact was equally beneficial across genders."<br>Correction: "They also found that the impact was equally beneficial across genders." | 142 |
| Original: "This second set of objectives can can be seen to be including..."<br>Correction: "This second set of objectives can be seen to be including..." | 188 |

## Conclusion and Recommendations

In conclusion, "Experiential Learning in Engineering Education" by Alan L. Steele stands as a seminal guide, rich in insights for weaving EL into engineering education. Steele's extensive experience and robust theoretical foundation render this book invaluable, particularly for faculties, educators, and researchers.

The book shines in its broad coverage, practical strategies, and insights into the evolving post-pandemic educational landscape, underscoring the critical role of learning by doing and reflection. The author's intention to highlight EL's versatility is evident, as he states, "If you read through this book and reached this point, I expect that you realize that experiential learning goes beyond running the labs that have run for the past few decades and liaising with the university's co-op office for getting students into relevant work placements."

Nevertheless, the book could be enhanced by addressing the inconsistency in chapter depth and the narrative's educator-centric focus, alongside providing clearer guidance on student reflection. The emerging threat of artificial intelligence tools in assessments also necessitates attention.

Future editions would benefit from a more balanced exploration across chapters, inclusion of diverse stakeholder perspectives, concrete strategies for student reflection, and strategies to address the implications of AI in assessments. Addressing these areas, alongside eliminating technical errors and enriching visual content, would solidify the book's standing as a pivotal resource in shaping future engineering education and nurturing well-rounded engineers.

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# Addressing the Training Gap for Ammonia-Fuelled Propulsion Systems: A Literature Review and Proposal for a New Job Training Program

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**Abstract**
The maritime industry is increasingly turning to ammonia as a promising alternative marine fuel to achieve sustainable and environmentally friendly shipping practices. However, this transition presents operational challenges and safety concerns that necessitate specialized training for marine engineers. This literature review examines the existing research on ammonia's operational challenges and identifies a critical research gap - the lack of comprehensive training programs for marine engineers to handle ammonia-fuelled propulsion systems effectively. The review highlights the importance of theoretical knowledge and practical training in such programs to ensure safe and efficient operations. Additionally, the study analyzes current training initiatives provided by leading maritime education institutions, Det Norske Veritas (DNV) Energy Academy, Lloyd's Maritime Academy, and Maritime Training Academy, to derive insights for developing a new job training program on ammonia-fuelled propulsion ships. The proposed program encompasses theoretical lectures and practical hands-on experiences, empowering marine engineers to navigate ammonia as a fuel source proficiently. By addressing this research gap and providing specialized training, the maritime industry can facilitate a smooth transition to ammonia as a marine fuel, promoting reduced environmental impacts and enhanced operational efficiency in the shipping sector. This literature review and proposal aim to contribute to the ongoing efforts in achieving sustainable and responsible maritime practices in the context of ammonia as a promising alternative marine fuel.

**Keywords**: Ammonia propulsion, Marine engineering, Sustainable maritime practices, effective training initiatives, Environmental sustainability, Operational complexities.

## Introduction

Ammonia has emerged as a promising marine fuel, offering a potential solution for bridging the gap between short-term environmental objectives set by the International Maritime Organization (IMO) and the eventual complete replacement of carbon-rich fuels to ensure a sustainable future for shipping (Yadav & Jeong, 2022). The appeal of ammonia lies in its carbon-free nature, presenting an eco-friendly alternative when considered on an economic scale (Machaj et al., 2022). Particularly in the shipping industry, ammonia demonstrates advantages over hydrogen, another zero-carbon fuel, due to its ease of handling and storage (Gerlitz et al., 2022).

However, the adoption of ammonia as fuel raises concerns about reduced thermodynamic engine efficiency, leading to higher energy consumption compared to traditional diesel fuel (Rodríguez et al., 2022). Ammonia's potential energy is only about half that of MGO (Gerlitz et al., 2022). Additionally, the safety implications of using ammonia as fuel differ from those associated with conventional fuels, given its toxic, corrosive, and flammable properties (Duong et al., 2023). The transportation and onboard utilization of ammonia also pose risks of exposure (Wang et al., 2023). Nonetheless, the advantages of green ammonia, including its carbon-free nature, relatively high-volume energy density, and ease of storage and transportation, continue to garner favorable attention (Tornatore et al., 2022).

In 2015, the International Convention for the Safety of Life at Sea (SOLAS) was updated to allow for the use of low flashpoint fuels, with ships required to comply with the International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code). The IGF Code outlines regulations and functional requirements for the design, construction, operation, maintenance, bunkering process, and seafarer training related to ships utilizing low flashpoint fuels, emphasizing safe operation and navigation (Wang et al., 2023). However, specific design requirements for ammonia-fueled ships have not been addressed in the IGF Code (Yadav & Jeong, 2022), necessitating tailored amendments to accommodate the unique characteristics of ammonia as a marine fuel (Cheliotis et al., 2021).

This study critically examines existing overseas job training initiatives focused on ammonia-fueled propulsion ships and proposes specialized courses for marine engineers dedicated to mastering ammonia-fueled propulsion systems. The recommended courses strike a balance between theoretical knowledge and practical training, empowering marine engineers to enhance their expertise and understanding of ammonia-fueled propulsion ships. By addressing the training gap in handling ammonia as a marine fuel, this research aims to facilitate a smooth and safe transition to sustainable shipping practices, reducing environmental impacts in the maritime industry.

The objective of this literature review is to examine the training gap for marine engineers operating ammonia-fueled propulsion systems and propose a new comprehensive job training program to address this gap. To achieve this objective, this literature review will explore a wide range of academic research articles, industry reports, and case studies related to the use of ammonia as a marine fuel. The review will also delve into training and education programs currently in place, both in academic institutions and within the maritime industry, to ascertain the extent to which they adequately prepare engineers for the specific demands of ammonia propulsion systems.

This review is delimited in scope to the precise identification of training necessities and essential competencies necessary for marine engineers to proficiently and securely operate ammonia-fueled propulsion systems. In focusing on this specific aspect, the aim is to pinpoint the exact requirements and knowledge areas that are essential to ensure the safe and efficient operation of such advanced propulsion technology in the maritime sector. By honing in on these critical training needs and competencies, this review will contribute to the development of targeted and effective training programs, thereby addressing a key component of the broader transition toward more environmentally sustainable and technologically advanced marine propulsion systems.

## Overview of Ammonia-Fueled Propulsion Systems

Ammonia-fueled propulsion systems are gaining interest as a potential carbon-free fuel for transportation and energy production (Kobayashi et al., 2019; Ma et al., 2023; Machaj et al., 2022; Tornatore et al., 2022; Valera-Medina et al., 2021; Xu et al., 2022). Ammonia is a molecule that can be synthesized from renewable energy sources and has a high energy density, making it a promising alternative to fossil fuels (Valera-Medina et al., 2021). Here is an overview of ammonia-fueled propulsion systems:

Advantages of ammonia fuel: Ammonia is a carbon-free fuel that can be produced from renewable energy sources, making it a promising alternative to fossil fuels. It has a high energy density, which means it can store more energy per unit volume than other fuels like hydrogen. Ammonia is also easier to transport and store than hydrogen because it can be stored as a liquid at room temperature and atmospheric pressure (Kobayashi et al., 2019; Ma et al., 2023; Machaj et al., 2022; Tornatore et al., 2022; Valera-Medina et al., 2021; Xu et al., 2022).

Challenges of ammonia fuel: Ammonia has a low flame speed, which means it burns slowly and requires high boost pressure and compression ratio to compensate. It also has a high ignition temperature, which makes it difficult to ignite in internal combustion engines. Ammonia is also toxic and corrosive, which requires special handling and storage procedures (Kobayashi et al., 2019; Ma et al., 2023; Tornatore et al., 2022).

Ammonia-fueled engines: There are two types of ammonia-fueled engines: pure ammonia-fueled engines and ammonia-blended engines. Pure ammonia-fueled engines have been developed and tested, but they have limitations due to the challenges mentioned above. Ammonia-blended engines, which use a mixture of ammonia and other fuels like hydrogen or diesel, are more feasible and have been shown to reduce emissions (Ma et al., 2023; Xu et al., 2022).

Research and development: There is ongoing research and development on ammonia-fueled propulsion systems, including combustion technology, engine design, and fuel storage and handling. The goal is to overcome the challenges of ammonia fuel and make it a viable alternative to fossil fuels (Kobayashi et al., 2019; Ma et al., 2023; Tornatore et al., 2022).

In conclusion, ammonia-fueled propulsion systems have the potential to be a carbon-free alternative to fossil fuels. While there are challenges to overcome, ongoing research and development are making progress towards making ammonia fuel a viable option for transportation and energy production.

## Lack of Effective Training on Ammonia-Fuelled Propulsion

The growing interest in ammonia as a sustainable and environmentally friendly marine fuel has garnered significant attention in recent years. Several studies have shed light on the technical and safety challenges associated with ammonia-fuelled propulsion systems (Agocs et al., 2023; Wang et al., 2023). However, a critical research gap becomes evident when reviewing the literature - the lack of emphasis on effective training and preparedness of marine engineers to effectively handle and operate ammonia-fuelled propulsion systems.

According to a bibliometric review and research agenda, a significant number of maritime accidents are primarily caused by deficiencies in knowledge, often attributed to a lack of experience, and inadequate training, with human error playing a pivotal role (Dominguez-Péry et al., 2021). Inadequate effective training can directly lead to accidents, particularly when heavy machinery is operated on ships or within harbor settings, potentially resulting in cargo load collapses and risks to workers below (Inadequate Training Accidents - Maritime Injury Center, n.d.). Applying the HFACS framework for incident analysis reveals that insufficient supervision from shore-based management is a major contributor to casualties and incidents. This encompasses failures to ensure the deployment of qualified personnel aboard vessels and to guarantee proper training in Safety Management Systems, equipment, and systems (Batalden & Sydnes, 2014). Therefore, comprehensive and effective training for maritime industry workers is essential, not only equipping them with job-specific skills but also instilling a deep understanding of safety protocols and equipment use. This approach can significantly mitigate risks, enhance safety standards, and reduce accidents in these high-risk work environments (Inadequate Training Accidents - Maritime Injury Center, n.d.).

In their research, Karvounis et al., (2022) have pinpointed certain areas that require further investigation. One notable aspect is the exploration of digital representations and the application of machine learning techniques and tools. These advancements aim to facilitate the effective, secure, and environmentally conscious functioning of ship power plants that utilize alternative fuels. Embracing these technologies can lead to significant improvements in the maritime industry's transition towards sustainable and eco-friendly practices.

Shim et al., (2023) anticipate a transformation in propulsion power sources, with a shift towards carbon-neutral fuels in the near future. They emphasize the increasing prevalence of electric/hybrid propulsion systems capable of accommodating diverse power sources. To validate the effectiveness, reliability, and safety of these various carbon-neutral technologies in the maritime domain, there is a crucial need for comprehensive demonstrations and evaluations.

Ammonia, as discussed by Duong et al., (2023), presents unique challenges in terms of safe handling procedures, storage requirements, and risk assessment. These challenges underscore the need for specialized effective training programs dedicated to equipping marine engineers with the necessary knowledge and skills. Unfortunately, the existing literature falls short in providing comprehensive effective training programs tailored explicitly to address the operational challenges of ammonia-fuelled propulsion ships.

Closing this training gap assumes paramount importance in ensuring the successful integration of ammonia as a marine fuel. Well-trained marine engineers will play a pivotal role in minimizing operational risks and maximizing the environmental and economic benefits of ammonia utilization in the maritime industry (Yadav & Jeong, 2022). Competence-based training programs should focus on critical areas, including fuel system maintenance, monitoring, troubleshooting, and emergency response in ammonia-related incidents (Duong et al., 2023).

Through well-designed effective training courses, marine engineers will be equipped with the expertise and confidence required to handle ammonia-fuelled propulsion systems safely and efficiently. This aligns with Duong's (2023) call for enhanced training and preparedness to meet the demands of a technology-driven market and a complex regulatory landscape.

The research methodology adopted for this study involved a systematic review of the available literature. This encompassed an extensive exploration of existing training programs, the identification of barriers, and an in-depth examination of research pertaining to the use of ammonia as a fuel source. In total, 17 relevant studies were rigorously analyzed to gain valuable insights and evaluate ongoing initiatives. The review extended to a meticulous investigation of course structures, content, and assessment methods, with the resulting compilation of this information serving as a foundational resource for the development of the proposed module.

## Existing training programs related to handling, storing and operating ammonia.

Ammonia has emerged as a promising alternative marine fuel, offering carbon-free properties and potential for a sustainable shipping future. However, its safe handling, storing, and operational aspects pose challenges, necessitating comprehensive training programs for marine professionals. In this context, this article delves into the existing training initiatives provided by leading maritime education institutions, Det Norske Veritas (DNV) Energy Academy, Lloyd's Maritime Academy, and Maritime Training Academy, focusing on their specialized courses that equip learners with in-depth knowledge and expertise in safely managing ammonia as a marine fuel.

### DNV Energy Academy

The DNV Energy Academy stands at the forefront of empowering professionals in the rapidly evolving energy industry, offering specialized training programs designed to equip participants with essential knowledge and expertise. Specifically, their comprehensive course titled "Role of Ammonia in a Hydrogen Economy" delves into the critical aspects of ammonia's role as a hydrogen carrier and its potential to drive a greener future.

DNV Energy Academy offers comprehensive training sessions covering various aspects of ammonia as a hydrogen carrier, as outlined in Table 1 on their website (dnv.com). The training program is highly flexible and can be tailored to be conducted either onsite or online, comprising of two half-day blocks (4 hours) divided into four modules. The training curriculum encompasses the value chain, market analysis, economics, technological advancements, and safety considerations in operations. Upon review, it becomes evident that the course can be predominantly focused on theoretical aspects.

Overall, the "Role of Ammonia in a Hydrogen Economy" course offered by DNV Energy Academy enables professionals to stay ahead of the curve in the energy industry's ongoing transition. By providing specialized knowledge and training, DNV Energy Academy empowers individuals to play a pivotal role in driving sustainable and innovative solutions in the ammonia and hydrogen energy sectors.

**Table 1 'Role of ammonia in a hydrogen economy' course syllabus at DNV Energy Academy**

| Module | Topics and subtopics |
|---|---|
| 1 | Understanding the green ammonia value chain<br>- Production, transportation, storage and utilization<br>- Carbon free ammonia - value chain<br>- Possible hydrogen carriers - comparing different carriers<br>- Market players - drivers, barriers, challenges |
| 2 | Technology & cost<br>- Green power production<br>- Hydrogen production<br>- Ammonia production - ammonia synthesis<br>-Ammonia transmission / storage<br>- Ammonia decomposition<br>- Hydrogen distribution |
| 3 | Operational safety<br>- Ammonia properties<br>- Safe design and operation<br>- Toxic and highly corrosive<br>- Personal protective equipment<br>- Regulation and standards |
| 4 | End-use challenges<br>- Ammonia as fuel<br>- Hydrogen as fuel<br>- Challenges with the combustion of ammonia<br>- Ammonia as feedstock<br>- Developing new combustion concepts |

*Source: (Training course Role of ammonia in a hydrogen economy, n.d.)*

**Lloyd's Maritime Academy**

As a leading institution in maritime education, Lloyd's Maritime Academy is committed to providing learners with comprehensive and interactive programs that foster accelerated learning. Their "Certificate in Alternative Fuels" course as outlined in Table 2 is no exception, offering a structured and engaging learning experience to equip professionals with expertise in the field of alternative marine fuels.

With a focus on convenience and flexibility, the course is designed as a single module that can be completed within six months. Learners benefit from a diverse range of learning activities, including online instructional materials, interactive forums to connect with peers and facilitators, investigation of real-world case studies, and practical application of knowledge through ongoing project submissions.

The course delves deep into the realm of alternative marine fuels, addressing the complex and evolving regulations on emissions. As shipping companies face increased demands to improve processes and remain competitive, the use of alternative fuels emerges as a strategic technique to meet environmental standards, enhance efficiency, and reduce costs.

Throughout the program, participants take a close look at a variety of new fuel alternatives, including LPG, methanol, hydrogen, and ammonia. These alternatives not only align with current and future restrictions but also offer potential for sustainable and cost-effective maritime operations.

Lloyd's Maritime Academy continues to empower learners with a comprehensive and interactive learning journey, fostering the growth of professionals as leaders in sustainable shipping practices and driving the industry towards a greener and more efficient future.

