ASEAN JOURNAL OF ENGINEERING EDUCATION

VOLUME 9 | ISSUE 2 | 2025

UTM
UNIVERSITI TEKNOLOGI MALAYSIA

ASEAN JOURNAL OF ENGINEERING EDUCATION

VOLUME 9 | ISSUE 2 | 2025

https://ajee.utm.my

e-ISSN : 2231-9433

Printed by:

Centre for Engineering Education
Universiti Teknologi Malaysia

Editorial Brief

Editorial for ASEAN Journal of Engineering Education (AJEE)

Volume 9, Issue 2, December 2025

ASEAN Journal of Engineering Education (AJEE) latest issue presents fourteen rigorously reviewed papers that collectively showcase the breadth, depth, and evolving priorities of engineering education research within ASEAN and the wider global community. This issue reflects AJEE's continued commitment to advancing high-quality scholarship that addresses contemporary pedagogical challenges, institutional transformation, and the future readiness of engineering graduates in an increasingly complex and technology-driven world.

We are also pleased to share an important milestone for the journal. AJEE has been successfully indexed in the Malaysia Citation Index (MyCITE) in December 2025, marking a significant achievement in the journal's development. This recognition affirms the quality, consistency, and scholarly contribution of AJEE, and strengthens its role as a credible regional platform for engineering education research. The editorial board views this achievement as both an endorsement of past efforts and a motivation to further elevate the journal's standards and international visibility.

A prominent theme in this issue is innovation in teaching, learning, and assessment. Several papers examine the redesign of laboratory experiences through open-ended, virtual, and hybrid models, offering insights into how problem-based and non-physical laboratories can enhance student engagement, adaptability, and critical thinking. Other contributions explore technology-enhanced learning through interactive classroom tools, eye-tracking combined with machine learning for learning diagnostics, and human-in-the-loop generative AI systems for assessment and feedback. Collectively, these studies demonstrate how digital technologies, when thoughtfully integrated, can support learning effectiveness while preserving academic integrity and human judgment.

Another key focus of this issue is quality assurance, accreditation, and continuous improvement in engineering education. Papers analysing ABET accreditation in Europe and documenting institutional experiences with global accreditation frameworks provide valuable comparative perspectives and practical guidance. These studies position accreditation not merely as a compliance mechanism, but as a strategic tool for benchmarking, internationalisation, and sustained program improvement—an increasingly relevant consideration for engineering institutions across the ASEAN region.

The issue also highlights the growing importance of human, organisational, and societal dimensions in engineering education. Contributions addressing workplace support and career advancement, emotional intelligence in engineering problem-solving, diversity, equity and inclusion in energy engineering education, and competency assessment in AI-enabled biomedical engineering underscore the need for a more holistic approach to graduate formation. These papers reinforce the view that future engineers must be equipped not only with technical expertise, but also with interpersonal skills, ethical awareness, adaptability, and organisational understanding.

Complementing the empirical studies are reflective and interdisciplinary contributions, including philosophical reflections on the changing nature of doctoral education in the age of artificial intelligence and a critical review of assessment-driven curriculum design. These works invite deeper reflection on the purpose of engineering education, the meaning of scholarly work, and the balance between efficiency, quality, and intellectual responsibility in contemporary universities.

Geographically, this issue features contributions from Malaysia, Indonesia, Brunei Darussalam, Nigeria, Europe, the Middle East, China, and Latin America, reinforcing AJEE's identity as a journal rooted in ASEAN perspectives while engaging with global discourse. This diversity of contexts and voices enriches the dialogue on engineering education and fosters cross-regional learning.

In sum, AJEE Volume 9, Issue 2 reflects the journal's ongoing mission to publish relevant, rigorous, and impactful research that informs practice, policy, and future directions in engineering education. With its recent inclusion in MyCITE, AJEE looks forward to further strengthening its contribution to the engineering education community and advancing towards greater regional and international recognition.

Assoc. Prof. Dr. Zaki Yamani Zakaria

Chief Editor,

ASEAN Journal of Engineering Education

https://ajee.utm.my/index.php/ajee

Editorial Boards

Contents

Assessing the Impact of the Non-Physical Laboratory Approach on Open-Ended Environmental Laboratory Practice

Article history
Received
7 October 2024
Received in revised form
29 July 2025
Accepted
3 August 2025
Published online
27 December 2025

Nurmin Bolong*, Ismail Saad and Siti Nor Farhana Zakaria
Faculty of Engineering, Universiti Malaysia Sabah
Kota Kinabalu, Sabah 88400, Malaysia
**nurmin@ums.edu.my*

Abstract

This study evaluates the impact of integrating virtual/online open-ended laboratories (OEL) into environmental engineering courses for undergraduate civil engineering students. Incorporating OEL allows students to engage in hands-on, problem-based learning activities that simulate real-world environmental challenges. This article focuses on the benefits, design considerations, and implementation strategies for integrating open-ended environmental laboratories into the undergraduate civil engineering curriculum, enhancing students' critical thinking, teamwork, and ability to develop sustainable engineering solutions. The study examines the implementation of problem-based laboratory techniques over four consecutive cohorts (n=229), capturing the transition from traditional OEL to fully online OEL during the COVID-19 Movement Control Order (MCO) and partially at subsequent post-pandemic conditions. Despite an initial decline in student learning performance during the first year of online OEL, subsequent years showed significant improvement. This trend aligns with student perception surveys, which reflect positive outcomes from the online OEL experience. One of the positive outcomes observed was the adaptability to future challenges. The experience of adapting to online learning environments prepared students for future professional scenarios that may require remote collaboration and virtual problem-solving. A notable insight from the partially online laboratory courses is the expanded opportunity to explore interactive virtual lab platforms and utilize remote data collection methods, enriching the teaching paradigm. Integrating open-ended laboratories in environmental engineering aligns with the Sustainable Development Goals (SDGs) and equips students with essential skills to address global sustainability challenges effectively.

Keywords: Outcome-based Education, Engineering Education, Open-ended Laboratory, Online-Lab, Perceptions, Post-COVID-19.