**Table 2 'Certificate in Alternative Fuels' course syllabus at Lloyd's Maritime Academy**

| Module | Topics and subtopics |
|---|---|
| 1 | Introduction to Alternative Fuels<br>- Definitions, rationale, background<br>- Why are alternative fuels required?<br>- What are the various alternative fuels available?<br>- Fuel challenges in shipping<br>- Various stakeholders and their work<br>- Challenges |
| 2 | Regulations<br>- Air pollution from shipping and IMO<br>- IGC Code for LNG carriers – an overview<br>- IGF Code for other ships – an overview<br>- Greenhouse gas (GHG) emissions<br>- sulphur oxides (SOx), nitrogen oxides (NOx), particulate matter (PM) |
| 3 | Alternative Fuel Options<br>- Short summary of various alternative fuels<br>- Comparison between alternative fuels |

| | |
|---|---|
| | - Renewable sources<br>- LNG/ LPG/ methanol/ biofuels/ hydrogen/ ammonia/ nuclear<br>- Not just fuel – solar, wind, wave |
| 4 | LNG<br>- LNG as a marine fuel<br>- Technology involved in LNG containment systems<br>- Safety systems associated with LNG fuel<br>- Environmental impact of LNG as fuel<br>- Commercial aspects associated with using LNG as fuel<br>- Bunkering of LNG and latest news on LNG bunkering |
| 5 | LPG, Biofuels<br>- LPG as a marine fuel<br>- The various biofuels available – methanol, Fatty Acid Methyl Ester (FAME), Hydrogenation-derived renewable diesel (HDRD), Dimethyl Ether (DME), biomass-to-liquid (BTL), gas-to-liquid (GTL), Liquefied Bio Gas (LBG)<br>- Methanol as a marine fuel<br>- Technology associated with LPG fuel & methanol fuel<br>- Safety and the environmental impact of LPG & methanol<br>- Commercial aspects and bunkering of LPG & methanol |
| 6 | Hydrogen & Ammonia<br>- Use of hydrogen as a marine fuel<br>- Fuel cells, batteries<br>- Ammonia as a marine fuel, latest news<br>- Technology, safety, environmental impact, commercial aspects associated with hydrogen and ammonia |
| 7 | Nuclear & Renewable Energy<br>- Nuclear energy as a marine fuel<br>- Various renewable energy sources, e.g., solar PV, wind (sails, rotors, turbines etc.), waves<br>- Technology, safety, commercial aspects involved in the use of renewable sources |

*Source: (Certificate in Alternative Fuels | Lloyd's Maritime Academy, n.d.)*

### Maritime Training Academy

In the dynamic realm of the maritime industry, sustainable practices and alternative marine fuels have emerged as paramount concerns. The Maritime Training Academy, known for its commitment to excellence in maritime education, offers a specialized online course, "Certificate in Alternative Fuels," as it is in Table 3 tailored to equip professionals with profound knowledge in this critical domain. This comprehensive program delves deeper into the subject of alternative marine fuels, providing participants with a holistic understanding of the advantages, disadvantages, hazards, properties, evolution, and basic operational criteria of these innovative fuel sources.

Structured as a single module, the course allows participants the flexibility to complete it within six months, accommodating their busy schedules. The module itself is thoughtfully designed, incorporating engaging text, charts, and pictures, ensuring a rich and immersive learning experience. Moreover, the program includes ten multiple-choice questions, serving as a valuable assessment tool, with participants expected to achieve a minimum passing score of 70%.

For professionals seeking to stay ahead in the ever-evolving maritime landscape, the "Certificate in Alternative Fuels" course at Maritime Training Academy provides a transformative educational experience, empowering them to champion sustainable practices and foster a future of responsible marine fuel utilization.

**Table 3 'Certificate in Alternative Fuels' course syllabus at Maritime Training Academy**

| Module | Topics and subtopics |
|---|---|
| 1 | Liquid Natural Gas (LNG) |
| 2 | Hydrogen and Marine Systems |
| 3 | Methanol and Biomethane and Marine Systems |
| 4 | Biomethane (Biogas) |
| 5 | (Bio) Ethanol |
| 6 | Biodiesel |
| 7 | Ammonia |
| 8 | Battery-powered Marine Systems |
| 9 | Alternative Marine Fuels (Advantages & Disadvantages) – Summary |

*Source: (Alternative Marine Fuels - Maritime Training Academy, n.d.)*

The maritime industry is witnessing a growing demand for comprehensive training programs focused on handling, storing, and operating ammonia as a sustainable marine fuel. DNV, Lloyd's Maritime Academy, and Maritime Training Academy have each developed specialized courses, equipping professionals with in-depth knowledge and practical skills to ensure the safe and efficient utilization of ammonia. With a collective commitment to fostering a greener and more responsible maritime future, these esteemed institutions play a vital role in empowering learners with the expertise needed to navigate the complexities of alternative marine fuels, contributing to a more sustainable and environmentally conscious shipping industry.

### Critique of Existing Programs

While institutions like DNV Energy Academy, Lloyd's Maritime Academy, and Maritime Training Academy offer courses related to ammonia as a marine fuel, these programs fail to adequately address the identified training gap for marine engineers handling ammonia-fueled propulsion systems.

For instance, the course offered by DNV Energy Academy provides a strong theoretical foundation on the ammonia value chain, market analysis, and safety considerations. However, the heavy focus on lectures creates a knowledge-driven rather than competency-driven program. The course lacks sufficient practical exercises and simulations to instil skills in critical areas like fuel system maintenance, hands-on ammonia handling, and emergency response (Training course Role of ammonia in a hydrogen economy, n.d.).

Similarly, Lloyd's Maritime Academy's course covers regulatory compliance, properties of ammonia, and environmental impacts through online modules and case studies. But the program does not incorporate immersive simulations and field experience for trainees to develop proficiency in tasks like troubleshooting fuel systems, maintaining safe storage conditions, and managing incidents (Certificate in Alternative Fuels | Lloyd's Maritime Academy, n.d.).

While the Maritime Training Academy's course explores various alternative fuels, it dedicates only one module to ammonia. This narrow coverage is insufficient to provide comprehensive training across the range of competencies needed for ammonia-fueled propulsion system operations (Alternative Marine Fuels - Maritime Training Academy, n.d.).

In summary, current training initiatives provide a starting point but lack the depth and rigor required to address the identified gap. A truly competency-based program with intensified practical components is needed to produce marine engineers who are experts in handling ammonia safety, fuel system optimization, and emergency preparedness. The proposed job training program in this paper aims to fulfil this need.

### Development of a job-training course model on ammonia fuelled propulsion ship

A comparative document analysis was conducted to systematically review and evaluate the existing job training programs offered by DNV Energy Academy, Lloyd's Maritime Academy, and Maritime Training Academy. This allowed insights to be derived for developing the proposed job training course model.

The course syllabi and materials from each training program were obtained and analyzed using a structured framework. Key aspects that were compared included the topics covered, number of lecture and practical hours allocated, learning outcomes and assessment methods.

From DNV Energy Academy's 'Role of Ammonia in a Hydrogen Economy' course, theoretical modules on the ammonia value chain, technological aspects, and safety considerations informed the inclusion of similar content areas in the proposed model.

Lloyd's Maritime Academy's 'Certificate in Alternative Fuels' covered a wide range of fuel types and regulatory issues. This guided the decision to incorporate modules on fuel properties, handling protocols, and compliance with international standards.

Maritime Training Academy's focus on individual fuel technologies through dedicated modules aided the structuring of topics in the proposed model, seen in Table 1.

The practical components of each program were also evaluated based on activities, intended skills and assessment criteria. This supported the design of hands-on modules encompassing simulation exercises, system maintenance workshops and onboard experience.

By conducting a systematic comparison of existing training programs through document analysis, key elements were identified and synthesized to develop an integrated course model addressing identified gaps. This helps to ensure the proposed model provides a rigorous and tailored job training experience.

### Proposed New Job Training Programme.

As the maritime industry strives to transition towards greener and more sustainable practices, the use of ammonia as a marine fuel has emerged as a promising solution. Embracing this paradigm shift requires a skilled workforce equipped with the knowledge and proficiency to operate ammonia-fuelled propulsion ships safely and efficiently. In response to this demand, we present our proposed Job Training Programs for Operation of Ammonia-Fuelled Propulsion Ships. This comprehensive competence-based training model is designed to empower learners with the essential theoretical understanding and practical skills needed to navigate the complexities of ammonia as a fuel source. Through a structured curriculum comprising lecture and practical hours, learners will gain insights into the properties of ammonia, handling and safety protocols, regulatory compliance, ammonia fuel systems, and operational considerations. The program culminates with immersive practical experiences that reinforce learners' proficiency in ammonia handling, system maintenance, emergency response, and collaborative problem-solving. Join us on this transformative journey towards a greener maritime future, where ammonia becomes a catalyst for change in the propulsion of our vessels.

**Table 4. Proposed Training for Masters, Officers, Ratings and Other Personnel on Ships Subject to Ammonia as Marine Fuel**

| Subject Area | Hours | | Assessment Criteria: Knowledge (K); Understanding (U); Proficiency (P) |
|---|---|---|---|
| | Lecture | Practical | |
| <u>Theoretical section</u><br>1. Introduction to Ammonia as a Marine Fuel<br>1.1 Properties and characteristics of ammonia as a fuel<br>1.2 Advantages and challenges of using ammonia in marine propulsion<br>1.3 Environmental impact and emissions reduction potential of ammonia | 6 | - | K: Written examination on properties, advantages, and environmental impact of ammonia as a fuel.<br>U: Group discussion on the challenges and potential of using ammonia in marine propulsion.<br>P: not appliable (N/A) |
| 2. Ammonia Handling and Safety<br>2.1 Safe handling procedures and best practices<br>2.2 Storage requirements and safety measures for ammonia fuel<br>2.3 Risk assessment and mitigation strategies for ammonia operations | 9 | 6 | K: Quiz on safe handling procedures and storage requirements for ammonia.<br>U: Practical assessment of safe handling techniques through simulation exercises.<br>P: Simulation-based assessment of risk assessment and response actions in ammonia-related emergencies. |
| 3. Regulatory Compliance<br>3.1 International regulations and standards for ammonia-fuelled ships<br>3.2 Compliance with safety and environmental guidelines | 3 | - | K: Multiple-choice questions on international regulations for ammonia-fuelled ships.<br>U: Case study on compliance with safety and environmental guidelines.<br>P: N/A |
| 4. Ammonia Fuel Systems<br>4.1 Components and infrastructure of ammonia fuel systems<br>4.2 Onboard fuel processing and delivery mechanisms<br>4.3 Performance optimization and efficiency considerations | 6 | 6 | K: Written examination on ammonia fuel system components and performance optimization.<br>U: Practical assessment of onboard fuel processing and delivery mechanisms.<br>P: Hands-on evaluation of performance optimization and efficiency considerations. |
| <u>Operational Aspects:</u><br>5. Operational Considerations for Ammonia-Fuelled Propulsion<br>5.1 Operational best practices for ammonia-fuelled propulsion | 3 | 6 | K: Quiz on operational best practices for ammonia-fuelled propulsion.<br>U: Practical assessment of operational considerations through simulation exercises.<br>P: Onboard observation of learners applying theoretical knowledge to actual ship operations. |
| 6. Fuel System Monitoring and Troubleshooting<br>6.1 Monitoring and troubleshooting of ammonia fuel systems | 3 | 6 | K: Multiple-choice questions on fuel system monitoring and troubleshooting.<br>U: Practical assessment of monitoring and troubleshooting techniques.<br>P: Onboard evaluation of learners' ability to identify and resolve potential challenges. |
| <u>Practical Section:</u><br>7. Hands-on Ammonia Handling<br>7.1 Safe handling techniques through simulation exercises<br>7.2 Real-life scenarios to develop practical ammonia handling skills | - | 12 | K: N/A<br>U: Practical assessment of safe handling techniques and responses to real-life scenarios.<br>P: Hands-on evaluation of learners' practical ammonia handling skills. |
| 8. Ammonia Fuel System Maintenance | - | 12 | K: N/A |

| | | | |
|---|---|---|---|
| 8.1 Inspection, maintenance, and troubleshooting of ammonia fuel systems<br>8.2 Identification and resolution of potential challenges | | | U: Practical assessment of fuel system maintenance and troubleshooting.<br>P: Hands-on evaluation of learners' ability to identify and resolve potential challenges. |
| 9. Emergency Response Training<br>9.1 Simulation-based emergency response training for ammonia incidents<br>9.2 Prompt and effective response actions in ammonia-related emergencies | - | 12 | K: N/A<br>U: Simulation-based assessment of learners' emergency response skills.<br>P: Evaluation of prompt and effective response actions in ammonia-related emergencies. |
| 10. Onboard Ammonia Operation<br>10.1 Real-world experience in managing ammonia fuel system on board ships<br>10.2 Application of theoretical knowledge to actual ship operations | - | 12 | K: N/A<br>U: Onboard observation of learners applying theoretical knowledge practically.<br>P: Evaluation of learners' competence in managing ammonia fuel systems on board ships. |
| 11. Collaborative Projects<br>11.1 Design, implementation, and evaluation of ammonia fuel system solutions<br>11.2 Collaborative problem-solving and teamwork | - | 12 | K: N/A<br>U: Assessment of collaborative problem-solving and teamwork skills.<br>P: Evaluation of learners' ability to design, implement, and evaluate ammonia fuel system solutions collaboratively. |

***Note**: The assessment criteria for each module include knowledge-based assessments (written examinations, quizzes), understanding-based assessments (group discussions, case studies), and proficiency-based assessments (practical evaluations, onboard observations). The total practical hours for the entire training program are 84 hours, distributed across different modules for hands-on learning and real-world experience.*

The proposed Competence-Based Training Program on Ammonia-Fuelled Propulsion Ships is a comprehensive and structured curriculum designed to equip maritime professionals with the necessary knowledge, understanding, and proficiency to operate ammonia-fuelled ships safely and efficiently. Through a combination of theoretical lectures and practical hands-on training, learners will delve into the properties and characteristics of ammonia as a fuel, explore its advantages and challenges in marine propulsion, and understand its environmental impact and emissions reduction potential. Safety and regulatory compliance are emphasized through simulations and case studies, ensuring learners are adept at safe handling, risk assessment, and mitigation strategies. Moreover, learners will gain in-depth insights into ammonia fuel systems, performance optimization, and operational best practices. The practical section of the program offers immersive experiences in ammonia handling, fuel system maintenance, emergency response, and collaborative projects, fostering hands-on proficiency and teamwork. By undertaking this training, maritime professionals will be at the forefront of driving sustainable practices in the shipping industry, contributing to a cleaner and greener future for our oceans and the planet as a whole.

## Conclusion

The transition to ammonia as a marine fuel holds great promise for a sustainable shipping future, as it offers a carbon-free alternative with relatively easy handling and storage conditions. However, challenges in terms of reduced thermodynamic efficiency and safety concerns pose significant obstacles. To overcome these challenges, specialized and effective training for marine engineers is essential. The literature review highlighted the research gap in the existing literature, emphasizing the lack of focus on training and preparedness of marine engineers to handle ammonia-fuelled propulsion systems effectively.

The existing literature calls for comprehensive training programs tailored specifically to address the operational challenges of ammonia-fuelled propulsion ships. Such training programs should cover areas such as safe handling procedures, storage requirements, risk assessment, fuel system maintenance, monitoring, troubleshooting, and emergency response in ammonia-related incidents. The literature also emphasizes the importance of incorporating theoretical knowledge and practical training in these programs to ensure marine engineers are equipped with the necessary expertise and confidence.

The current training landscape offers specialized courses from leading maritime education institutions like DNV Energy Academy, Lloyd's Maritime Academy, and Maritime Training Academy. These courses cover aspects of ammonia as a marine fuel, its value chain, technological advancements, safety considerations, and end-use challenges. However, there is still room for further development of a comprehensive job-training course model that combines theoretical lectures and practical hands-on experiences.

The proposed job training program on ammonia-fuelled propulsion ships aims to fill this gap and address the demands of the maritime industry. The program's theoretical section encompasses essential topics related to ammonia as a marine fuel, while the practical section focuses on hands-on experiences in safe handling, fuel system maintenance, emergency response, and collaborative problem-solving. By undertaking this program, marine engineers will become proficient in operating ammonia-fuelled propulsion ships, contributing to a greener and more responsible maritime future

## Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used ChatGPT and QuillBot in order to improve the language and readability. After using these tools/services, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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# Implementing Book-end Division Approach using ClassPoint to Energize Electrical and Electronics Engineering Student Engagement

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**Abstract**

This study investigates the efficacy of using ClassPoint in improving student engagement during class and its impact on academic performance among electrical and electronics engineering students by using student engagement framework that established by technology-enhanced learning (TEL) environment microsystem. To achieve this objective, five instructors teaching various courses incorporated ClassPoint into their classes. Then, quantitative data on student engagement and academic performance were collected via surveys. The student's comments are extracted from university teaching evaluation survey (EPAT) for thematic analysis. The descriptive analysis revealed a significant increase in student engagement after ClassPoint was implemented. Furthermore, students appreciated the use of ClassPoint features such as slide-drawing, multiple choice questions, and word clouds during classes. Survey results also show students have greater attentiveness, active participation, and improved interactions with their peers and instructors. Likert scale responses indicate positive correlation between the use of ClassPoint and students' enhanced performance in class discussions, idea integration, increased interest in learning, and improved classroom dynamics. Moreover, thematic analysis shows the empowering of five element in TEL microsystem with ClassPoint increase the student engagement. This study highlights ClassPoint's effectiveness in creating an inclusive and interactive learning environment, thus, transforming teaching methods for electrical and electronics engineering students.

**Keywords**: ClassPoint, student engagement, classroom dynamics, learning environment, e-learning.

## Introduction

Student engagement in class is very important in ensuring that the delivery of lectures is well distributed. Some students may find it challenging to understand electrical and electronics engineering courses at times because, for example, they are unable to see how electricity flows with the naked eye. Hence, the motivation of this study is to enhance the learning experience of Electrical and Electronics Engineering in the classroom.

The student engagement framework by (Bond & Bedenlier, 2019) as shown in Figure 1, represents the relationship between student engagement and outcomes within a Technology-enhanced Learning (TEL) microsystem. Student engagement is influenced by a range of factors. Within TEL microsystem, the integration of technology empowers teachers, activities, the environment, and peers. Proficient utilization of technology in the learning environment and community fosters active student engagement, consequently yielding a spectrum of short- and long-term academic and social outcomes. The short-term outcome elevated higher-order thinking skills, heightened motivation, and improved interpersonal connections facilitated by peer-to-peer learning and collaboration. In the long term, these outcomes contribute to lifelong learning, enhanced personal development, and heightened participation in the broader educational community. Importantly, the commitment and energy invested by students circulate back into the TEL activities and learning environment, establishing a reciprocal dynamic.

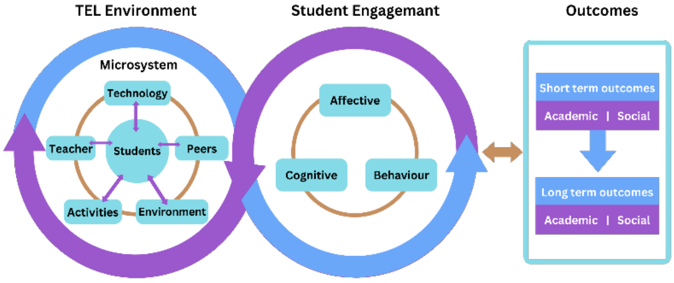


**Figure 1. Student engagement framework (Bond & Bedenlier, 2019)**

Traditional teaching methods often struggle to engage students in technical fields. Thus, the TEL environment in student engagement framework was used, and this study aims to address this challenge by making learning more interactive and participatory, especially in online teaching and learning setup. A study published in Ref. (Libre, 2021) found that there was a dearth of interaction during online learning between students and instructors or between students themselves. By creating interactive and engaging classrooms, students can actively participate, think critically, collaborate, and navigate digital platforms effectively. This approach ensures that students not only excel academically but also acquire the 21st-century skills as shown in Table 1, making their learning experiences more comprehensive and applicable. We employed the book-end approach as active learning approach in our class to increase the student engagement. Active learning involves students in the learning process through activities that encourage critical thinking, problem-solving, and engagement. Within the TEL microsystem, technology acts as a catalyst for active learning.

**Table 1. 21st century skills (Helmi et al., 2019)**

| Foundational Literacy | Competencies | Character Qualities |
|---|---|---|
| · Literacy<br>· Numeracy<br>· Scientific literacy<br>· ICT literacy<br>· Financial literacy<br>· Cultural and civic literacy | · Critical thinking /Problem solving<br>· Creativity<br>· Communication<br>· Collaboration | · Curiosity<br>· Initiative<br>· Persistence / grit<br>· Adaptability<br>· Leadership<br>· Social and cultural awareness |
| Lifelong learning | | |

Moreover, traditional lectures often struggle to captivate the attention of students, especially in engineering disciplines. The motivation arises from the aspiration to make learning an engaging and interactive experience, ensuring that students are not just passive recipients of information but active participants in their learning process. Student engagement, according to (Villiers & Amanda Werner, 2018) is the act of participating in activities and circumstances that are associated with high-quality learning. In student engagement framework; behaviour, emotion, and cognitive components all play a part in the meta-construct of student engagement during learning process (Hassona, 2020). Keeping students connected with the course and, their learning is a key element in successful student engagement (Dixson, 2015). Therefore, the ability of the instructor to design and create a welcoming class for student engagement is extremely important.

Moreover, integrating teaching with educational tools is crucial for enhancing student engagement in the classroom. Sometimes educators feel alone when giving lectures (N.E. Ghazali, 2021). In today's digital age, students are accustomed to interactive and dynamic learning environments. Utilizing educational tools not only captures their attention but also provides a more immersive and participative learning experience. These tools can transform abstract concepts into visual and interactive lessons, making the learning process more engaging and memorable. Concurrently, several studies have demonstrated that the use of instructional tools increases student engagement for the instructor (Nadeem, 2019)(Gon & Rawekar, 2017)(Alim et al., 2019). However, if you are teaching using Microsoft PowerPoint, all the educational tools must be used across multiple platforms.

In this study, we are using ClassPoint as an educational tool to support the book-end approach in our teaching and learning. ClassPoint is the all-in-one plug-in application in PowerPoint that allow multiple interactive activities for online and face-to-face class. Previously used multiple platforms for the interactive activities, it was so tedious to change from one platform to another platform during the lecture. Table 2 shows the comparison of engagement tools without ClassPoint versus those with ClassPoint. The ClassPoint eliminates the need to use multiple platforms for class engagement.

**Table 2. The comparison of engagement tools.**

| Activity | Engagement tools before using ClassPoint | Engagement tools after using ClassPoint |
|---|---|---|
| Opening | Mentimeter, Kahoot!, Quizizz, socrative | All-in-one teaching tool in PowerPoint<br>Multiple Choice, Word Cloud, Short Answer, Slide Drawing, Image Upload, Fill in the Blanks, Audio Record, Video Upload |
| Intermittent discussion | padlet, Jamboard | |
| Closure | Mentimeter, Kahoot!, Quizizz, Kahoot! | |

The features inside the ClassPoint already cover other engagement tools such as multiple choice, word cloud, short answer, slide drawing, image upload, fill-in-the-blanks, audio recording, and video upload. This choice is enough for the lecturer to handle the activities in their classes without use another platform.

**Procedure of Proposed Approach using Class Point**

*Class Design using Book-end Approach*

The book-end approach is the easiest instructional design of the active learning method that divides the classroom session into three parts; advanced organizing, intermittent discussion, and closure (Helmi et al., 2019). Advanced organizing is an introduction session to activate prior knowledge of the students. Intermittent discussion helps student to engage with the topic's learned, active learning activities where student can discuss among themselves is happened here. While the closure session used to summarize the class session and obtain students' understanding. Figure 2 shows the instructional design for a 50-minute class session based on the book-end division approach. In traditional teaching, most of the time is one-way communication happened, where only the lecturer giving lecture. By using this approach, the class session is divided into several session to allow student participation in class activities. The lecture session is chunk into several session to giving students time to digest all the new knowledge.

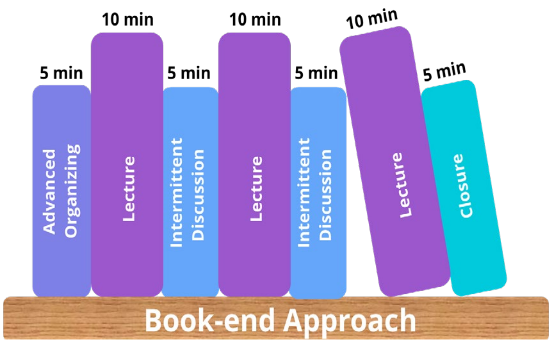


**Figure 2. Book-end division approach (Smith et al., 2009)**

The TEL microsystem is established by incorporating the book-end approach with ClassPoint as shown in Table 3. There are multiple active learning activities offered in ClassPoint, such as multiple-choice question, word cloud, short answer, slide drawing and image upload. Each class is unique. At the beginning of each class session, class code is given to the students. After joining the class, student can participate in all activities by using their handphone, computer or tablet. All the students' responses for each activity is received in real-time and lecturer can give immediate feedback that helps student boost their understanding during class session. This will reinforce student's engagement in the learning process and promoting continuous improvement.

*Student Engagement Survey Design*

To implement ClassPoint among electrical and electronics engineering students, we have identified several factors, which are: survey on the current method for student engagement and identify the courses that are possible to be used as the test data for our approach.

**Table 3. Active learning activities using ClassPoint.**

| Book-end Division session | ClassPoint Activity |
|---|---|
| Advanced Organizing | Word cloud, multiple-choice question, short answer |
| Intermittent discussion | Slide drawing, image upload, multiple-choice question |
| Closure | Word cloud, multiple-choice question, short answer |

To implement ClassPoint among electrical and electronics engineering students, we have identified several factors, which are: survey on the current method for student engagement and identify the courses that are possible to be used as the test data for our approach.

A survey was designed to measure the student engagement based on cognitive engagement, behaviour engagement and affective engagement. Cognitive engagement is defined as how much students are willing to work hard and understand difficult concepts and skills. On the other hand, affective engagement is about how students feel about their teachers, classmates, school, and if they feel like they belong there. Behavioral engagement refers to how students participate in class, behave, and take part (Maroco et al., 2016). In this study, we are focusing on cognitive engagement of the students during class session, outside classroom and the impact on assessment preparation.

We are studying how students engage in electrical and electronics engineering classes, by referring to established methodologies and question structures from the survey Utrecht Work Engagement Scale (UWES) design by (Schaufeli & Bakker, 2010). The UWES is develop to measure the work engagement for workers. This survey was adapted to measure student engagement in university settings (Bresó et al., 2011).

The survey instrument was designed to collect data on demographic characteristics, student engagement, perceptions of technology use in the classroom, and student impression of the class atmosphere. The demographic information collected included gender, race, and learning mode. It consisted of 39 questions, including multiple-choice and 5-point Likert scale.

There are two phases to verify the quality assurance of the question survey. The first phase is a pilot test. A pilot test was conducted with a small group of 5 participants to assess the clarity, relevance, and effectiveness of the survey questions. The pilot sample's results were not included in the analysis. After the correction of the pilot test, it went through the second phase of verification, which is a review from an expert in education field. An expert from UTM has been appointed, Dr. Mohd Fadzil Daud from Center for Engineering Education (CEE) to review the question survey. After that, the survey was administered online over a period of one week after end of the semester for two consecutive semesters. The data collected were organised, categorised, and tabulated by using excel file. Finally, the data were presented using descriptive analysis in the form of frequency, and percentage.

*University Teaching Evaluation System*

Moreover, for every semester, student will evaluate the lecturer twice by using teaching evaluation survey (EPAT) establish by the Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA). After each semester, all the feedbacks and comments from students is available for each lecturer. The feedbacks were used by the lecturer and faculty for continuous quality improvement. The related comments with class data were thematically analyze to complement the quantitative findings and provide a more holistic view of student engagement in the used framework.

## Results and Discussion

The study involved a sample size of 130 participants from Electrical and Electronics Engineering students. Participants in the survey were undergraduate degree and diploma students enrolled in courses stated in Table 4 at Faculty of Electrical and Electronics Engineering Technology (FTKEE), UMPSA. A majority of the sample belonged to degree students (74%) and 36% is from diploma level as tabulated in Table 4.

**Table 4. Electrical and electronics engineering courses participate in this study.**

| Course Code | Course Name | Level |
|---|---|---|
| BHE1213 | Digital Electronics | Degree<br>Number: 96<br>Percentage: 74% |
| BTE3222 | Digital Logic Design Laboratory | |
| BTE3243 | Electronics 2 | |
| BTE3223 | Digital Logic Design | |
| BTE4743 | Power Electronics | |
| BTS3133 | Signals and Networks | |
| BTS4253 | Computer Vision System | |
| BVE1124 | Technical Reporting | |
| DRE1213 | Computer Programming | Diploma<br>Number: 34<br>Percentage: 26% |
| DRE1223 | Digital Electronics | |
| DRE2213 | Programming and Data Structure | |

Table 5 shows there are 70% male and 30% female students' participant in this study. The demographic data reveals a diverse composition of the participants, with 75% identifying as Malay, 10% as Chinese, 10% as Indian, and 5% falling under the "Other" category. In terms of learning mode preferences, 62% participants are from face-to-face class, 31% attending a hybrid learning, combining in-person and online components, and 7% attending fully online learning mode.

**Table 5. Demographic characteristics of the students.**

| Profile | | Number | Percentage |
|---|---|---|---|
| Gender | Male | 91 | 70% |
| | Female | 39 | 30% |
| Race | Malay | 97 | 75% |
| | Chinese | 13 | 10% |
| | India | 13 | 10% |
| | Other | 7 | 5% |
| Learning mode | Face-to-face | 81 | 62% |
| | Hybrid | 40 | 31% |
| | Online | 9 | 7% |

The findings for this research will only concentrate on a few tools that the instructors actively utilized in the ClassPoint courses that were selected in the above section. Figure 3 shows the frequency distribution of tools in ClassPoint that have been actively applied during class session. The multiple-choice question type contributed the most to student involvement (35%), followed by the short answer (24%), and other categories (18% - image upload, 15% - word cloud, and 8% - slide drawing). It is very useful when a lecturer spontaneously wants to ask simple questions to the students regarding their lectures. Multiple choice is a simple tool that can be used by the lecturer and all the students can see the result in real time.

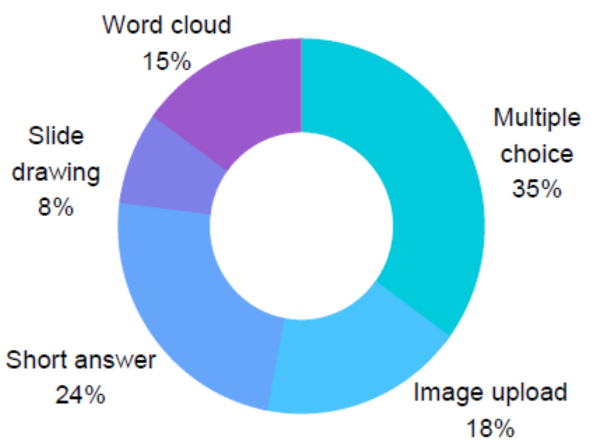


**Figure 3. Tools in ClassPoint that had been actively applied**

The Likert scale responses reveal enhanced performance in class discussions and idea integration as shown in Figure 4. ClassPoint positively contributes to student's participation in group discussions and asking questions. More than 100 students are clearly in agreement that they are actively participating in discussions in small groups and raising questions when they do not understand the instructor. The findings indicate that ClassPoint not only enhances individual engagement but also contributes to a vibrant and interactive classroom ecosystem, essential for holistic learning experiences.

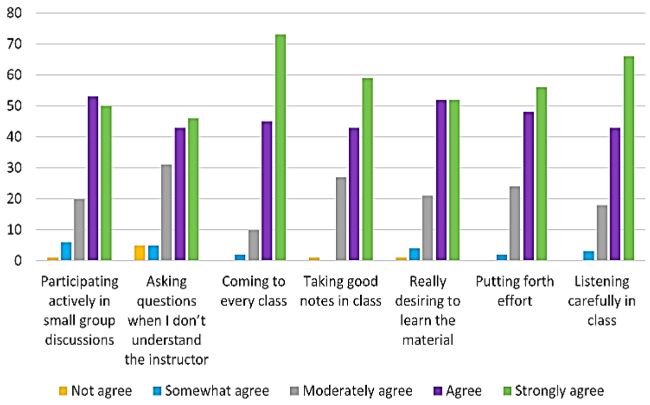


**Figure 4. Student engagement during class session**

In addition, the observed data shows that more than 102 students agree and strongly agree they are actively participating in cognitive engagement. Also, more than 78% of the students consistently attend, take good notes, desire to learn, exert effort, and listen actively to achieve higher academic performance, deeper comprehension, and a more enriching educational experience. These indicators collectively signify a high level of cognitive engagement, suggesting that students are not only physically present in class but actively participating, processing information, and demonstrating a genuine interest in learning.

Moreover, the results illustrated in Figure 5 indicate that cognitive engagement echoes students' independent learning outside the classroom. By using this approach, students not only actively participate during class but also demonstrate a commitment to ongoing learning, such as doing all homework and regularly thinking about the course. This extended engagement, beyond the confines of class meetings, reflects a proactive and self-directed approach to understanding the course material. From Figure 5, it can be observed that less than 10% of the students do not agree with the approach that helps them to engage with the course outside the classroom.

On the other hand, more than 68% of the students agree and strongly agree that they are engaged with the course outside of classroom sessions. Such students are likely to have a deeper appreciation for the course content.

The correlation between classroom engagement and outside-class activities further influences students' efforts and preparation in completing assessments for successful learning outcomes as shown in Figure 6. About 103 students are agree and strongly agree that they will seeking clarification through questions when faced with uncertainty about assessments, such as quizzes, tests, exams, projects, or assignments. A significant majority, more than 72% of the students recognize the correlation between actively participating in class and achieving good grades.