Introduction

In an engineering or technical program, practical and hands-on experiences during laboratory courses help students develop a multidisciplinary understanding of the topics. These experiences also allow students to apply theoretical knowledge in practical settings, leading to an enhanced learning experience. Meeting the requirements of the Engineering Accreditation Council (EAC) in Malaysia, the criteria stress the importance of inclusive education for laboratory experiments. This approach aims to produce graduates who have a strong theoretical foundation, are proficient in practical applications, and can understand complex real-world situations. They need to be able to design and conduct experiments, analyze and interpret data effectively, and work well in group settings (Zaiton et al., 2013).

Laboratory courses usually involve straightforward and quantifiable assessment of exercises and assignments (Samarakou et al., 2014). In these courses, the instructor provides students with guidelines and instructions for conducting experiments or completing assignments, which are then graded by the educator or the system. However, there is a need to better align this traditional laboratory approach with the current context of outcome-based learning environments. As a result, a recent shift has been towards upgrading laboratory courses' teaching and learning methods to open-ended laboratories (Kofli & A. Rahman, 2011). Open-ended laboratories (OEL) go beyond the traditional approach by giving students more autonomy and freedom to explore and experiment. Additionally, OEL activities are not limited to engineering courses but are applicable across various disciplines. Wilcox and Lewandowski (2016) examined the impact of OEL in undergraduate laboratory physics courses on students' epistemologies and expectations. Their findings revealed that OEL positively influenced students' understanding of the nature of experimental physics and resulted in significantly higher scores compared to students in courses using only traditional guided labs, both pre- and post-instruction ($p \ll 0.01$).

Bolong, N., Saad, I., Zakaria, S.N.F (2025), Assessing the Impact of the Non-Physical Laboratory Approach on Open-Ended Environmental Laboratory Practice, *ASEAN Journal of Engineering Education*, 9(2), 81-87. https://doi.org/10.11113/ajee2025.9n2.164

Implementation of online-OEL supported by the Problem-Based Learning educational model, that emphasizes student-centred learning through engagement with authentic, ill-structured problems. In combination to Kolb's Experiential Learning Theory, it involves four-stage learning cycle: experience, reflective observation, abstract conceptualization and active experimentation, particularly when transitioning between traditional and virtual laboratory formats (Kolb, 1984)

Particularly in environmental engineering laboratories, open-ended approaches are vital to bridge the gap between theory and real-world applications, encouraging students to think critically, design their experiments, and develop innovative solutions related to environmental problems. Some of the key characteristics of open-ended laboratories are based on the aspect of problem-based learning, whereby learners were challenged to think critically, provide creative solutions and have freedoms to design their experiments. Furthermore, according to McCrory et al. (2020), laboratories have the capability for sustainability transition transformation approaches and provide a basis for case-based comparisons. Engineering education is changing rapidly due to the rapid growth of new technologies and the adoption of modern education methods (Kim et al., 2023); hence online learning in engineering is not new and can be applied in courses like laboratory subjects. The COVID-19 pandemic has also enforced a global need for online teaching/learning opportunities. UNESCO states that more than 1.5 billion students worldwide have been affected due to closures and educational changes (UNESCO, 2022). Various issues negatively influenced online engineering education, including logistical/technical problems, learning/teaching challenges, privacy and security concerns, and insufficient hands-on training (Asgari et al., 2021).

Therefore, this paper examines the impact of online teaching on the OEL of environmental engineering laboratory courses, which are typically taught through face-to-face instruction. This study investigates the insights gained from empirical evidence and provides recommendations for addressing the challenges posed by COVID-19 until the recovery/post-pandemic period.

Methodology

The study aimed to analyze the impact of online teaching on the environmental engineering laboratory course. It assessed the effect of online teaching and learning of lab course during the Movement Control Order (MCO) and the transition to a combination of physical and online laboratory approaches on the learning experiences and outcomes of final-year undergraduate students taking the civil engineering environmental laboratory course over four consecutive cohorts. The cohorts were divided into three categories (Table 1).

Table 1. Cohort Category

Cohort ID	Categorisation
Cohort A	Physical Laboratory
Cohort B1 and B2	Hybrid Physical and Virtual Lab
Cohort C	Physical Laboratory

The laboratory sessions divided undergraduate students into small groups of four to five members. The purpose of this group arrangement was to encourage effective communication, teamwork, and peer discussions among the students throughout the laboratory investigation process until the technical journal report submission. The Environmental Laboratory introduced the open-ended lab (OEL) format during the regular course, which has been compared to traditional lab courses in our previous work (Bolong et al., 2014). As part of ongoing curriculum restructuring, and continuous quality improvement (CQI), assessments for Course Outcomes 4 (CO4) and 5 (CO5) were introduced starting with cohort B1. The course spanned fourteen consecutive weeks, with each session lasting three hours, focusing on the learning outcomes outlined below (Table 2).

Table 2. Course Learning Outcome (CO)

CO ID	Learning Outcome
CO1	Conduct experiments following standardised procedures and techniques to address environmental problems of water quality, air pollution, and noise pollution
CO2	Evaluate and interpret the experimental data; with proper justification on the experiments outcome
CO3	Effectively communicate technical concepts, procedures, and results to peers and instructors, using precise and appropriate scientific terminology
CO4	Function effectively as an individual and as a member or leader of a team
CO5	Adhere to lab protocols, including proper attire, maintaining cleanliness and adhering to safety regulations.

Due to the educational institutions were closed due to the coronavirus pandemic and the Movement Control Order (MCO) enforcement, a modified approach combining partial physical laboratory work and online components was implemented to adapt to the situation. It includes online video demonstrations of relevant instruments, utilizing secondary data from available local websites (such as published air quality data based on collection stations), and utilizing mobile phones for noise measurement in students' respective houses. Starting from chort B1, CO4 is evaluated using peer assessment, highlighting its relevance to collaborative learning and critical assessment between members. Whereas CO5 employs online test after reviewing video resources based on laboratory safety and protocols to ensure foundational knowledge prior practical activities. Table 3 summarizes the transition and changes in the implementation of the OEL.