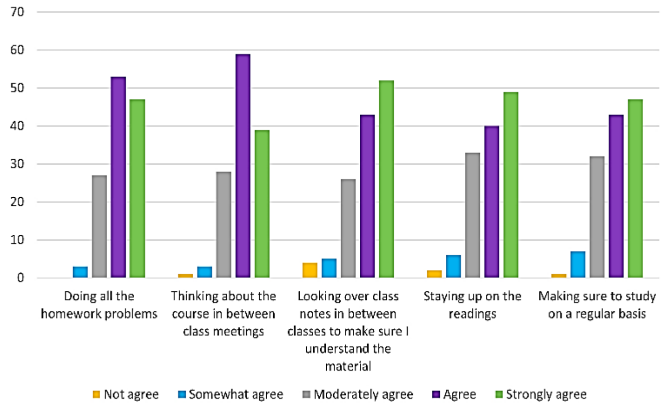


**Figure 5. Student effort to engage with the knowledge outside classroom session**

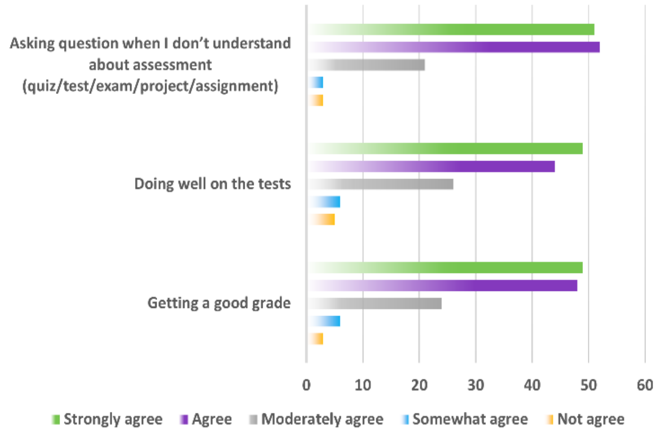


**Figure 6. Student effort to engage with the knowledge in getting good grade**

These actions underscore a proactive approach to learning, emphasizing both academic excellence and a commitment to understanding the material thoroughly. By prioritizing comprehension, diligent preparation, and seeking clarity, students lay the foundation for not only academic success but also for a deeper and more meaningful engagement with their educational journey.

Furthermore, the thematic analysis has been done by using related comments extracted from the UMPSA teaching evaluation survey (EPAT). The provided feedback from the EPAT reflects a positive engagement within the TEL environment, aligning with the Student Engagement Framework. The microsystem, enriched by the integration of technology using ClassPoint, plays a pivotal role in fostering an interactive and enjoyable learning experience. The data were thematically analyzed and the findings shows high correlation with the student engagement framework.

1. *Effective technology integration.*

   Feedback 1: "Interesting use of technology and very clear presentation."
   Feedback 2: "She knows how to use technology to make students understand each subject and very interesting lecturer."

The feedback emphasizes the lecturer's adept use of technology, indicating that the microsystem effectively integrates technology to capture student interest and enhance clarity in content delivery.

2. *Peer interaction and enjoyable environment.*

   Feedback 3: "I like the way the lecturer let the students approach each other using the class point because it's fun."
   Feedback 4: "Fun approach to learning. Explained everything in detail and made it easier for me to understand."
   Feedback 6: "Learning using ClassPoints is fun. Madam is an understanding person."

The use of ClassPoint is noted for facilitating peer interaction, injecting an element of fun into the learning process. This aligns with the framework's emphasis on environment and enjoyable learning experiences as one of the elements for increasing student engagement.

3. *Formative assessment as learning activities.*

   Feedback 5: "She always explains every problem we ask in more detail, and also madam conducts some pop quizzes during class which are really fun."

The incorporation of detailed explanations during lecture and formative assessments as intermittent discussion, such as pop quizzes, aligns with the framework's focus on academic challenge and supportive feedback, contributing to cognitive engaging and dynamic learning activities.

## Conclusion

Based on the use of ClassPoint to implement the book-end division approach in student engagement framework, the results of the study indicate a very positive response among students in the electrical and electronics engineering field. The use of ClassPoint in TEL microsystem has been shown to increase student cognitive engagement, which is a critical factor in student success. The book-end division approach, which involves providing students with a clear understanding of the learning objectives at the beginning of a lesson and then revisiting those objectives at the end of the lesson, has been shown to be an effective way to increase student engagement.

Overall, the findings of this study suggest that the use of ClassPoint and the book-end division approach in TEL microsystem can be an effective way to improve student engagement in the electrical and electronics engineering field. Future work research is needed to explore the potential benefits of this approach in other fields and to identify best practices for implementation.

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# Integrated Mass and Energy Balance Course Project using Spreadsheet for a Chemical Engineering Degree Program

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**Abstract**
In this innovation, team projects from two courses offered in different semesters are integrated. On top of that, students are trained to use a spreadsheet-based tool to solve the problem in the project. Those two courses are Mass Balance (SETK 1123) and Energy Balance (SETK 2133) offered to Chemical Engineering students in Universiti Teknologi Malaysia at their second and third semester. The main objective of the innovation is to scaffold the students' understanding of the problems given to them in the projects. At the end of the project, they should be able to clearly see the overall processes in a typical chemical industry, starting from raw materials to the targeted products, by-products, and wastes produced. In addition to that, the projects also foster digital skills by enhancing the students' skills to use the spreadsheet tools to solve Chemical Engineering problems. This is inline with their study as the students learnt about computer programming and spreadsheet tools in their first semester. From the students' reflections, it can be concluded that this innovation are able to increase the comprehension of the students on the two courses, increase the skills in using spreadsheet tools for solving problems and also inculcate critical thinking and problem solving skills.

**Keywords**: Chemical Engineering Education; Mass Balance; Energy Balance; Spreadsheet; Digital Skills

## Introduction

Mass Balance (SETK 1123) and Energy Balance (SETK 2133) form the core curriculum offered to first- and second-year students pursuing the Bachelor in Chemical Engineering with Honours program at the Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia (Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, 2022). Despite the simplicity of the calculations involved, the primary challenge arises from the complexity of problem descriptions presented to students, given their limited exposure to real industrial processes during the initial semesters. The problem-solving approach entails creating flow diagrams, labelling process streams, and solving unknown parameters through basic algebraic equations. Failure to grasp the problem can lead to inaccuracies in the flow diagram and incomplete stream labelling, hindering the student's ability to find a solution. Moreover, while industrial settings commonly employ process simulators for flow diagrams and calculations, introducing this tool early in the curriculum may overwhelm students.

Consequently, an alternative approach has been implemented: an integrated spreadsheet-based team project. This project aims to enhance students' comprehension of assigned problems, allowing them to visualize the entire process in a typical chemical industry, encompassing raw materials, end products, by-products, and generated waste. The project centres on the production rate of the main product as the starting point. Additionally, it serves as an introduction to computer tools in engineering calculations, aligning with students' prior exposure to spreadsheet and programming-based software in their first semester, as detailed in Sadikin et al., 2021. This initiative not only strengthens digital skills but also prepares students for future utilization of process simulators in their final year.

The innovation, grounded in constructivism learning theory (Dagar and Yadav, 2016), emphasizes critical thinking in problem solving with meaningful support at each step. The innovation is constructed based on the seven effective principles of constructivist pedagogy. The initial principle underscores the importance of not merely memorizing and reproducing knowledge but actively utilizing and transforming it. The second principle challenges the notion of separate phases for acquiring and using knowledge, emphasizing that knowledge is best learned through its application. The third principle highlights the practical application of knowledge, especially in problem-solving. In the context of the innovation, students are required to transform information from a problem description into a process

Mustaffa, A.A., Jamaluddin, J., Zubir, M.A. (2023), Integrated Mass and Energy Balance Course Project using Spreadsheet for a Chemical Engineering Degree Program, *ASEAN Journal of Engineering Education*, 7(2), 58-63.

flow diagram, utilizing a scaffold provided in the form of a summary mass and energy balance table, and subsequently solving for unknown information. The fourth principle focuses on stimulating students' thinking activities and enhancing their metacognitive and self-regulative skills in the study of content knowledge. This prompts students to strategize how to approach problem-solving. Working in a team, as encouraged by the fifth principle, places social interaction at the core of the learning process. The sixth principle integrates the assessment of learning within the learning process itself. Finally, the seventh principle emphasizes the active involvement of students in the assessment of their own learning.

Regarding the utilization of spreadsheets in problem-solving, Udugama et al. (2023) conducted a study examining the preferences and requirements for digital tools in chemical engineering education. Their research involved surveying department heads at IChemE institutions and members of IChemE committees specializing in digitalization. The findings revealed various factors that could impede the adoption of specific tools, including the complexity of mathematical/programming aspects, maintenance ease, and the high initial investment costs. Respondents expressed a preference for simpler digitalization platforms like Excel (a spreadsheet tool) and scripting languages over more advanced options such as Virtual or Augmented Reality, whenever feasible.

There exists a degree of resemblance in the integration of projects or problems between the Chemical Engineering program's Introduction to Engineering and Introduction to Programming courses at Universiti Teknologi Malaysia. In a study by Malim-Busu et al. (2022), they detailed their efforts to integrate these courses utilizing the Cooperative Problem Based Learning (CPBL) framework, with a specific emphasis on incorporating real-world scenarios into the projects. This approach aims to alleviate the learning time demands on students and enhance their engagement and interest in Engineering programs.

## Methodology

In this section, the methodology is detailed from two perspectives: (1) the development of innovation and (2) the implementation of innovation in learning. Concerning innovation development, the project problem description is delineated into multiple parts, as illustrated in Figure 1. The initial part covers the background of the chemical or product to be produced, offering an overview of the reasons for its production based on demand and application. The subsequent part provides a detailed description of the overall process, elucidating the functions of each individual process and their interconnections. Input data are also provided in this section. The third part furnishes detailed instructions to guide students in solving the problem, outlining the required outputs such as a concise report, a spreadsheet file containing a fully labelled process flow diagram, and detailed calculations. The final section includes a comprehensive summary table highlighting unknown values that students must determine, serving as a scaffold to ensure accurate interpretation of the problem description. An example of the project description can be found in Figure 2 and 3.

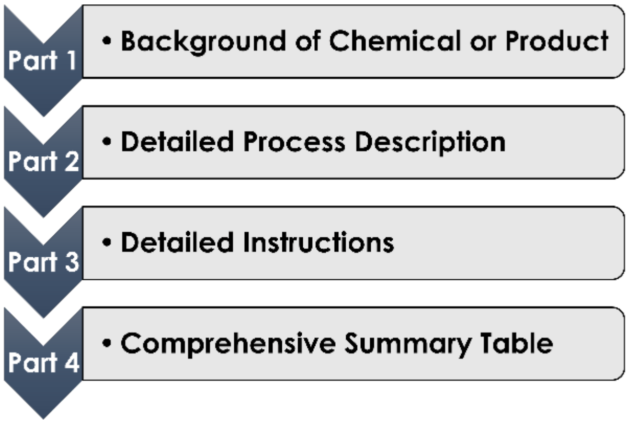


**Figure 1: Elements of Innovation**

**ENERGY BALANCE (SETK 2133)**
**SEMESTER 1 SESSION 2020/2021**

**TEAM MINI PROJECT**

Published Date: 3 Jan 2021 (in e-learning)
Submission Dateline: 23 Jan 2021 (through e-learning – Microsoft Excel files)

**Topic:** Production of 5000 MTA of Acetophenone from Oxidation of Ethylbenzene

**A) Background:**

Acetophenone ($C_8H_8O$) is an organic compound used as an ingredient in perfumes and as a chemical intermediate in the manufacture of pharmaceuticals, resins, flavouring agents, and a form of tear gas. It also has been used as a drug to induce sleep. The compound can be synthesized from benzene and acetyl chloride, but it is prepared commercially by the air oxidation of ethylbenzene. Pure acetophenone is a colourless liquid, with a melting point of 20.2 °C (68.4 °F) and a boiling point of 202.4 °C (396.3 °F). It is only slightly soluble in water but is freely soluble in ethanol (ethyl alcohol), diethyl ether, and chloroform. (Reference: Britannica.com)

**B) Process Description:**

In this process, acetophenone (ACP) is produced through the oxidation of ethylbenzene (EB) at 126 °C and 2 atm with water as the by product. In a year, this chemical plant operates 24 hours a day for 330 working days with a total production of 5,000 metric tonne of acetophenone. There are two side reactions, producing benzoic acid (BA), carbon dioxide ($CO_2$) and phenyl methyl carbinol (PMC) as the undesired side products. 15 % aqueous manganese (II) acetate (MA) is used as the catalyst for the reaction. Details of the reaction are as follows:

$$C_8H_{10}\,(l) + O_2\,(g) \rightarrow C_8H_8O\,(v) + H_2O\,(v)\ \text{(Main reaction)}$$

$$C_8H_{10}\,(l) + 0.5O_2\,(g) \rightarrow C_8H_9OH\,(v)\ \text{(Side reaction 1)}$$

$$C_8H_{10}\,(l) + 3O_2\,(g) \rightarrow C_7H_6O_2\,(v) + CO_2\,(g) + 2H_2O\,(v)\ \text{(Side reaction 2)}$$

Fresh ethylbenzene from a storage tank is added with a recycle stream containing ethylbenzene and some acetophenone and fed to the oxidation reactor. Before feeding it to the reactor, the mixed stream is heated to 126 °C and pumped to 2 atm. 30% excess compressed air is fed to the reactor through another stream. At the same time, 15% aqueous manganese acetate which act as a catalyst is fed to the oxidative reactor. The same amount of this catalyst is removed from the system through bottom stream of extraction column 1. However, the mass balance for this catalyst can be excluded from the calculation. The reactions are exothermic, thus, the reactor is equipped with cooling coils that use river water to maintain the reaction temperature at 126°C.

**Figure 2: Example Background and Process Description**

Another noteworthy aspect of the innovation is the use of spreadsheet software for constructing the process flow diagram, labelling streams, performing calculations, and creating a presentable file.

**Table 1:** Summary Mass Balance Table (with unknowns – U/N)

| Stream No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Stream | Input to Jet Mixer | Input to Jet Mixer | Input to Reactor | Input to Cooler | Input to Distillation Column | Distillation Bottom Stream | Distillation Top Stream |
| From | Storage | Storage | Jet Mixer | Reactor | Cooler | Distillation Column | Distillation Column |
| To | Jet Mixer | Jet Mixer | Reactor | Cooler | Distillation Column | Output | Output |
| Vapour Fraction | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 |
| Total Mass Flowrate (kg/hr) | U/N | U/N | U/N | U/N | U/N | U/N | U/N |
| Total Molar Flowrate (kmol/hr) | U/N | U/N | U/N | U/N | U/N | U/N | U/N |
| **Components Molar Flowrates (kmol/hr)** | | | | | | | |
| Acetylene | U/N | | U/N | U/N | U/N | U/N | U/N |
| Hydrogen Chloride | | U/N | U/N | U/N | U/N | U/N | U/N |
| Vinyl Chloride | | | | U/N | U/N | U/N | U/N |
| **Molar Compositions** | | | | | | | |
| Acetylene | 1.00 | | 0.50 | U/N | U/N | U/N | U/N |
| Hydrogen Chloride | | 1.00 | 0.50 | U/N | U/N | U/N | U/N |
| Vinyl Chloride | | | | U/N | U/N | U/N | U/N |
| Total Mole Fraction | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **Energy Data** | | | | | | | |
| Temp. (°C) | 25 | 25 | -80 | 200 | -20 | -30 | -10 |
| Pressure (atm) | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Total Enthalpy (kW) | U/N | U/N | U/N | U/N | U/N | U/N | U/N |

**Figure 3: Example Summary Mass and Energy Balance Table**

Regarding assessment, four criteria are considered: (1) clarity of the process flow diagram and completely labelled streams (3 marks), (2) interconnections of input values and other data in the diagram (2 marks), (3) a brief report on the steps taken to solve the problem (2 marks), and (4) final answers, including the filled summary table and other questions from the instructions (3 marks). This project constitutes 10% of the total course marks for each course. The rubrics are shown in Table 1.

**Table 1: Assessment Rubrics for Both Projects**

| Criteria | Description | Marks |
|---|---|---|
| Document: Spreadsheet | | |
| Process Flow Diagram (PFD) | • Contains all the block that represent the equipment.<br>• Contains the overall stream summary and its value.<br>• Contains the stream summary for each equipment and its value.<br>• Labels at each stream are complete.<br>• The PFD are drawn neatly. | 3 |
| Data Interconnection | • The stream summary connected with mass and energy balance for each equipment.<br>• Calculations between different equipment are interconnected<br>• All calculations are made using the spreadsheets' function | 2 |
| Document: Word/PDF | | |
| Report | • Contains the steps used to develop the spreadsheet file.<br>• Prepared in maximum of 2 pages | 2 |
| Answer | • The answers are accurate (unknowns and based on questions given) | 3 |
| **Total Marks** | | **10** |

Moving on to the implementation of the innovation in learning, as depicted in Figure 2, both courses cover mass and energy balance calculations for non-reactive systems, reactive systems, and multiphase systems (Mustaffa, 2022 and 2023). However, this integrated project specifically addresses the first two topics. The project is introduced after covering these topics in classes, around week ten of the syllabus. Students, organized into cooperative teams early in the semester, receive the project descriptions through the e-learning portal (elearning.utm.my). They are given one day to review the problem description before attending a briefing session conducted by the project coordinator. The coordinator, assigned for the entire student batch, clarifies any questions during the briefing. Students typically have three weeks to complete the project, with questions only allowed in the first two weeks to discourage last-minute work.