Table 3. Comparison of Laboratory Course Delivery and Assessment Approaches Between Cohorts A, B and C

Course outcome	Cohort A (n=53)	Cohort B1 (n=53) and B2 (n=56)	Cohort C (n=67)
CO1	Laboratory work (Experiment design)	**Secondary data and lab work**	Laboratory work (Experiment design)
CO2	Discussions and presentation (physical)	Discussions and presentations **(online)**	Discussions and presentation (physical)
CO3	Written report in journal format	Written report in journal format	Written report in journal format
CO4	Not applicable	Peer assessment and observation	Peer assessment and observation
CO5	Not applicable	Safety test	Observation and Safety test

The study employed a combination of direct and indirect measurement approaches to assess learners' achievement and investigate the effects of transitioning from a physical to a partially online laboratory system. The analysis of the factors listed in Table 4 provided a comprehensive empirical evaluation of how the instructional methods influenced the attainment of course outcomes and the effectiveness of implementation strategies.

Table 4. Factors employed for data analysis

Data analysis factor	**Measurement indicator**	**Quantification Unit**
Course learning outcomes (COs)	Student continuous assessment. *direct measurement method	Evaluation marks indicator from <u>'Very poor' to 'Very Good.'</u> *Very poor: 0 to 19* *Poor: 20 to 39,* *Satisfactory: 40 to 59* *Good: 60 to 79, and* *Very good: 80 to 100*
Student perception feedback (CO perception)	Based on self-rating on the course outcome questionnaire. **indirect measurement	<u>Likert scale</u>: rate 1 to 4 (1-poor and 4-Very good)
Course evaluation	The institution's quality academic survey (PK07) that conducted to gather feedback from students regarding the implementation of the course. **indirect measurement	Item rating <u>Likert 1 to 5</u> and averaged based on: 1) Facility (equipment and learning management) 2) Learning outcome (knowledge, competency) 3) Soft skills attainment (communication, critical thinking, life-long learning, etc.)

The direct measurement used the attainment of course outcomes to measure student performance. Course outcomes, also known as learning outcomes or learning objectives, specify the knowledge, skills, or competencies that students are expected to acquire or demonstrate by the end of a course. The direct measurement of course outcomes involved assessing students' performance through various means such as practical assessments, laboratory reports, lab exams/tests, and observation/performance assessments. These assessments evaluated students' understanding, application of concepts, practical skills, and critical thinking abilities.

In addition to the direct measurement methods, this study incorporated two indirect measurement approaches to gather student feedback and perceptions. These methods included student perception feedback surveys and course evaluation surveys, which provided at the semester's end. The perception survey utilized an average arithmetic calculation of all rating scales to obtain a comprehensive overview of student evaluation.

The first indirect measurement method was the student perception feedback survey, which assessed students' self-perception of their attainment in the lab course. This survey allowed students to reflect on their achievements and provide feedback on their learning experiences. The survey captured their subjective perceptions of their performance and progress in meeting the course outcomes, in a likert-scale rating from 1 to 4, represented based on poor (1) to very good (4), coded comparable to grade pointer expected for respective outcomes.

The second indirect measurement method involved administering the university's quality academic course survey, a compulsory evaluation completed by all students. This survey provided a broader perspective on the course covering aspects such as teaching quality, course materials, assessments, and overall satisfaction. Together, these methods offered a comprehensive and structured view of student experiences, which were then analyzed qualitatively to enrich the study's findings and ensure consistency in interpreting the data.

Results and Discussion

The analysis of quantitative data regarding student performance in open-ended environmental laboratories is presented in Figure 1a (CO1-3) and Figure 1b (CO4-5). The achievement of course outcomes is influenced by the assessment approach employed. Hence a comparison was made between the attainment of the different cohorts based on the assessment of course outcomes. In open-ended laboratories (OEL), certain key elements are crucial. These elements include delivering laboratory assessments that enable students to design and execute experiments, analyze and interpret data, and collaborate effectively within a group setting (Azida et al., 2018). Therefore, this study measured the attainment of course outcomes (COs) by assessing students' knowledge, skills, and competencies in conducting water quality testing, air quality determination, and noise measurement; in terms of, i.e., CO1-experimental design, CO2-analysis, CO3-journal, CO4-team, and CO5-safety. The course implemented an open-ended laboratory approach, wherein students were tasked with designing and executing their experiments centered around environmental topics, specifically focusing on water, air, and noise. These learning experiences aim to equip students with the necessary skills to tackle the intricate challenges associated with sustainable infrastructure development and environmental measurement impact.

The open-ended laboratory approach aimed to foster students' critical thinking skills and encourage independent problem-solving by requiring them to develop testing instructions and strategies while demonstrating appropriate reasoning, knowledge background, and logical justification. While designing their experiments, students were also required to consider and adhere to relevant testing standards and guidelines. The laboratory work played a crucial role in helping students understand environmental issues by providing them with hands-on experiences in conducting experiments and tests related to real-world problems such as water quality, air, and noise pollutant issues. Specifically, in determining water quality testing and analysis, assess air pollution and noise problems by correlating to the required local and community standards and regulations. This approach allowed students to apply their theoretical knowledge and practical skills to address environmental challenges.

As shown in Figure 1a, for the evaluation of experiment design (CO1), there was an observed increase in the 'good' achievement trend, despite the challenges posed by online work. Cohort C demonstrated a return to normalcy and adaptation to the physical learning environment. In the case of lab analysis (CO2), attainment in the 'very good' category was initially high during ordinary situations. However, during partial lab work due to the Movement Control Order (MCO) (for cohort B1), the attainment became more varied, possibly due to reduced engagement among learners and the course instructor compared to face-to-face labwork (before MCO).

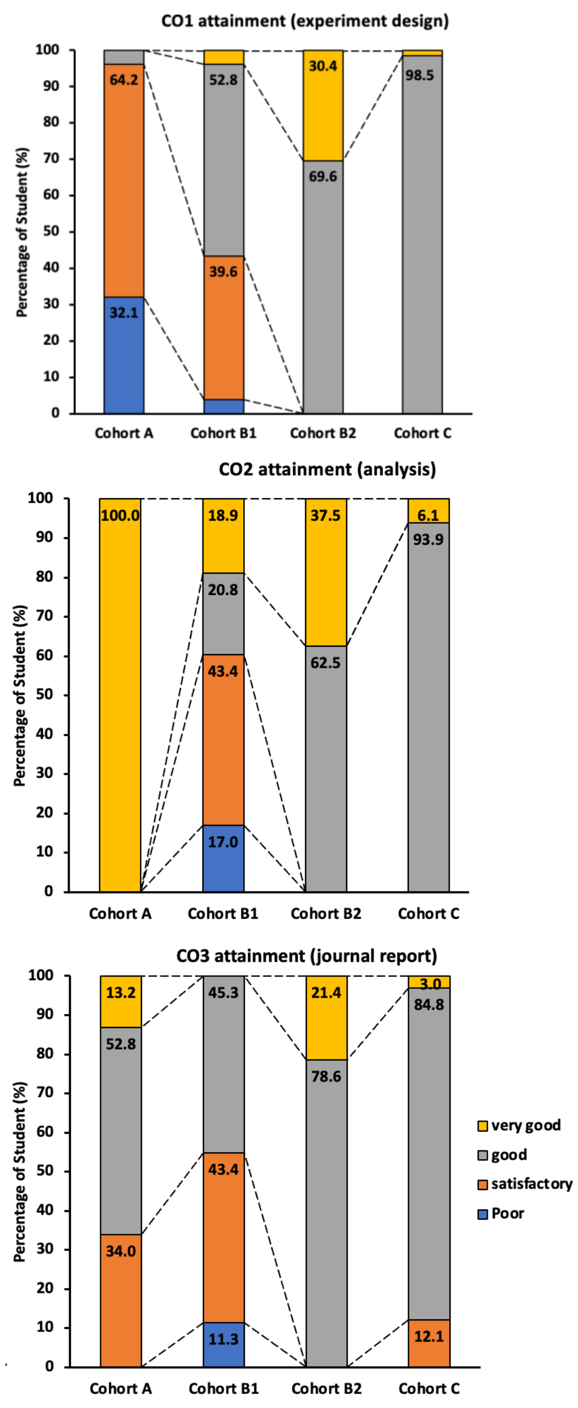


Figure 1a. Attainment of different cohorts based on course outcomes assessment (CO1, CO2, CO3).

Nevertheless, most students still achieved the 'good' category and showed improvement in subsequent years. Interestingly, cohort B1, which experienced partial physical lab work, attained higher levels of 'very good' compared to the following year of physical lab work (cohort C), indicating a potential adjustment period during the post-pandemic phase. Regarding the course outcome for the journal report (CO3), most students achieved the 'good' category. Still, there was a slight reduction during partial physical lab work (cohort B1), followed by an increase in the subsequent year.

Considering the three course outcomes (CO1, CO2, and CO3), it is evident that the initial online lab implementation resulted in lower and more varied levels of attainment compared to the previous typical year. Hands-on laboratory activities reinforce learning, and transitioning to virtual or online classes presents challenges (Schneider et al., 2022). However, improvement was observed in the subsequent years. A hybrid learning approach, where students partially engage in on-campus laboratory experiences, work with equipment and components, and collaborate in teams, has shown positive results like other work (Sarwono and Lyau, 2023). Although the modification of fully hands-on laboratory work and physical engagement slightly affected student learning, improvements were observed once the lab implementation returned to regular, necessitating adjustments from both lecturers and students. Another study by Noor et al. (2023), made a similar observation, noting that most students performed well in the course after adjustments to their assessment methods and procedures. Additionally, implementing open-ended labs during partial virtual/lab as in this work, such as utilizing secondary data from meteorological stations and conducting noise measurements using mobile devices, presented opportunities for more creative assessments. This approach challenged teachers and learners to think critically beyond traditional equipment-based laboratory experiences.

Whereas for Figure 1b, the assessment of CO4 and CO5 was conducted only for the most recent three cohorts (B1, B2, and C), as program syllabus revision was implemented. Regarding CO4, using peer assessment and observation during partial lab work improved students' attainment, with the majority achieving the 'good' category. This indicates the effectiveness of peer assessment and remarks in enhancing students' performance and understanding of the subject matter.

Interestingly, concerning CO5, which pertains to lab rules and safety, there was a reduction in attainment in the 'very good' category. This could be attributed to the assessment method used for the online safety test, which may have provided a better grasp of the concepts compared to the actual safety test and observation during lab implementation. To address this, it is suggested to consider incorporating more practical and hands-on assessments for lab rules and safety to ensure a comprehensive understanding among students. This could involve conducting physical safety tests and providing opportunities for direct observation during lab sessions. By doing so, students will have a more accurate and practical understanding of lab rules and safety measures, leading to improved attainment in this course outcome.

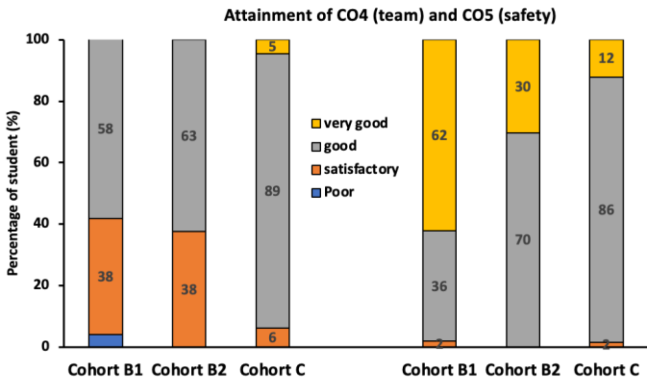


Figure 1b. Attainment of Cohort B and C; based on course outcomes assessment (CO4, CO5).

Comparing the results of indirect assessment through the Student Perception Feedback Survey with the students' learning attainment and course evaluation survey (PK07) revealed exciting trends, as depicted in Figure 2 and Figure 3.