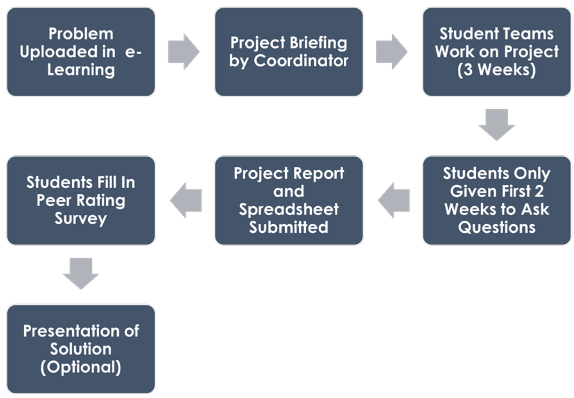


**Figure 2: Implementation of Innovation**

Additionally, at the project's conclusion, students complete a peer rating survey to evaluate their teammates' performance. While team working skills are not directly assessed, the peer rating helps prevent free riders, and each team member's marks are influenced by their efforts, following the auto-rating factor method (Brown, 1995). The peer rating survey consists of six criteria which include contribution and attitude, cooperation, focus and commitment, team role fulfilment, communication, and work accuracy where each member evaluates their team members including themselves. Table 2 show the peer rating tool where the rating of member is averaged to obtain the individual average (IA). IA of each member is then averaged to obtain the overall average (OA). The auto-rating factor (AF) is obtained by dividing IA with OA. The maximum value is capped at 1.05 while the lower limit is not set. The AF obtained will be multiplied with the project mark.

This process is applied to both courses, with the Energy Balance course involving additional tasks related to calculating enthalpies and energy requirements for some process equipment. Importantly, previous Mass Balance course calculations may not be applicable in the Energy Balance course if team compositions differ. Teams must reevaluate and adjust their process flow diagrams and calculations unless the previous work is identical, allowing them to select one teammate's work and continue.

**Table 2: Peer Rating Tool**

| | | Ratings | | | | Average |
|---|---|---|---|---|---|---|
| Criteria 1 | Student 1 | 1.0 | 3.0 | 3.0 | 2.0 | 2.3 |
| | Student 2 | 2.0 | 3.0 | 3.0 | 2.0 | 2.5 |
| | Student 3 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| | Student 4 | 4.0 | 3.0 | 3.0 | 4.0 | 3.5 |
| Criteria 2 | Student 1 | 2.0 | 3.0 | 3.0 | 4.0 | 3.0 |
| | Student 2 | 3.0 | 4.0 | 4.0 | 3.0 | 3.5 |
| | Student 3 | 4.0 | 5.0 | 5.0 | 4.0 | 4.5 |
| | Student 4 | 5.0 | 4.0 | 4.0 | 3.0 | 4.0 |
| Criteria 3 | Student 1 | 5.0 | 4.0 | 4.0 | 5.0 | 4.5 |
| | Student 2 | 4.0 | 5.0 | 5.0 | 5.0 | 4.8 |
| | Student 3 | 3.0 | 5.0 | 5.0 | 4.0 | 4.3 |
| | Student 4 | 2.0 | 4.0 | 4.0 | 4.0 | 3.5 |
| Criteria 4 | Student 1 | 2.0 | 3.0 | 3.0 | 3.0 | 2.8 |
| | Student 2 | 3.0 | 3.0 | 3.0 | 4.0 | 3.3 |
| | Student 3 | 3.0 | 4.0 | 4.0 | 3.0 | 3.5 |
| | Student 4 | 4.0 | 3.0 | 3.0 | 4.0 | 3.5 |
| Criteria 5 | Student 1 | 4.0 | 3.0 | 3.0 | 4.0 | 3.5 |
| | Student 2 | 4.0 | 4.0 | 4.0 | 5.0 | 4.3 |
| | Student 3 | 4.0 | 5.0 | 5.0 | 4.0 | 4.5 |
| | Student 4 | 4.0 | 4.0 | 4.0 | 3.0 | 3.8 |
| Criteria 6 | Student 1 | 5.0 | 5.0 | 5.0 | 4.0 | 4.8 |
| | Student 2 | 5.0 | 5.0 | 5.0 | 3.0 | 4.5 |
| | Student 3 | 5.0 | 5.0 | 5.0 | 4.0 | 4.8 |
| | Student 4 | 5.0 | 5.0 | 5.0 | 4.0 | 4.8 |
| | Member | IA | OA | AF | | |
| | Student 1 | 3.46 | 3.79 | **0.91** | | |
| | Student 2 | 3.79 | 3.79 | **1.00** | | |
| | Student 3 | 4.08 | 3.79 | **1.08** | | |
| | Student 4 | 3.83 | 3.79 | **1.01** | | |

## Results and Discussion

The example output of the process flow diagram (PFD) and calculations in the spreadsheet tools is highlighted in Figure 3. The diagram is drawn neatly with labels in each stream containing the stream condition and composition. The data between different streams must be interconnected also between individual equipment in different sheets. It means that, there is one sheet for the overall diagram and separate sheets for individual equipment. This is clearly highlighted in the instructions given to the students in the project description and during the briefing.

The main findings from the implementation of this innovation are extracted from the learning reflection prepared by the students. Some representative reflections are presented in Table 3. Some students (see reflection 9) appreciate the integration made between the two courses where it is easier for them as they are already familiar with the problem. Plus, they can also relate the previous lesson with the new lesson that they learnt. The next obvious findings would be the digital skills obtained (see reflections 1, 2, 4, 5, 6, 7).

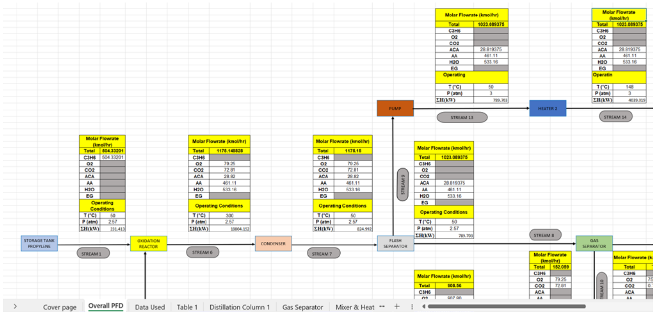

**Figure 3: Example of PFD and Calculations in a Spreadsheet Tool.**

Even though digital skills are not part of the learning outcomes, it is an important skill for a chemical engineer and need to be embedded in a least one course per semester. In addition, from the project, the students can develop critical thinking and problem-solving skills (refer reflections 3, 5, 8) as the project itself aim to promote higher order thinking skills. Finally, since the comprehensive project are conducted in cooperative teams, indirectly team working skills are also enhanced (see reflection 7). The implementation of the peer rating really helps to strengthen this.

**Table 3: Feedback from Students on the Integrated Project**

| No. | Student Feedback |
|---|---|
| 1 | *"For mini project, we were instructed to do all the calculations in Microsoft Excel which **led me to learn how to use MMULT and MINVERSE functions for simultaneous equations** through YouTube which was quite contemporary to me. I enjoyed throughout the whole process with my teammates. We divided the tasks, and everything went smoothly."* |
| 2 | *"I learned to **use Excel while doing the mini project** as I think it's going to be beneficial by learning it earlier."* |
| 3 | *"On next week, we obtained mini project assignment which we assigned to use Microsoft Excel to draw process flow diagram of overall and each equipment and show calculation using it. **We exposed to difficult and higher thinking question**, but we succeed to overcome and finish this project. We learned a lot from this mini project specially to use Microsoft Excel."* |
| 4 | *"The mini project was also an eye-opening experience for me. The length of the problem* |

| | |
|---|---|
| | *statements was tremendous, however after breaking it into PFD it was readable and solvable through the efforts of our team.* ***I love it when we were asked to solve the problem by using Excel as this really reflect on how it should be done on real work environment****."* |
| 5 | "During completing this mini project, **I learnt more effective skills using Microsoft Excel and I can understand more on the chapter on multiple process units.**" |
| 6 | *"While for the mini project, the first impression on so many process units are very difficult but with the discussion with other members it becomes easier when each part of it is being solved. Through his project, I found that* ***Microsoft Excel plays an important role in industry*** *because by changing one of the values the following variable will also change which I think is* ***very convenient for later if I want to create a system****."* |
| 7 | *"By doing the mini project given, I can* ***develop the soft skill which is teamwork*** *as this mini project is group work. Without any help or other opinions, it is difficult to finish this project alone. We need to do all the calculations in Excel so that I* ***can enhance my knowledge about using Microsoft Excel****. Besides, we can use the knowledge that we learned for the few first topics to solve the solution."* |
| 8 | *"From this mini project, I learnt that we will* ***not always find a perfect solution as stated in the textbooks to solve the real world's problem****. Therefore,* ***ability of critical thinking is significant*** *for us to find out an alternative solution to solve the problems."* |
| 9 | *"The mini project was* ***similar to the one conducted in our mass balance class****. But this time, we had to include energy balance calculations in our solution. It was pretty* ***easy as we already had experience doing it during our mass balance class last semester****. My team and I did a really good job, and I are proud of the teamwork, fellowship, and friendship that we have managed to attain".* |

Throughout the implementation of the integrated project for around 8 years, three lecturers have administered the project. Table 4 presented the reflection of the lecturers on the integrated project.

**Table 4: Lecturers' Reflection**

| Lecturer | Reflection |
|---|---|
| 1 | *"I have been administering this integrated project for more than 5 years. Along the years, I have seen that the same method was used during the* ***final year plant design project*** *during the preliminary manual mass and energy balance part. The transition from merely pen and paper is enormous as students now are able to utilize digital tools to solve problems. My future plan is to copyright all the project descriptions that we have developed so that other institutions can also use the innovation."* |
| 2 | *"In the integrated project of mass and energy balance where students used a spreadsheet-based tool for calculations in chemical engineering, the tool effectively* ***simplified complex calculations****. This helped students understand key concepts and prepared them for more challenging courses like plant design project. Some students demonstrated excellent collaboration, similar to a real engineering environment, while others faced challenges in task distribution, indicating a need for more structured teamwork guidance. Overall, this project was a great way for students to learn and for me to see what we can do better next time."* |
| 3 | *"Integrating the mass and energy balance project allows students to understand the relationship between these two courses. These two courses are very important for chemical engineering students since they serve as a foundation for the upcoming senior year courses. In the future, the project can be further improved by integrating* ***elements of sustainability****."* |

From the reflections, we can see that there are many benefits of the innovation but more importantly what more that can be further improved.

## Conclusion

This spreadsheet-based project introduces a novel approach to mass and energy balance calculations, offering students the opportunity to synthesize content from two foundational courses and gain insight into processes typical in chemical industries. The project, spanning Mass Balance (SETK 1123) and Energy Balance (SETK 2133) courses, integrates knowledge sequentially, allowing students to apply prior understanding to new concepts. The innovation lies in the coordination between classes and the shift from manual calculations to spreadsheet tools like Microsoft Excel, enhancing digital skills crucial in the 4th industrial revolution. The creative aspect involves students using their cumulative knowledge and given information to construct process flow diagrams and perform comprehensive calculations, fostering higher-order thinking skills. Ultimately, this project equips students with practical skills essential for designing chemical plants in their final year.

## Acknowledgement

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# Emotions and Course Learning Outcomes in Geology Fieldwork among Petroleum Engineering Undergraduates

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**Abstract**
Quantitative approaches have been conducted on petroleum engineering students' emotions before and after fieldwork experiences affected course learning outcomes. The study found positive-feelings experiences increased from pre-field to post-field such as confidence about what is expected and gladness that they are going to the field which is learning outside of the classroom. However, there is a small number of students worried before the fieldwork is conducted that they need to adapt to a new environment. Positive feeling experiences emotions shows a significant relationship with learning outcomes as compared to negative feelings; it has no significant value. Overall, the importance of these findings depends on improving awareness of the components that influence students' learning experiences and highlighting the importance of considering the complete spectrum of emotional and learning-related aspects into consideration when creating a fieldwork learning program.

**Keywords**: geology fieldwork, petroleum engineering undergraduate, emotions, course learning outcomes.

## 1. Introduction

In recent education, a variety of skills are given preference, including academic, technical skills, competently communicational, social in nature and community, and global capabilities. It is crucial to develop student's competencies and spark their innovative thinking. In addition, it may grow as a result of pedagogical innovation, training, and rapid construction processes. Shifting from one place to another from eternity to reality is crucial for the new teaching methods to be successful. Several factors, including student emotions, feelings, and attitudes, may influence the learning outcomes (Huang et al., 2015). Therefore, constructing practical fieldwork knowledge and abilities is seen as one of the core goals of education across several fields, particularly in the geoscience and petroleum engineering disciplines.

Geology fieldwork is an essential component of petroleum engineering undergraduates because it provides the necessary foundation for understanding geological formations (Cannon, 2019). It has been recognized as an efficient method of education in the geoscience fields. Meanwhile, petroleum engineering involves the exploration, drilling, and production of oil and gas from reservoirs, which requires a detailed understanding of the geology of the area. During geology fieldwork, geologists collect data on the rock formations, sedimentary layers, and structural features of the earth's crust. They use various techniques, including mapping, sampling, and analyzing lithology, rock, and sediment samples to identify potential hydrocarbon reservoirs. This data is then used by petroleum engineers to design drilling and production plans that maximize the recovery of oil and gas from these reservoirs (Basu, 2022).

Petroleum engineers rely on geologists to provide accurate information about the area's geology, including the depth and thickness of sedimentary layers, the type of rock formations, and the presence of faults or fractures that can affect the flow of hydrocarbons. They use this information to design drilling plans that take into account the unique characteristics of each reservoir, such as the permeability and porosity of the rock formations, to ensure that the maximum amount of oil and gas can be extracted. Thus, geology fieldwork provides the necessary foundation for petroleum engineering students by providing detailed information about the geology of an area, which is essential for designing efficient and effective drilling and production plans (Gluyas & Swarbrick, 2021).

Generally, undergraduate petroleum engineering students participating in geology fieldwork can provide valuable hands-on experience and practical knowledge that can help their future careers. Fieldwork can also help develop important skills such as critical thinking, problem-solving, and teamwork (Raath & Golightly, 2017). It can teach how to work effectively in a group, communicate with other team members, and coordinate efforts to achieve a common goal. The student may have the chance to interact with geologists and other petroleum engineers working in the field, which can help build relationships and learn about potential career paths. Furthermore, participating in geology fieldwork as an undergraduate petroleum engineering student can provide valuable knowledge, practical experience, and important skills that can help them succeed in their future career.

However, there are several limited factors in the student learning process in fieldwork mode such as prior knowledge and experience pre- and post-execution of fieldwork, emotions, and lastly impact on learning outcomes. Students' experiences of the learning environment affect the methods that they use, which can in turn affect learning outcomes. By encouraging the desire to study for own purpose and improving cognitive engagement, motivation serves as an intrinsic reason for learning. Extrinsic motivation, on the other hand, encourages the urge to complete tasks to obtain something unrelated to the action itself. Therefore, this study attempted to evaluate learning geology fieldwork influence factors that support student learning, especially for undergraduate petroleum engineering students.

*Fieldwork Programme Outcomes*

Outcome-based education (OBE) is an approach to education that focuses on defining and measuring the outcomes that students are expected to achieve by the end of a particular course. The outcomes are based on the knowledge, skills, and attitudes that students should have upon graduation. In the field of engineering, the Engineering Accreditation Council (EAC) is responsible for accrediting engineering programs in Malaysia. The EAC uses an outcome-based approach to evaluate the quality of engineering programs teaching and learning (T&L) and to ensure that they meet national and international standards. Hence, by adopting an outcome-based approach, engineering programs can ensure that their curriculum is aligned with the needs of industry and society and that their graduates are well-prepared for the workforce.

The OBE has been implemented in this case study university since 2010. The implementation of OBE was a response to the Ministry of Higher Education's (MOHE) call to enhance the quality of higher education in Malaysia by aligning the curriculum with the needs of the industry and society. These learning outcomes were aligned with the Malaysian Qualifications Framework (MQF) and the EAC requirements. The petroleum engineering undergraduate program in this case study university was established in 1983. Over the years, the program has undergone several changes and improvements to keep up with the evolving needs of the industry and advances in technology. In 2020, the program was revised to align with the OBE framework released by EAC, which emphasized the importance of defining clear and measurable learning outcomes for students.

The EAC has defined twelve Programme Outcomes (POs) that align with the MQF and the Washington Accord, which is an international agreement that recognizes the equivalence of engineering qualifications among signatory countries (Engineering Programme Accreditation Manual, 2020). The PO included Engineering Knowledge (PO1), Problem Analysis (PO2), Design or Development of Solutions (PO3), Investigation (PO4), Modern Tool Usage (PO5), The Engineering and Society (PO6), Environment and Society (PO7), Ethics (PO8), Individual and Teamwork (PO9), Communication (PO10), Project Management and Finance (PO11) and Lifelong Learning (PO12). There are a variety of assessment methods that are aligned with the POs and designed to measure students' attainment of the POs. These assessment methods may include written examinations, assignments, laboratory work, projects, fieldwork, and industrial training. Through a high level of stakeholder participation, the course and program-level assessment of POs for continuous quality improvement (CQI) will be carried out.

The faculty has decided that the geology fieldwork subject will be taken during year three in semester one. The total student learning time (SLT) for geology fieldwork is 41 hours and depicted as one hour credit with four-course outcomes (CO) in the petroleum engineering course. The university has been setting more than 65% of COs as Key Performance Indicator (KPI) achievement. Table 1 shows PO and CO mapping in geology fieldwork subjects. Additionally, the faculty decided in OBE and taxonomies level for fieldwork are C1 (Knowledge), C2 (Comprehension) and C3 (Application). The T&L in fieldwork subjects are student-centered and cooperative learning with implemented outdoor class activities and problem-based learning. The learning expected to meet several objectives which are an ability to practice competent field skills; construct a geological map referred to field-based data and ability to demonstrate professional manners, systematically, and work as a team.

**Table 1. PO and CO with bloom taxonomy of geology fieldwork**

| CO | Description | Taxonomy | PO |
|---|---|---|---|
| CO1 | Demonstrate rock units and geologic structures such as beds, folds, faults, and joints. | C1 | PO1 |
| CO2 | Illustrate the stratigraphy and geological history of Peninsular Malaysia and the distribution of different kinds of rocks in Peninsular Malaysia or North and Central Sarawak. | C2 | |
| CO3 | Carry out compass directions or bearing, the strike, and dip of bedding or joint planes, and construct simple geological mapping using the compass-step method. | C2 | PO2 |
| CO4 | Use resources and technology to communicate and demonstrate knowledge and experience acquired from the fieldwork. | C3 | |

The evaluation of this fieldwork subject is formative assessments with rubrics which are Field Notes (20%), Geological Interpretation (20%), Teamwork (10%), Peer Evaluation (10%), and Final Report (40%). The fieldwork timing within one week before a new semester starts students and staff must share living and social areas during fieldwork due to nearby accommodations, where all student and technical staff have few and simplistic facilities.

*Emotions and Learning Outcomes*

Learning and emotions have a more sophisticated interaction. Positive emotions have a less predictable impact on learning, despite very consistent findings showing that elevated negative emotions, including anxiety, usually impede learning by creating an unnecessary cognitive load (Fraser et al., 2012). In addition, based on previous studies, positive emotions have been linked to increased motivation and improved problem-solving in learning (Um et al., 2012). However, other studies have shown a reverse impact, showing that learning and positive feelings have a negative relationship (Oaksford et al., 1996). It is unclear under what circumstances positive feelings promote or inhibit learning, nevertheless, it has been proposed that since all emotions provide additional cognitive stress, the overall impact of positive emotions may rely on how they react to additional forms of cognitive load (Fraser et al., 2012).

## 2. Methodology

The respondent selected for this study is 60 undergraduate students who have registered geology fieldwork subject in semester 1 session 2022/2023 and they are also divided into small groups. This annual geological fieldwork is located in and around the East Coast of Malaysia Peninsular which observes several outcrops along road cuts, beaches, quarries, and limestone caves. Three main types of rock can be seen during fieldwork and consist of igneous, sedimentary, and metamorphic rocks. Moreover, the geological features related to geomorphologies, mineralization, fossils, structures, and geological engineering construction input were observed.

The measurement instrument conducted in this study is a self-administered structural questionnaire and it consists of two sections. The first section is for demography of respondents that only considers genders and cumulative grade point average (CGPA). The study used pre- and post-experienced fieldwork observations modeled by Stokes and Boyle (2009). This second section to measure positive or negative feelings about fieldwork which are described by ranks indicated by yes (1) or no (0). Description of a negative and positive feelings of the pre-and post-fieldwork is depicted in Table 2. The Course End Report (CER) developed by the faculty is a report summary of the points, learning outcomes, conclusions, and responses from an educational program from the respective subject. It may be used to assess the effectiveness of the learning process, highlight areas that need improvement, and report to the faculty about learning findings.

**Table 2. Negative and positive taxonomy of feelings achievement description (Stokes & Boyle, 2009).**

| Pre-Fieldwork | |
|---|---|
| Positive | Negative |
| • Happy<br>• Relaxed<br>• Can't wait<br>• Eagerly anticipating<br>• Confidence about what expected | • Concerned<br>• Worried<br>• Don't want to go<br>• Don't know what to expect<br>• Apprehensive |
| **Post-Fieldwork** | |
| Positive | Negative |
| • Want to go again<br>• Learned a lot<br>• Glad we had to go<br>• Enjoy it<br>• Worthwhile | • Lived up to my fears<br>• Did not enjoy<br>• Didn't know what to expect<br>• Wish not compulsory<br>• Found hard |

Moreover, the questionnaires were distributed in their e-learning system attached with a Google Form link, and collected before and after fieldwork. Furthermore, the statistical analysis used a series of one-way analyses of variance (ANOVA), where positive and negative feelings for both pre- and post- fieldwork as the independent variables, and CO achievement was taken as the dependent variable (Figure 1). Hence, the level of significance for analysis was set to 0.05. Finally, all the data were analyzed by using the Statistical Package for Social Science (IBM SPSS) v. 22.

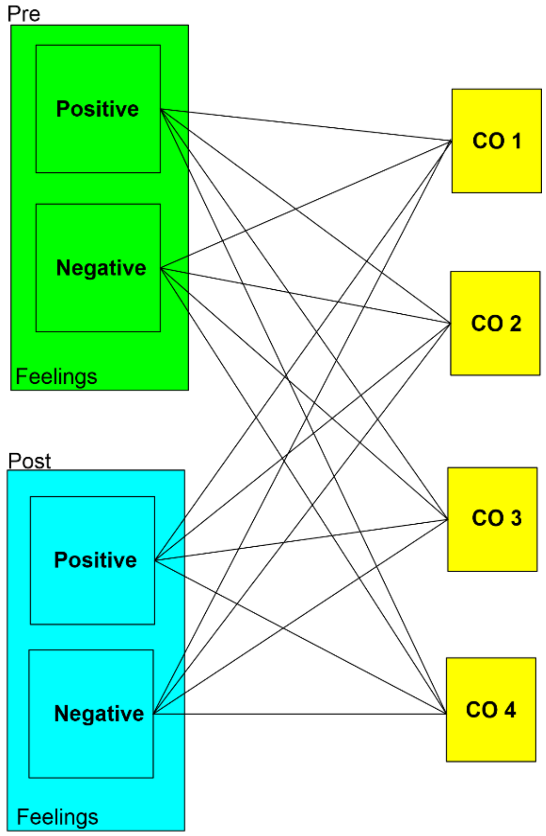


**Figure 1. Conceptual framework**

## 3. Results and Discussion

For the demography measure in the reflection and anticipation in this fieldwork, a total of 61 respondents were divided into two sections, and the maximum for each section is 30 students who participated in the study. The respondents were separated into small groups and each group contains 5 students. Figure 2 depict the majority of the respondent are female (53.1%) and less than half are male (46.9%). The results in line with findings from Shahzad et al. (2020) mentioned that in 2020 majority of students in universities in Malaysia were female compared to male. This is not surprising as reported by Khazanah Research Institute (2023) found in 2021 female students from Malaysian high institutions made up 53.2 percent based on Graduate Trace Study (GTS).

Figure 3 shows the CGPA among respondents indicating most of them had better academic performance with 58.5 percent. It has been discovered that cooperative learning processes will raise students' attitudes toward the subject and improve their results more than traditional approaches (Zakaria et al., 2010).

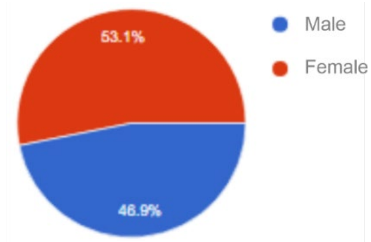


**Figure 2. Gender distribution.**

More possibilities for students to get involved in the conversation and problem-solving skills developed by the petroleum engineering program. It is evidence exists indicating the teaching and learning process had a major impact on students' academic success. To motivate students to actively participate in class, lecturers need to enhance their methods of instruction.

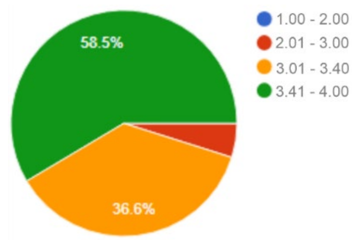


**Figure 3. CGPA distribution.**

Emotions associated with success in learning may not only be the results of accomplishing activities and outcomes, but they may also be crucial for future education (Pan et al., 2022). The influence of emotional achievement on pre- and post-fieldwork was examined (Figure 4). It can be seen that most of the respondents' feelings were positive at the beginning of fieldwork about 87.6 percent. However, there are some respondents about 12.4 % answered 'yes' with negative feelings before fieldwork started. Most negative feelings are indicated by worry about fieldwork exercises. It is probably because they are learning to adjust to various environments and a culture has likely been difficult for them before to the field. As mentioned by Punch (2012) fieldwork presents complicated practical, emotional, and individual challenges that are still hardly ever addressed in methodological rationales. In positive feelings, most of them feel 'confidence about what is expected'. It could be they already prepared and discussed among their senior about fieldwork experiences.

After the fieldwork excursion, the negative feelings reduced to 2.3 %, and still a small number of them answered "don't know what to expect'. This is because managing orders of magnitude's amount of geological data is challenging. In the field, students need to visualize geological data such as structures of the outcrop, learn about demand at work, and analyze strike/dip. Furthermore, limited imagination skills (cognitive) may affect students understanding of geological structures in the field (Shipley et al., 2013). Pre- and post-fieldwork emotions in statistical data were shown to differ significantly (Table 3), it could be students need to travel to a new locality or station and get to know staff. Nevertheless, positive feelings found increased from before and after fieldwork realizing teamwork as a valuable component of learning then realizing teamwork as a valuable component of learning (Nyarko & Petcovic, 2023). The outdoor program was intended to promote both independent functioning and constructive and progress in both categories is evidenced by students' gaining confidence in their ability to make decisions on their own in cooperation in the field.

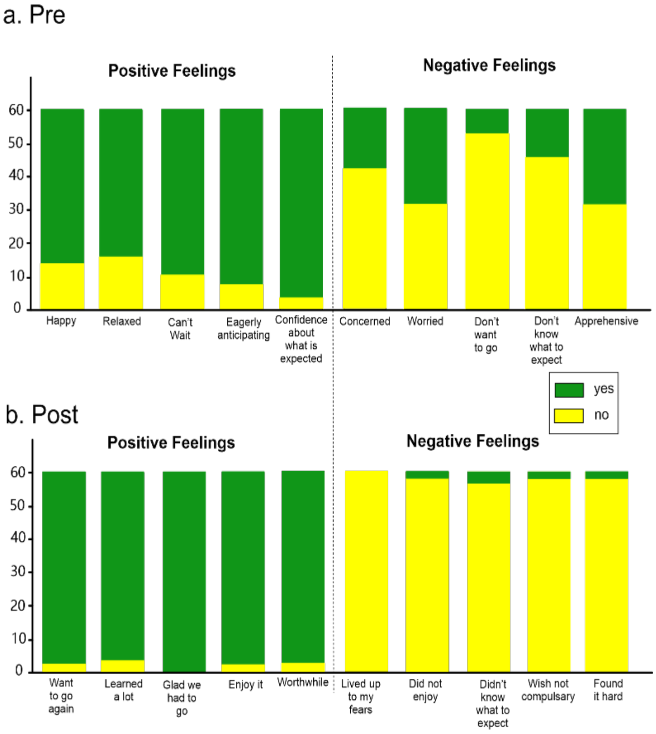


**Figure 4. Respondent's feelings before (a) and after (b) fieldwork**

**Table 3. Statistical for the pre-and post-fieldwork score that several students answered 'yes' shown by means.**

| Pre-Fieldwork | n | mean | SD |
|---|---|---|---|
| Positive | 61 | 0.876 | 0.919 |
| Negative | 61 | 0.124 | 0.632 |
| **Post-Fieldwork** | **n** | **mean** | **SD** |
| Positive | 61 | 0.977 | 0.262 |
| Negative | 61 | 0.023 | 0.441 |

As shown in Table 4, all COs indicate above KPI (>65%) as standardized by the university. This indicates most of the students can analyze and demonstrate geology fieldwork. It also reflected the effectiveness of T&L at the field deliverable in gaining understanding among students. According to Feder (2019), it represents the finest practice in pedagogy to accomplish continuous learning outcomes in Petroleum Engineering students in the United States.

**Table 4. Course learning outcomes achievement summary**

| Course Learning Outcome | Average (%) |
|---|---|
| CO1 | 84.7 |
| CO2 | 85.1 |
| CO3 | 84.5 |
| CO4 | 84.6 |

Table 5 shows there are significant relationship between positive emotions with CO achievement (P<0.05). As mentioned by Row et al., (2015) Positive feelings can help students understand situations more broadly, consider possibilities, persevere through difficulties, and react appropriately to disagreement and disappointment.

**Table 5. Statistical summary for the relationship between emotions and COs achievement.**

| Pre-Fieldwork N=61 | | | | |
|---|---|---|---|---|
| Feelings (I) | CO (J) | Mean Diff. (I-J) | Std. Error | Sig. |
| Positive | CO1 | 0.029 | 0.225 | 0.000 |
| | CO2 | 0.025 | 0.311 | 0.000 |
| | CO3 | 0.031 | 0.312 | 0.000 |
| | CO4 | 0.030 | 0.305 | 0.000 |
| Negative | CO1 | -0.723 | 0.677 | 0.819 |
| | CO2 | -0.727 | 0.781 | 0.992 |
| | CO3 | -0.721 | 0.814 | 0.874 |
| | CO4 | -0.722 | 0.883 | 0.904 |

| Post-Fieldwork N=61 | | | | |
|---|---|---|---|---|
| Feelings (I) | CO (J) | Mean Diff. (I-J) | Std. Error | Sig. |
| Positive | CO1 | 0.130 | 0.119 | 0.000 |
| | CO2 | 0.126 | 0.022 | 0.000 |
| | CO3 | 0.132 | 0.177 | 0.000 |
| | CO4 | 0.131 | 0.208 | 0.000 |
| Negative | CO1 | -0.842 | 0.677 | 0.995 |
| | CO2 | -0.828 | 0.781 | 0.904 |
| | CO3 | -0.822 | 0.814 | 0.895 |
| | CO4 | -0.826 | 0.883 | 0.902 |

* The mean difference is significant at the 0.05 level

## 4. Conclusion

The study evaluated petroleum engineering undergraduate emotional experiences before and after fieldwork T&L may affect the course learning outcomes. The results indicated student perceptions about fieldwork are positive and enjoyed due to the T&L method derived effectively. Although there are a small number of students who have negative feelings before conducting fieldwork. However, after the end of the course, the negative perspective decreased. In statistical data, positive emotions have a significant relationship with learning outcomes achievement. Thus, based on the findings shown in geological fieldwork despite more challenges due to outdoor activities, students can cope and work as a team following the expectations of the program.

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# Mathematical Competence of Practicing Engineers in Engineering Tasks

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## Abstract
Due to the complexity of the problems that engineers must solve; they must receive training in real-life problem-solving scenarios. The Engineering Accreditation Council (EAC) and Board of Engineering of Malaysia (BEM) place a significant emphasis on engineering competencies in Program Learning Outcome (PLO), including the ability to apply mathematical knowledge to engineering problems. However, students at universities face challenges in understanding engineering mathematics, as they are not typically taught by specialized instructors. Therefore, a phenomenological approach was utilized in this study to identify the mathematical competencies (MC) among practicing engineers in manufacturing workplaces. Three engineers were selected as potential respondents, but only one participated in the study. Data was collected through intensive interviews conducted in the workplace. The phenomenological reduction technique was employed, utilizing Epoche, Identification of significant statements, Meaning Units, Textural Description of the Experience, Structural Descriptions of the Experience, and Textural-Structural Synthesis phenomenology for data analysis. This method offers a logical, systematic, and coherent design that produces an essential description of the experience. The study's findings indicate that mathematical competencies frequently used by engineers include mathematical thinking, problem-solving skills, and mathematical communication. This study could inform instructors about developing mathematical competencies relevant to real-life problem-solving in engineering activities and academic programs at their institutions.

**Keywords**: Mathematics at the workplace, mathematics in industry, phenomenological method, mathematical competency.

## Introduction

In embracing Industrial Revolution 4.0, engineers in the field of engineering, there is a need to solve highly complex problems, particularly those that are encountered in real-life situations. Manufacturing Engineers, for instance, are tasked with designing products, selecting optimal technologies, and manufacturing processes, planning and designing production facilities, and overseeing their operation, maintenance, and repair. In addition, they are also involved in various aspects of supply chain management, logistics, distribution, quality control, environmental management, and life cycle management. Overall, Manufacturing Engineering is a branch of engineering that deals with the analysis and improvement of complex industrial and manufacturing systems.