Figure 2 illustrates that during the first year of the Movement Control Order (MCO), Cohort B1 experienced a decrease in students' self-achievement compared to the previous year (cohort A). However, Cohort B2 and Cohort C improved their confidence levels in the following years, as evidenced by an increased average rating.

Moreover, the student's course evaluation survey (Figure 3) demonstrated a constant improvement in feedback ratings. Students provided higher and more positive ratings, indicating an enhanced perception of the overall course. The implementation of open-ended laboratories (OEL) requires students to possess high levels of self-motivation and independence, indirectly cultivating their professional engineering skills (Haron et al., 2013). A comparative study between traditional and open-ended laboratories in the learning process has also shown that OEL improves students' understanding of the subject matter more effectively than conventional laboratories (Rahman et al., 2011). Additionally, OEL promotes student independence in learning, fosters creativity in problem-solving, and enhances teamwork and communication skills (Gowtham et al., 2020).

These findings suggest that while there was a temporary setback during the initial MCO year, subsequent cohorts demonstrated increased self-achievement and more positive perceptions of the course. It is crucial to analyze these trends further and identify the factors contributing to the observed improvements to enhance future educational practices.

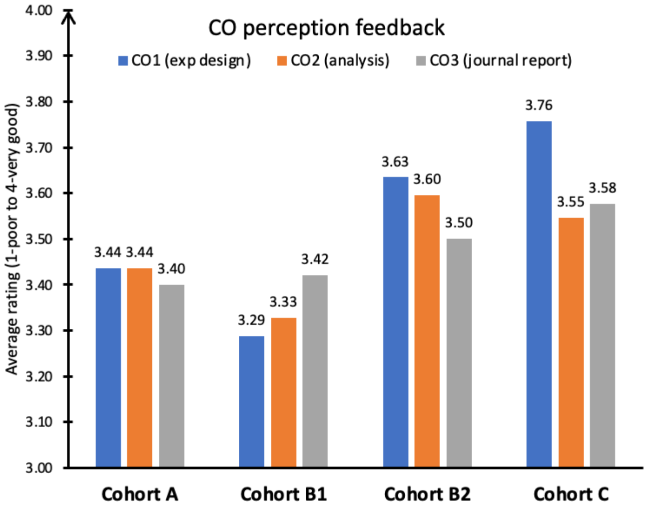


Figure 2. Student feedback survey on self-perceived achievement of course outcomes (COs).

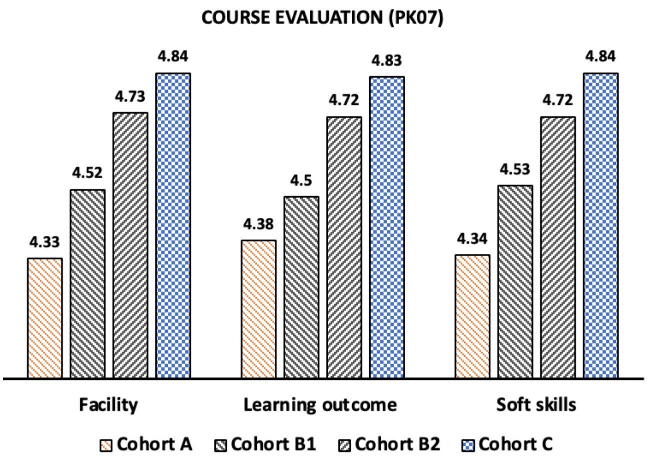


Figure 3. Course evaluation survey on facility quality, learning outcome achievement, and self-assessment of soft skills development.

Conclusion

Despite challenges and various limitations in the Open Ended environmental laboratory implementation for civil engineering undergraduates due to the disruption of the COVID-19 pandemic, the institution continued to ensure the best learning opportunities and strive for sustainable recovery. The empirical insight from the outcomes and experience in this study generally shows that the initial online or non-physical OEL (during MCO) implementation resulted in lower and more distributed attainment than the previous normal year (before MCO). However, improvement was observed in the later years when the lab implementation adjusted and returned to normal, highlighting the importance of hands-on laboratory work and physical engagement. Adjustments from both lecturers and students were necessary during the transition. Additionally, implementing open-ended labs during partial lab work fostered creative assessments and challenged critical thinking skills beyond traditional equipment-based laboratory experiences. Quantitative data analysis in open-ended environmental laboratories provides valuable insights into student performance and course outcomes. The assessment approach influences the attainment of course outcomes used.

Additionally, this study also holds transformative potential not only for environmental engineering but also for the broader spectrum of engineering education. The study highlights the ongoing relevance of virtual lab environments and adaptive pedagogical strategies in today's educational landscape. As educational needs and technological capabilities continue to evolve, integrating diverse, flexible, and globally-informed approaches remains critical for equipping students with practical skills in a digital-first world. The findings also contribute to the broader discourse on modernizing lab-based learning, demonstrating that innovative virtual solutions play a vital role in addressing accessibility and fostering hands-on learning experiences across diverse educational contexts. As educational institutions increasingly embrace technology-driven solutions, hybrid models offer a sustainable framework to enhance engagement, promote interdisciplinary learning, and equip students with the adaptive skills necessary for a rapidly evolving world. Emphasizing these possibilities aligns the study with emerging trends in educational technology, underscoring its significance in modernizing engineering and broader educational practices.

To further enhance student learning in open-ended environmental engineering laboratories and the inclusiveness of continuous quality improvements, the following was recommended:

- The positive insight in online lab implementation provides a better opportunity to explore interactive laboratory and virtual lab platforms and utilize remote data collection methods.
- Strengthen practical engagement by reinforcing hands-on laboratory work through active participation and exploration to deepen students' comprehension and skill development.
- Innovative assessment methods should be embraced by exploring diverse approaches to evaluation. For instance, virtual environmental monitoring simulations allow students to replicate environmental monitoring scenarios using tools such as GIS-based platforms. Students are required to design and execute virtual experiments to predict the outcomes of environmental changes, followed by submitting a written report or video explanation. However, this approach necessitates access to computational devices and specialized software, which can be costly and may present challenges in resource-constrained settings.