For many years, the importance of mathematical competence in engineering education has been recognized. Professional organizations such as ABET (2020) and BOKS (2020) have identified Mathematics as one of the foundational pillars, along with basic science, social science, and humanities, that support the development of technical and professional skills in engineering. Mathematical competence is therefore considered a crucial learning tool that facilitates the understanding and mastery of engineering concepts.

In the context of engineering tasks, mathematical competence is viewed as an essential perspective that is woven into the EAC-BEM criteria, which outlines the attributes that prospective engineers should possess. These attributes include the ability to apply mathematical and engineering knowledge, analyze and interpret data, and formulate and solve engineering problems. By incorporating mathematical competence into their approach to engineering, professionals can meet these criteria and achieve success in their field.

One of the key outcomes emphasized in engineering programs is the application of mathematical knowledge in analyzing and solving complex engineering problems (ABET, 2020; EAC-BEM, 2020). However, research has shown that many undergraduate engineering students in the US struggle with calculus and are not able to effectively apply mathematical concepts to real-world engineering problems (Prahmana et al., 2019). This is partly because engineering undergraduates are required to solve highly complex mathematical problems in a short amount of time, which is different from the elementary mathematics they learned in school (Nortvedt & Siqveland, 2019).

Moreover, engineering students often face challenges in understanding mathematical concepts as they are not taught by teachers specializing in their respective fields, and the teaching approaches used for mathematics and engineering undergraduates are different (Flegg et al., 2011; Manseur et al., 2010). Mathematical communication, which is essential for teaching students how to use mathematical terminology to describe real-life events, is often not included in undergraduate curricula (Tahir, 2016; Wood, 2010). This abstract approach to teaching engineering mathematics can worsen students' understanding as they cannot relate mathematical principles to real-world applications (Irish Academy of Engineering, 2015).

To address these challenges, engineering education needs to be realigned and refocused to better promote the characteristics desired in practicing engineering (National Academy of Engineering, 2022). This should be done in the context of an increased emphasis on the research base underlying engineering education, as the field of engineering is rapidly evolving with new application domains (National Academy of Engineering, 2022). Developing an enhanced understanding of the model of engineering practice in this evolving environment is essential to preparing students for the complex engineering problems they will face in their careers.

The above findings provide subtle but important indicators that are immediately relevant to mathematical competence in the context of the engineering workplace. Therefore, having an insight into the relevant mathematical competencies in engineering practice is considered to lubricate and accelerate the process of understanding, applying, and transferring mathematical knowledge into engineering education. Therefore, the study examines the elements involved in mathematical competencies for engineering classes based on the experience of practicing engineers.

## Methodology

*Participants*

To ensure representativeness and inclusion of practicing engineers regardless of their gender, level of achievement, and cultural background, a purposive sampling strategy was employed (Campbell et al., 2020). This technique is used when researchers want to select a purposive sample that closely represents a broader group of cases. Homogeneous sampling was utilized in this study, which involves selecting individuals with similar traits or characteristics (Tam et al., 2020, Creswell, 2019). The initial step involved searching for a company registered with the Federation of Malaysia Manufacturing (FFM) that produces specific products. An electronic manufacturing company located at Pasir Gudang, Johor, was chosen for this investigation. The manufacturing department of the company, where problem-solving is critically performed by experienced engineers in the field, was selected for this study. An engineer who demonstrated expertise in mathematical competencies and problem-solving was selected as the sample for this investigation. The nature of work in the engineering department was consistent with the requirements of the intended study, which aimed to examine mathematical competencies among engineers in the workplace.

*Phenomenology method*

Phenomenology, a branch of qualitative research, emerged as a distinct discipline and philosophical movement in the early 20th century, with different approaches and characteristics that define the discipline. Descriptive phenomenology, the original form, aims to uncover and describe the meanings of people's experiences, while interpretive phenomenology or hermeneutics aims to interpret those meanings (Neubauer et al., 2019). According to Errasti-Ibarrondo et al. (2018), subjective qualitative knowledge is a precursor to the attainment of objective quantitative knowledge, as a phenomenon is experienced by a person pre-reflexively before generating impetus for the researcher to measure the phenomenon objectively.

Therefore, a phenomenological study seeks to understand how engineers experience mathematical competence in the workplace, as well as the meanings they attribute to those experiences and in what circumstances (Moustakas 1994). To achieve this, the research must capture participants' perspectives in their own words and describe their experiences as authentically as possible (Neubauer et al., 2019). Phenomenological research is typically inductive and frequently collects data using semi-structured interviews, which allows participants the freedom to fully express themselves (Neubauer et al., 2019, Qutoshi, 2018). The benefit of giving participants control of the interview is that new knowledge emerges that is unknown to the researcher but known to a practicing engineer (Tam et al., 2020). Using phenomenology influences the types of research questions asked and the forms of knowledge generated (Salamon, 2018, Qutoshi, 2018). As phenomenology is the study of the perceptions of people experiencing a phenomenon rather than the empirical study of the phenomenon itself, Figure 1 shows the Flow Chart for Phenomenological Methodology and Analysis.

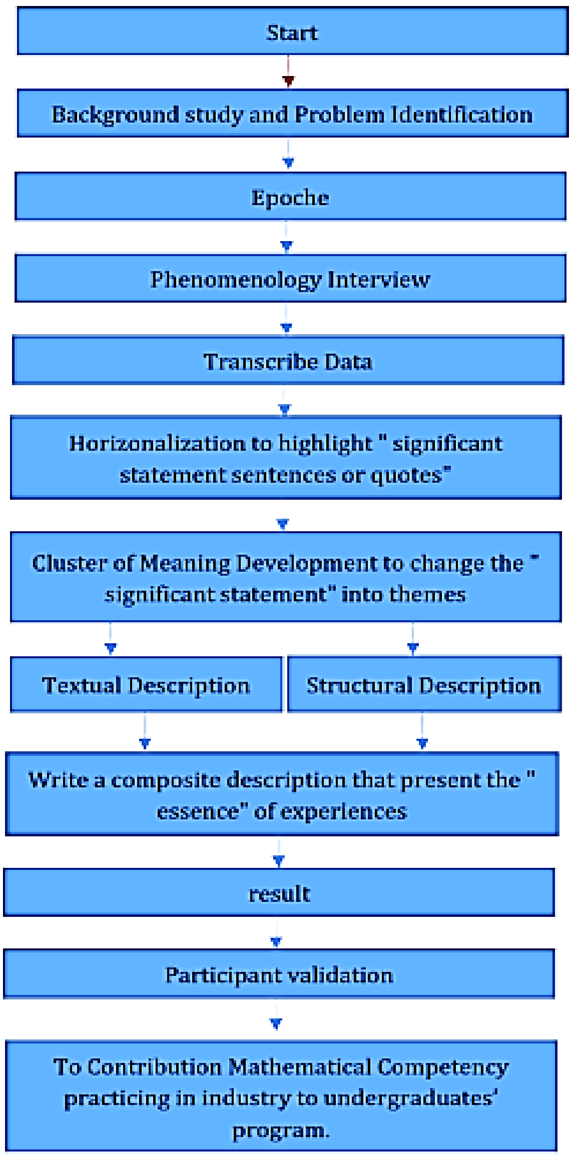


**Figure 1. The Flow Chart for Phenomenological Methodology and Analysis**

## Data Analysis

*Significant Statements*

The initial step of the analysis involves horizontalization, which entails identifying specific statements in the transcripts that offer insight into the participants' experiences. These significant statements are extracted from the transcripts and presented in a table, enabling readers to comprehend the diverse perspectives on the phenomenon (Moustakas, 1994).

In Table 1, we compiled verbatim statements from the mentors, which represent unique and non-redundant significant statements. These statements were derived subjectively from the transcripts and comprised complete sentences. We did not attempt to categorize or sequence them in any way. Our objective in this analysis phase was to grasp how individuals perceive the term "Mathematical Competence." By reviewing their statements, we can obtain a more comprehensive understanding of how people experience reinvesting in others. According to Moustakas (1994, p. 95), the horizon refers to "the grounding or context of the phenomenon that gives it a distinct character." As we examine each horizon and its textural properties, we can gain insight into our self-awareness and reflections on the experience.

*Transcribe Data (Phenomenology interviews)*

In adopting Moustakas' (1994) phenomenological model using phenomenological reduction, the following step identifies significant statements, Meaning Units, Textural Descriptions of the Experience, structural Descriptions of the Experience, and Textural-Structural synthesis. The purpose is to identify a significant statement.

*Horizonalization (Significant Statements Identification)*

As shown in Table 4, column 2, the researcher identified individual verbatim statements shared by the respondent (E1) depending on each PDCA step for purposely showing only for step *Plan* to show how to analyze at this step. These statements represent non-repetitive, non-overlapping significant statements. These statements reflected entire sentences and were a subjective extrapolation from the transcripts. No attempt was made to group these statements or order them in any way. In this analysis phase, the researcher wanted to learn how individuals viewed the term. Reading their statements provides details about how individuals experience reinvestment in others. These significant statements are gleaned from the transcripts and provided in Table 3 so that researchers can identify the range of perspectives on the phenomenon (Moustakas, 1994).

**Table 1: Individual Verbatim Statements**

| Construct | Horizonalization (H) / Original transcript | Researcher interpretation |
|---|---|---|
| Engineering task | “ **-** .. At the beginning stage, **I will read and understand the meaning of the information** I received as an example, Problem: PCB warpage (out of spec), Qnty: n = 10, r = 4 (2.6mm), spec: 1.56mm<br><br>“….- .. **this means**, PCB has a problem: warpage from 10 pieces they take for inspection or measurement and found four pieces are problematic that is out of the given limit, the limit is 1.56mm, and the problematic measurement is 2.6mm and above. Suppose you follow the percentage in the 40% problem ratio. Apart from that, I also try to recall previous issues of whether I have ever experienced the same problem or the same condition or a new problem, especially specification and reject quantity. It can help to analyze this problem. …”<br><br>“…. Apart from that, **I also try to recall** previous issues of whether I have ever experienced the same problem, same condition, or a new problem, especially specification and reject quantity. It can help to analyze this problem | The engineer shows the realized data |
| Engineering task | "………I'm going to ask for a broken item from the department that reported the problem; it's for me to do my research **so that I can get a picture of the real problem**"<br><br>"….. After receiving an email from the sender, I often **read the details of the email, see the actual part**, see another department for additional information, and do the analysis myself. Once I get the real picture, I'll call a meeting to explain the real problem. Before doing once again a real analysis……"<br><br>"……**I took the actual PCB part to analyze and take my measurements**. I have checked by measuring all 10 points in their original state, and after the oven process, after seeing I feel confident in my first guess. This is due to the oven process because there is a heating process | The engineer analyses the actual problem |
| Engineering task | "……….I received various forms of data. There were types of information received verbally; there was text form data, there was data in the form of small informal notes, there was email, **and most of the data was raw data that had not been analyzed yet….**"<br><br>"…..**based on the datasheet** specifications, each country has different data. For example, the frequency dummy carrier for Argentina (AG) is 18db, **but it is reduced compared** to the Lebanese (LB), which is 12db. For RF level items, **the setting is the same** for all countries, which is 70dbm…."<br><br>"…..**I need to set up the settings on the machine before** the start date of the production path. And after the setting, the passage is verified by the quality department…." | Engineer does self-thinking |
| Engineering task | "….. Before I proceed to the new design, **I will make a test and confirmation** of the same machine that has been built, it is intended to make improvements in machine quality and safety…"<br><br>"…**I was trying things out or evaluating** them with the help of special tools to get the best results, which was help with the machine's final design."<br><br>"…. When designing a patching pressure machine, I used my knowledge in mathematics **to calculate how much pressure** it takes to flex the corresponding wind tank so that the knob was moved with the right pressure…….." | The engineer does the simulation problem |

| | | |
|---|---|---|
| | "..... after obtaining the approval mandate from several parties regarding the report **I have produced, I will move several actions**, including extending this analysis report to PCB suppliers..."<br><br>" ........... I was bringing the data sheet provided to **discuss with all departments**, such as the Production and Quality Department, to make final certainty. For example, the graph requires the certainty of the graph gradient graph shape and the coordinates of the temperature graph over time. **Each arch of the graph represented a direct impact on the product produced…."**<br><br>"...... **While discussing the temperature graph on the smelter machine with the Quality engineer**, the Quality Engineer asked about the frequency of inspection setting the machine according to the specification graph. It is very stressful for me because every problem needs to examine the root cause of the problem and the proposed solution, then the emphasis on quality. I was discussing with the quality engineer well and prudently......." | Engineers show how they make decision |
| | "..... After calculating the time and output for one day, **I decided that by using six cutting machines,** we will have enough capacity to carry out production...." | Engineers show mathematical decision |
| | "... **Based on calculations**, machine one has an output of 134 pieces taking into account 90 percent of the operating time and load and unload part of 15 seconds, it also takes into account the cutting point which takes into account between 54 points to 72 points...." | |

*Development of meaning units*

The next step is meaning Units or Themes, as every significant statement is initially treated as possessing equal value, as in Table 5. This next step deletes those statements irrelevant to the topic and, for this study, what is always mathematical Competency frequently used. The remaining statements are the horizons or textural meanings. The researcher carefully examines the identified significant statements and clusters them into themes or meaning units (Moustakas, 1994). But this paper will show only for step *Plan* to show how to analyze at this step. Constructing themes based on deductive methods, Deductive ways are the knowledge, theory, or framework that has since become a code/theme (Boyatzis, 1998).

*Meaning Units or Themes.*

As every significant statement is initially treated as possessing equal value, this next step deletes those statements irrelevant to the topic and others that are repeated or overlapping. The remaining statements are the horizons or textural meanings. The researcher carefully examines the identified significant statements and then clusters the statements into themes or meaning units (Moustakas, 1994). From the thematic analysis, the researcher then describes "what" was experienced in textural descriptions, and "how" it was experienced in structural descriptions. Textural descriptions are considered, and additional meanings are sought from different perspectives, roles, and functions (Moustakas, 1994). This process of imaginative variation leads to the structural textures resulting in essential structures of the phenomenon. This is called Textual and Structural Descriptions. Three themes emerged from this analysis about how participants experienced the ripple effect of investing and reinvesting in others, influencing others positively, giving and receiving, and establishing interconnectedness among relationships (see Table 2).

## Discussion of Mathematical Competency

*Mathematical competence: Mathematical Communication*

Mathematical Communication is an important criterion for engineers as it helps them to interpret data and analyze complex problems. Such a tool is extremely useful in the workplace as it allows engineers to better understand the data they are working with and make decisions based on accurate information. With the help of communication Mathematics, engineers can determine the exact quantity that has been subtracted from a given set of data, as well as the percentage of error present. Additionally, communication Mathematics can be used to determine the correct specification value for a given problem.

**Table 2. Themes or Meaning Units and Evidence**

| Themes/Meaning Units | Evidence Statements |
|---|---|
| Mathematical Communication | "….- based on raw data, this means, PCB has a problem that is warpage from ten pieces they take for inspection or measurement and found four pieces are problematic that is out of the given limit, the limit is 1.56mm and the problematic measurement is 2.6mm and above. if you follow the percentage, in the 40% problem ratio. Apart from that…" |
| | "....Before starting analysis information, ...I will read all the provided data and spec limit to ensure that there is no misinformation and that all changes are made……" |
| | "Based on the datasheet specifications shows that each country has different data, for example, the frequency dummy carrier for the country of Argentina (AG) is 18db, but it is reduced compared to the Lebanese (LB) which is 12db. For RF level items, the setting is the same for all countries which is 70dbm…." |
| Analyse Problem | "…. after reading the information, I start to plan how to start process solving problem." |
| | "..... As I always do, I am going to do measurements and analysis and compare drawing and actual part...." |
| | " ..... Sample some PCBs should be taken as they will be taken readings and look at the situation, besides, data collection is also necessary..." |
| Thinking mathematically | "....to produce good code, I need to, look at and understand the specifics of the limits given to be included in my coding program. For example, each limit has a tolerance of +/-, which means high and low limits. Next, examine the previous program to see if it is similar or needs to be improved and so on, checking the hardware for where to execute the download of the program...." |
| | "…… based on the datasheet specifications shows that each country has different data, for example, the frequency dummy carrier for the country of Argentina (AG) is 18db, but it is reduced compared to the Lebanese (LB) which is 12db. For RF level items, the setting is the same for all countries which is 70dbm…." |
| | " ... when planning to make or design a "cold press" machine, I listed a few things to do, among them is the required to confirm machine pressure calculation. The calculation process is critical to avoiding accidents involving humans and products...." |

The form changes depending on the Mathematical and communication skills of the person speaking and the person listening, but some things set Mathematics discourse apart from other forms. For example, it is often very symbolic and uses pictures as well, as (Black & Hernandez-Martinez, 2015; Marliani et al., 2021) said in their summary of research on how text and symbols interact. The author also talks about the role of graphs and says that to model real-world problems, symbolic expressions need to be made, and then graphs need to be made from the symbolic models. Mathematical discourse is also different from natural language in other ways. For example, it uses fewer words, it encapsulates ideas in a way that makes connections clearer, and it is easier to work with mathematical objects when they are written in their syntax.