- Continuously improving and adapting the strategies based on student feedback and changing education needs is vital. Regularly reviewing the effectiveness of the assessment methods and making necessary adjustments will ensure the course remains relevant and impactful to students.
- Incorporating open-ended environmental laboratories into the undergraduate civil engineering curriculum requires educators to reimagine their teaching methods, providing students with meaningful experiences that prepare them for the complex challenges of sustainable infrastructure development and environmental stewardship. By fostering sustainable engineering practices, these open-ended laboratories contribute to attaining the Sustainable Development Goals (SDGs).

Acknowledgement

The authors would like to express their sincere gratitude to Universiti Malaysia Sabah (UMS) for their continuous sponsorship and support, which has been instrumental in enabling the successful completion of this critical study. Special thanks are extended to the Civil Environmental Engineering laboratory staff, Ms. Dayang and Ms. Afini for their valuable assistance. The authors also extend their heartfelt appreciation to the reviewers for their insightful input and helpful suggestions.

Conflict of Interest Statement

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

References

Asgari, S., Trajkovic, J., Rahmani, M., Zhang, W., Lo, R. C., & Sciortino, A. (2021). An observational study of engineering online education during the COVID-19 pandemic. PLOS ONE, 16(4), e0250041.

Azida, A. A., Farina, M. N., Zuhaida, M. Z., Fauzi, B., & Hasbullah, H. M. (2018). Implementation of open-ended laboratory (OEL) in Environmental Engineering subject for Civil Engineering Diploma Program. International Journal of Asian Social Science, 8(4), 173-178.

Bolong, N., Makinda J., Saad I., (2014), Effect of Open-Ended Laboratory toward Learners Performance in Environmental Engineering Course: Case Study of Civil Engineering at Universiti Malaysia Sabah, World Academy of Science, Engineering and Technology, International Journal of Educational and Pedagogical Sciences Vol:8, No:8, 2014.

Gowtham, N., Shankar, S., & Gowda, S. (2020). Structured Evaluation of Laboratory Course Content for Better Attainment of Program Outcomes. Procedia Computer Science, 172, 869-874.

Haron, Z., Mohammad, S., & Sam, A. R. (2013). The Implementation of an Open-Ended Experiment in the Civil Engineering Laboratory. Procedia-Social and Behavioral Sciences, 102, 548-559.

Kim, J., Kim, K. S., Ka, J., & Kim, W. (2023). Teaching Methodology for Understanding Virtual Reality and Application Development in Engineering Major. Sustainability, 15(3), 2725.

Kofli, N. T., & Abd Rahman, N. (2011). The open-ended laboratory for measurement of communication skill for chemical/biochemical engineering students. Procedia-Social and Behavioral Sciences, 18, 408-414.

Kolb, D. A. (2015). Experiential learning: Experience as the source of learning and development, Prentice Hall, Pearson.

Kolil, V.K., Achuthan, K. Virtual labs in chemistry education: A novel approach for increasing student's laboratory educational consciousness and skills. Educ Inf Technol (2024).

McCrory, G., Schäpke, N., Holmén, J., & Holmberg, J. (2020). Sustainability-oriented labs in real-world contexts: An exploratory review. Journal of Cleaner Production, 277, 123202.

Noor, S. N. A. M., Lat, D. C., Yusof, D. A. M., Rahman, N. S. A., & Zainuddin, A. N. (2023). Transformation of Delivery and Assessment for Laboratory Course During Covid-19 Pandemic: The Case Study of Soil Engineering Laboratory. International Journal of Academic Research in Progressive Education and Development, 12(1), 69–82.

Rahman, N. A., Kofli, N. T., Takriff, M. S., & Abdullah, S. R. S. (2011, April). Comparative study between open ended laboratory and traditional laboratory. In 2011 IEEE Global Engineering Education Conference (EDUCON) (pp. 40-44). IEEE.

Samarakou, M., Fylladitakis, E. D., Prentakis, P., & Athineos, S. (2014). Implementation of Artificial Intelligence Assessment in Engineering Laboratory Education. International Association for the Development of the Information Society.

Sarwono. E. and Lyau, N-M (2023). Virtual Labs in Electrical Engineering Education During the Covid-19 Pandemic: A Systematic Literature Review. Proceedings of the 4th Vocational Education International Conference (VEIC 2022), Atlantis Press, 52 (59), 2352-5398.

Schneider, J., Felkai, C., & Munro, I. (2022). A Comparison of Real and Virtual Laboratories for Pharmacy Teaching. Pharmacy 2022, 10, 133.

UNESCO, (2023) COVID-19: Education - from school closure to recovery. United Nations Education, Scientific and Cultural Organization (UNESCO). https://en.unesco.org/covid19/educationresponse

Wilcox, B. R., & Lewandowski, H. J. (2016). Open-ended versus guided laboratory activities: Impact on students' beliefs about experimental physics. Physical Review Physics Education Research, 12(2), 020132.

ABET Accreditation in Europe: A Comparative Analysis

Mohammed Mujahid Ulla Faiz [a*]***, Sai Kiran Oruganti*** [a]***, Ganesh Khekare*** [b]

[a]*Lincoln University College, Petaling Jaya, 47301, Selangor, Malaysia*
[b]*Vellore Institute of Technology, Vellore, 632014, Tamil Nadu, India*
**pdf.mujahidullafaiz@lincoln.edu.my*

Article history
Received
13 July 2025
Received in revised form
25 October 2025
Accepted
27 October 2025
Published online
27 December 2025

Abstract

Accreditation serves as a critical marker of educational quality, with ABET representing a global benchmark in engineering and technology. While European nations maintain robust national accreditation systems, a strategic pursuit of ABET accreditation by select institutions persists. This study presents the first comprehensive, quantitative analysis of ABET-accredited programs across eight European nations, employing a structured benchmarking framework to move beyond descriptive counts. Our analysis reveals that ABET adoption in Europe is a targeted strategy for international differentiation rather than a broad quality assurance measure. This is evidenced by the overwhelming dominance of Engineering Accreditation Commission (EAC) programs (94.34%), a complete absence of Engineering Technology Accreditation Commission (ETAC) accreditation, and a high concentration of programs in elite technical universities in Turkey and Spain. Furthermore, historical data underscores the challenge of sustaining accreditation, highlighting the long-term resource commitment required. The European experience offers valuable lessons for global stakeholders, particularly in emerging educational hubs in the Association of Southeast Asian Nations (ASEAN) region, demonstrating that ABET functions most effectively as a complementary, top-tier credential within a multi-layered quality assurance ecosystem.