*Mathematical competence: Analyse Problem*

The practice of problem-handling is an effective way for engineers to analyze and solve real-world problems. This approach involves breaking down a problem into its parts and then examining each part to identify the root cause. In addition, problem handling allows engineers to consider alternative solutions and evaluate the potential outcomes of each option.

In terms of its efficacy in helping engineers to identify and solve problems, problem handling has several advantages. According to Subramaniam et al., (2020), the ability to analyze complex problems allows engineers to deconstruct them into more manageable components. This makes it easier for them to understand the problem and to identify specific solutions. Ueki & Guaita Martínez, (2020) stated that problem handling helps engineers to identify the root cause of a problem. By doing this, they can find and correct any underlying causes. Finally, problem handling allows engineers to evaluate the potential consequences of various solutions. This can help them to make informed decisions about which option is best suited for their situation.

Overall, there is evidence that problem-handling is an effective means of self-analysis for engineers. This approach allows them to identify and solve problems quickly and efficiently. Consequently, it is a valuable tool in the arsenal of an engineer's problem-solving skills.

*Mathematical competence: Self-thinking Mathematically*

Engineers are essential to the success of any business. From creating new products to ensuring the safety of existing products, engineers are relied upon to solve problems and drive innovation. To do this, engineers must be able to think mathematically and use this knowledge to make informed decisions (Sahroni et al., 2022).

Mathematical thinking is an important skill for any engineer. It involves using logic and mathematical formulas to solve problems. This ability is essential for engineers, who must think critically and solve complex problems. In the workplace, this thinking is used to self-manage tasks and manage projects (Osman et al., 2015). Engineers employ the mathematical thinking proposed by Niss (2003) while doing job activities. According to (Calder, 2018) studying Mathematics is the fundamental approach to developing mathematical thinking. Schoenfeld (1992) proposed it as well, defining mathematical thinking as the capacity to use five parts of cognition: fundamental information, problem-solving or heuristic techniques, monitoring and control, trust and influence, and practice. Journal et al., (2012) agreed, defining mathematical thinking as a dynamic process that enhanced the complexity of manageable concepts and changed as a result. While Jawad et al., (2021) highlight thinking Mathematics as a mental activity involved in the abstraction and generalization of mathematical knowledge, this indicates that mathematical thinking is critical in the process of issue-solving in the workplace since it entails a mental process that encourages the ability to think mathematically to solve engineering difficulties.

## Conclusion

Engineering students need to develop a range of skills to be successful in their field. Three of the most important skills are self-thinking mathematically, analyzing problems, and mathematical communication. Self-thinking mathematically is the ability to think critically and creatively about mathematical concepts and apply them to real-world problems. Analyzing problems involves breaking down complex problems into smaller, more manageable parts and developing strategies to solve them. Mathematical communication is the ability to communicate mathematical ideas and concepts effectively to others.

According to a study by Tolbert and Cardella (2020), mathematics contributes to the core of engineering and serves as a source of knowledge from which engineering students can draw the study also found that engineering students must have the ability to apply mathematical knowledge and skills to problem-solving and engineering design tasks 1.

In addition, the study by Tolbert and Cardella (2020) found that students who have knowledge and a large repertoire of problem-solving strategies provide more complete and correct answers to given problems 1. This highlights the importance of self-thinking mathematically and analyzing problems in engineering tasks.

Mathematical communication is also an essential skill for engineering students. A study by Hanif Batubara et al. (2022) found that students who received problem-based learning assisted by GeoGebra 3D Augmented Reality based on Culture had higher mathematical communication skills than students who did not receive this type of learning 2.

In conclusion, the results show that MC is suitable for applying problem-solving in the workplace. Therefore, it is suggested that the focus of mathematics teaching for prospective engineers should consider mathematical competencies, and these competencies should be included as important learning outcomes. Given that, the National Academy of Engineers (2022) states that the future engineering curriculum should be built around developing skills such as analytical and problem-solving skills rather than teaching content knowledge. Furthermore, emphasis should be laid on teaching students about methods to derive solutions rather than giving the solutions (the National Academy of Engineers, 2020).

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# TRIZ – Systematic Innovation in Manufacturing: Book Review

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**Abstract**
"TRIZ - Systematic Innovation in Manufacturing" is a comprehensive guide unveiling the transformative potential of the Theory of Inventive Problem Solving (TRIZ) within manufacturing contexts. This insightful book delves into the core principles of TRIZ, equipping professionals and engineers with a structured approach to tackle intricate challenges and drive innovation. Offering a blend of theory and practical applications, the book elucidates TRIZ methodologies through illustrative case studies, examples, and exercises tailored to the manufacturing sector. It navigates through inventive principles and contradiction resolution strategies, showcasing TRIZ's efficacy in optimizing processes, enhancing designs, and overcoming operational bottlenecks. While potentially challenging for those new to TRIZ, this resource serves as an invaluable asset for professionals seeking inventive solutions and systematic problem-solving approaches within manufacturing environments.

**Keywords**: Innovation in Manufacturing, Engineering Contradiction, Engineering System, Engineering Education

## Introduction

"TRIZ - Systematic Innovation in Manufacturing" is an illuminating guide that unveils the power of the Theory of Inventive Problem Solving (TRIZ) within the manufacturing landscape. Authored by Yeoh Teong San, Yeoh Tay Jin, and Song Chia Li, this book stands as a comprehensive resource for professionals, engineers, and innovators seeking to revolutionize their approach to problem-solving and innovation.

At its core, the book delves deep into TRIZ methodology, elucidating its principles, tools, and practical applications within the manufacturing sector. It offers a structured framework for identifying and overcoming complex technical challenges, stimulating inventive thinking, and fostering a systematic approach to innovation.

One of the book's strengths lies in its ability to bridge theory with real-world implementation. It seamlessly integrates TRIZ concepts with manufacturing scenarios, providing numerous case studies, examples, and practical exercises, including STEM education (Abdul Rahim, 2020). These serve as invaluable aids in understanding how TRIZ can be effectively applied to resolve intricate issues and drive innovation in manufacturing processes.

Moreover, the authors adeptly demonstrate how TRIZ transcends conventional problem-solving methods. By highlighting the inventive principles and contradiction matrix, they showcase how seemingly contradictory aspects can be leveraged to unearth ingenious solutions, optimize product designs, improve processes, and reduce costs within manufacturing environments.

However, for readers new to TRIZ, the book's depth of technical content might pose a slight challenge, requiring careful attention and gradual assimilation of concepts.

This ingenious book serves as an indispensable guide for those aiming to elevate their problem-solving capabilities and drive innovation within the manufacturing realm. It is a testament to the efficacy of TRIZ methodologies in unlocking inventive solutions, positioning itself as an invaluable asset for professionals seeking to transform challenges into opportunities within the manufacturing landscape.

TRIZ is a systematic innovation methodology. The book very well explain it as a structured methodology for modelling the problem, tools to work with the models, and finally models of solutions for breakthrough idea generation. TRIZ is a recognized international science of creativity, based on the laws of physics and innovative patents distilled to numerous problem-solving tools. It is a toolbox that provides users with methods to create breakthrough ideas. This book was written to enable an in-depth understanding of the philosophy, methodology, and tools used. In addition, the application of TRIZ in manufacturing (using semiconductor manufacturing examples) will further illustrate the power of TRIZ in providing a systematic approach from problem identification to innovative solution generation.

The book (Figure 1) acts as a valuable resource for beginners exploring TRIZ, offering foundational knowledge and touching on advanced tools while outlining TRIZ's overarching philosophy. Its primary strength lies in an abundance of manufacturing-specific case studies and examples, catering specifically to TRIZ practitioners, and providing compelling insights and practical applications within the manufacturing domain.

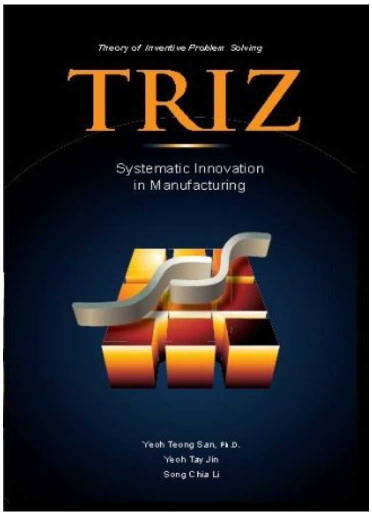


**Figure 1. TRIZ – Systematic Innovation in Manufacturing Book Cover**

## Structure and Content

The structure and content of the book were carefully designed to enable systematic comprehension by its readers. The chapters of the book are detailed in Table 1. The book provides valuable technical knowledge not only for mastering TRIZ, but also for developing innovative strategies and ideas for solving problems. For instance, the manufacturing case studies depicted in Chapter 8 offer practical ways to enable good visualizations of how TRIZ can be applied. The three appendices list down all the *39 System Parameters*, *Contradiction Matrix*, and *76 Standard Inventive Solutions* that are required for TRIZ application.

**Table 1. Chapters offered in the book**

| Chapters | Chapter Title |
|---|---|
| 1 | Introduction |
| 2 | TRIZ Problem Solving Process |
| 3 | Overview of TRIZ Models and Tools |
| 4 | Function Analysis |
| 5 | Product Analysis |
| 6 | Cause & Effect Chain Analysis |
| 7 | Trimming |
| 8 | Contradictions |
| 9 | Manufacturing Case Studies |
| 10 | Substance-Field Model |
| 11 | ARIZ |
| 12 | Summary |
| Appendix A | 39 System Parameters |
| Appendix B | Contradiction Matrix |
| Appendix C | 76 Standard Inventive Solutions |

## Advantages of This Book

"TRIZ - Systematic Innovation in Manufacturing" presents several strong points that make it an invaluable resource:

*Structured Approach*: The book provides a systematic framework for problem-solving and innovation within manufacturing. It offers a structured methodology through TRIZ principles, aiding engineers and professionals in approaching complex problems methodically.

*Practical Application*: It seamlessly integrates theory with practical examples and case studies specific to the manufacturing industry. This application-centric approach assists readers in understanding how TRIZ can be effectively utilized in real-world scenarios.

*Inventive Principles*: It effectively illustrates inventive principles and contradiction resolution strategies, showcasing how these principles can be applied to enhance product designs, streamline processes, and overcome technical obstacles in manufacturing.

*Problem-Solving Tools*: The book offers a rich array of problem-solving tools and methodologies tailored to the manufacturing sector. These tools empower readers to identify and address challenges innovatively, leading to enhanced efficiency and creativity in problem-solving.

*Insightful Guidance*: Authored by experts in the field, the book provides insightful guidance, offering a wealth of knowledge and practical insights that professionals can apply directly within their manufacturing environments.

## Educational Theories Related to TRIZ Application

This book intersects with several educational theories, enhancing its relevance within educational contexts, particularly in fostering problem-solving skills and innovation within engineering education.

One prominent educational theory connected to the book is Constructivism. TRIZ aligns with Constructivist principles by emphasizing active learning and the construction of knowledge through experience. It encourages learners, in this case, engineering students, to actively engage with problem-solving methodologies, allowing them to construct their understanding of inventive problem-solving processes. By presenting case studies, practical examples, and tools within the book, TRIZ facilitates a learning environment where students can construct their problem-solving skills by actively engaging with TRIZ methodologies.

Another pertinent theory associated with the book is the Experiential Learning Theory by David Kolb. TRIZ's emphasis on practical application aligns with Kolb's theory, which posits that learning occurs through concrete experiences. TRIZ encourages learners to engage in hands-on problem-solving exercises, analyze real-world scenarios, and apply TRIZ principles to solve manufacturing challenges. This experiential approach allows engineering students to reflect on their experiences, generalize their learnings, and apply them to novel situations—a core aspect of Kolb's theory.

Furthermore, the book resonates with aspects of Problem-Based Learning (PBL). TRIZ offers a problem-centered approach where students are confronted with authentic engineering problems and guided through structured methodologies to resolve them (Jiang et al., 2015). This approach mirrors the principles of PBL, fostering student-centered learning, critical thinking, and collaboration. By presenting practical problems and guiding learners through inventive solutions, TRIZ aligns with the PBL approach, encouraging students to explore solutions collaboratively and develop a deeper understanding of engineering problem-solving processes.

Overall, the book's incorporation of Constructivist principles, alignment with Experiential Learning Theory, and resonance with Problem-Based Learning approaches solidify its relevance within educational theories. It offers a practical, experiential, and problem-centered framework, fostering inventive problem-solving skills crucial for engineering students within educational contexts.

## Engineering Education Application

The book intertwines engineering education by offering a transformative approach to problem-solving and innovation. Within engineering education, the integration of TRIZ principles catalyzes fostering inventive thinking and structured problem-solving methodologies among aspiring engineers.

One significant association lies in TRIZ's provision of a systematic framework that aligns seamlessly with engineering education's quest to impart structured problem-solving skills. By introducing TRIZ concepts within engineering curricula, educators enable students to navigate intricate technical challenges systematically. This approach nurtures students' ability to dissect complex problems, identify contradictions within systems, and explore innovative solutions—a skill set crucial for engineering graduates entering diverse industrial landscapes.

Moreover, the book's emphasis on real-world applications through case studies and practical examples serves as an invaluable resource for engineering education. It bridges the gap between theoretical concepts and practical implementation, offering insights into how TRIZ methodologies can be effectively employed within manufacturing scenarios. By integrating these case studies into coursework, educators equip students with a profound understanding of TRIZ's application, preparing them for real-world problem-solving in engineering practice.

TRIZ also accentuates the importance of creative problem-solving within engineering education. By encouraging engineers (and engineering students) to explore unconventional solutions while adhering to systematic principles, TRIZ fosters a culture of creativity and innovation—a cornerstone of engineering education. This integration propels students to approach challenges with ingenuity, considering contradictions as opportunities for innovative breakthroughs—an essential mindset for tomorrow's engineers facing dynamic industry demands. Ultimately, the association between engineering education and "TRIZ - Systematic Innovation in Manufacturing" underscores the significance of TRIZ methodologies in enhancing problem-solving skills, nurturing creativity, and preparing engineering students for the intricacies of real-world manufacturing challenges (Sire et al., 2015).

## Suitability for Engineering Students

"TRIZ - Systematic Innovation in Manufacturing" holds significant value for engineering students aiming to enrich their problem-solving acumen within the realm of manufacturing. For students seeking to enhance their analytical and inventive skills, this book offers a structured framework in the form of TRIZ, providing a systematic approach to dissecting and resolving complex engineering challenges. It serves as a practical guide, imparting invaluable problem-solving methodologies that students can potentially apply in their academic projects and future careers.

Moreover, the book's emphasis on real-world applications tailored to the manufacturing sector renders it a pertinent resource for engineering students. Through a multitude of case studies and examples, it bridges the theoretical aspects of TRIZ with practical scenarios encountered in manufacturing environments. This integration allows students to grasp the tangible implications of TRIZ methodologies, connecting theoretical concepts with their prospective engineering practices.

Furthermore, the book fosters an environment conducive to innovation and creativity among engineering students. By showcasing how TRIZ identifies contradictions as opportunities for inventive solutions, the book instills a mindset that encourages creative problem-solving—an indispensable skill in engineering design and innovation.

While the technical depth of certain sections might pose a challenge for students with limited prior knowledge, the book, overall, serves as a valuable companion for engineering students seeking to cultivate systematic problem-solving skills, innovative thinking, and a deeper understanding of practical applications within manufacturing contexts.

## ARIZ Process and Manufacturing Case Study

ARIZ stands for Algorithm for Inventive Problem Solving and is a significant methodology within the TRIZ framework, that is discussed to a great extent in Chapter 11 of this book. This algorithmic approach is designed to guide engineers and innovators in systematically addressing complex problems by providing structured steps and guidelines.

ARIZ offers a systematic process to analyze contradictions and conflicts within a system or process. It aids in identifying inventive solutions by breaking down problems into manageable parts, analyzing contradictions, and seeking innovative resolutions without compromising other elements of the system. The methodology includes multiple versions or levels (e.g., ARIZ-85C) tailored to different problem-solving scenarios.

Within the context of the book, ARIZ is likely discussed as a powerful problem-solving tool specifically applied to manufacturing scenarios. It helps in guiding engineers through the intricate process of identifying and resolving contradictions or technical challenges within manufacturing processes, ultimately fostering innovative solutions.

## Conclusion

In summary, TRIZ - Systematic Innovation in Manufacturing" book culminates as an invaluable guide, illuminating the transformative power of the Theory of Inventive Problem Solving (TRIZ) within the manufacturing landscape. With its structured approach, practical applications, and insightful strategies, the book equips professionals and engineers with a systematic toolkit to navigate complex challenges. Through inventive principles and real-world case studies, it empowers readers to optimize processes, enhance product designs, and drive innovation within manufacturing environments. As a comprehensive resource authored by experts in the field, it stands as an indispensable asset, fostering a culture of creative problem-solving and innovation within the realm of manufacturing.

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