Keywords: ABET, Accreditation, Engineering, Technology, Europe, Benchmarking, Internationalization.

Introduction

Quality education is a core aspiration of the United Nations' Sustainable Development Goals, and program accreditation is an internationally accepted mark of academic excellence (United Nations, n.d.). An intense peer-review process, accreditation guarantees programs to be of acceptable international quality, but to remain accredited involves sustained quality enhancement through regular evaluations. Among numerous accrediting agencies, ABET has become the gold standard for quality assurance especially in engineering and technology programs globally.

European nations have established varied methods of quality assurance. Portugal has adopted a double accreditation system with compulsory institutional evaluation and the EUR-ACE quality seal for engineering degrees (Rocha et al., 2010). Spain has some special challenges, with certain Higher Education Institutions (HEIs) seeking ABET accreditation at the expense of money, internal imbalance, etc. while others support having a national-level EUR-ACE quality seal (Suarez et al., 2011). Germany's decentralized system is plagued by fragmentation and lack of alignment with measures of institutional quality, generating a lack of transparency (Kehm, 2013). Portugal's A3ES agency is a model of a centralized program evaluation (Reis et al., 2014), whereas the Netherlands' system is an implementation of New Public Management (NPM) doctrine in its political, institutional, and operational aspects (Enders & Westerheijden, 2014).

The implementation of quality assurance systems usually runs concurrently with other educational reforms. Spain's new accreditation system evolved concurrently with its transition to the European degree system (Ríos, 2015). Portugal exhibits partial compliance with European faculty quality standards (Cardoso et al., 2015), while Turkey has made substantial though unfinished improvements in quality management, as seen in a wide-ranging institutional survey (Eryılmaz et al., 2016). Comparative analyses identify Poland's tighter integration with ESG 2015 than Ukraine's continuous adaptation (Mazurkiewicz et al., 2017), while the Dutch-Flemish systems evidence post-convergence divergence despite their common NVAO framework (Bakhuis, 2019).

Professional quality assurance issues continue in varied educational environments. Spanish higher education institutions struggle with creating useful models of assessment for e-learning (Marciniak, 2018), and engineering schools globally need to include both microethical and macroethical aspects within their curriculum, with cultural background playing an important role in pedagogical strategies (Polmear et al., 2019). Quality assurance development in Turkey has a well-defined policy cycle from formulation to

Faiz, M.M.U., Oruganti, S.K., & Khekare, G. (2025), ABET Accreditation in Europe: A Comparative Analysis, *ASEAN Journal of Engineering Education*, 9(2), 88-95. https://doi.org/10.11113/ajee2025.9n2.194

implementation (Yilmaz, 2019), whereas Georgia's reforms are mainly based on EU association agreements (Amashukeli et al., 2020). Austrian theory is best explained using historical-pedagogical description and structural-functional modeling (Mukan et al., 2020).

Large-scale educational reform efforts attest to the worldwide significance of quality assurance. Georgia's reforms in STEM education, underwritten by substantial U.S. investment through the Millennium Challenge Corporation, illustrate the international scope of quality improvement efforts (Goldman et al., 2021). Institutionally, studies using the DEMATEL method have found continuous quality improvement and program educational objectives to be the most important ABET criteria, while documentation culture and academic excellence were found to be less significant (Dursun et al., 2024).

While this study's primary data is geographically focused on Europe, its analytical framework and findings are designed for global relevance, with particular implications for emerging educational hubs in the Association of Southeast Asian Nations (ASEAN) region. European nations, with their well-established national accreditation systems (e.g., EUR-ACE), provide a critical case study for understanding why institutions voluntarily pursue additional, resource-intensive international accreditation like ABET. For ASEAN nations, which are actively harmonizing educational standards (e.g., through the ASEAN University Network-Quality Assurance) while competing for global talent and prestige, the European experience offers valuable lessons. Analysing the strategic drivers behind ABET adoption in a mature educational market like Europe can illuminate potential pathways, challenges, and strategic considerations for ASEAN institutions seeking to enhance their international visibility and graduate competitiveness.

Related Work

Existing research on ABET accreditation in Saudi Arabia reveals distinctive patterns at both institutional and regional levels. Study (Faiz & Almutairi, 2015) documented all ABET-accredited programs (associate to master's) in Saudi institutions as of 2015, identifying a unique concentration in specialized fields like aerospace engineering and biomedical technology—disciplines unaccredited in neighbouring Gulf Cooperation Council (GCC) countries. By 2021, follow-up research (Faiz & Almutairi, 2021) showed a threefold expansion of accredited bachelor's programs, while confirming King Fahd University of Petroleum & Minerals (KFUPM) as the sole institution maintaining ABET accreditation across all degree levels (Faiz & Almutairi, 2015).

Saudi quality assurance studies span multiple scales, from course-level evaluations (Faiz et al., 2014; Faiz & Almutairi, 2015) to program-wide assessments (Faiz & Almutairi, 2021a, 2021b; Faiz, 2023). This work is complemented by recent regional comparisons of GCC, non-GCC, Canadian, and Russian accreditation practices (Faiz et al., 2025a, 2025b, 2025c), which methodologically mirror the approach of the present study.

European ABET research, by contrast, suffers from three persistent gaps: (1) institution- or nation-specific focus, (2) disproportionate representation of faculty-authored case studies on ABET accreditation processes, and (3) lack of comprehensive cross-border analysis—a critical omission given the rising influence of international accreditation standards in higher education quality frameworks.

Methodology

The data for the master's degree programs listed in Table 1 were collected and analyzed according to the following procedure, using the ABET accreditation portal (ABET, 2025):

1. Navigate to the ABET accreditation portal at: https://amspub.abet.org/aps/category-search.
2. Apply the following filters in the drop-down menus:
   - **Commissions:** All Commissions
   - **Lead Societies:** All Lead Societies
   - **Disciplines:** All Disciplines
   - **Degree Level:** Master Degree
   - **Country:** Select each country individually (e.g., Spain), as listed in Table 1.
3. Ensure the following options are unchecked:
   - "Include institutions with historically accredited programs"
   - "Include programs available 100% online"
4. Click the "Export" button and select the "All" option to download the results into an Excel file for analysis.
5. In the downloaded Excel file, count the number of active master's programs by reviewing the appropriate data column.
6. Before querying the next country, click the "Reset" button to clear all previous filters.

This procedure was repeated to collect and analyze the data for all subsequent tables, adjusting the selections in the drop-down menus and checkboxes as required.

Comparative Analysis

To enable a comparative analysis, a benchmarking framework was developed based on the structure of the ABET criteria itself. The analysis proceeds across four key dimensions identified within the data:

1. **Scale and Concentration:** Benchmarking the volume and institutional concentration of

accredited programs to identify leaders and outliers.
2. **Programmatic Focus:** Analyzing the distribution of programs across the four ABET's commissions to reveal strategic priorities and alignment with national strengths.
3. **International Alignment:** Assessing participation in international mutual recognition agreements (e.g., Seoul Accord) as an indicator of global integration beyond the ABET seal itself.
4. **Sustainability and Volatility:** Examining historical accreditation data to gauge the long-term stability and challenges of maintaining ABET compliance.

This framework allows for a systematic cross-national comparison that moves beyond mere counts to interpret the strategic choices and outcomes of ABET accreditation in the European context.

Table 1 (ABET, 2025) displays the count of ABET-accredited programs in European countries as of 2025. Among the eight countries listed, Georgia and Turkey are transcontinental. According to the table, Turkey has the highest number of ABET-accredited bachelor's degree programs, followed by Spain, which leads in ABET-accredited master's degree programs.

Notably, the majority of Turkey's ABET-accredited bachelor's programs are concentrated at Istanbul Technical University (25), while Middle East Technical University offers 19 such programs across its Ankara and Northern Cyprus campuses. Similarly, in Spain, Universidad Politécnica de Madrid offers the highest number of ABET-accredited bachelor's programs (13), while Universitat Politècnica de València leads in master's programs (5).

It should also be noted that none of the listed European countries provide ABET-accredited associate degree programs.

Table 1. Number of active ABET-accredited programs in European countries (2025)

Countries	**Associate**	**Bachelor's**	**Master's**
Austria	0	1	0
Georgia	0	4	0
Germany	0	0	0
Netherlands	0	2	0
Poland	0	4	1
Portugal	0	1	1
Spain	0	21	11
Turkey	0	73	0
Total	**0**	**106**	**13**

Table 2 (ABET, 2025) presents the number of higher education institutions offering ABET-accredited programs in European countries as of 2025. The data shows that Turkey has the highest number of institutions with ABET-accredited bachelor's degree programs, followed by Spain, which also leads in institutions offering ABET-accredited master's degree programs.

In Turkey, some ABET-accredited bachelor's programs include Aeronautical Engineering and Textile Engineering, among others. Similarly, in Spain, accredited bachelor's programs include Aerospace Engineering and Telematics Engineering, along with others.

Table 2. Number of higher education institutions offering ABET-accredited programs in European countries (2025)

Countries	**Associate**	**Bachelor's**	**Master's**
Austria	0	1	0
Georgia	0	3	0
Germany	0	0	0
Netherlands	0	2	0
Poland	0	3	1
Portugal	0	1	1
Spain	0	4	4
Turkey	0	9	0
Total	**0**	**23**	**6**

Table 3 (ABET, 2025) displays the number of ABET-accredited programs in European countries that hold international mutual recognition agreements as of 2025. The data indicate that none of these countries have such agreements for associate or master's degree programs. At the bachelor's level, Poland leads with the highest number of ABET-accredited programs covered by international mutual recognition agreements. Notably, all four ABET-accredited bachelor's degree programs in these countries are recognized exclusively under the Seoul Accord, as highlighted in Table 3. It should also be noted that while Turkey and Spain collectively host the highest number of ABET-accredited bachelor's degree programs, none of these programs from either country have international mutual recognition agreements.

Table 3. Number of ABET-accredited programs covered by international mutual recognition agreements in European countries (2025)

Countries	Associate	Bachelor's	Master's
Austria	0	0	0
Georgia	0	1	0
Germany	0	0	0
Netherlands	0	0	0
Poland	0	2	0
Portugal	0	1	0
Spain	0	0	0
Turkey	0	0	0
Total	**0**	**4**	**0**

Table 4 (ABET, 2025) outlines the accreditation commissions responsible for ABET-accredited programs in European countries as of 2025. The table shows that three out of the four ABET accreditation commissions oversee accreditation activities at both bachelor's and master's degree levels in these countries. These commissions are: the Applied and Natural Science Accreditation Commission (ANSAC), the Computing Accreditation Commission (CAC), and the Engineering Accreditation Commission (EAC).

Table 4. Recognized accreditation commissions overseeing ABET-accredited programs in European countries (2025)

Countries	Associate	Bachelor's	Master's
Austria	-	EAC	-
Georgia	-	CAC, EAC	-
Germany	-	-	-
Netherlands	-	ANSAC	-
Poland	-	CAC, EAC	EAC
Portugal	-	CAC	EAC
Spain	-	EAC	EAC
Turkey	-	EAC	-

Table 5 (ABET, 2025) presents the number of ABET-accredited programs under ANSAC in European countries as of 2025. The data show that the Netherlands is the only country among these nations that hosts ANSAC-accredited bachelor's degree programs. Also, ANSAC-accredited programs constitute only 1.89% of all ABET-accredited programs in the 8 European countries compared.

Table 5. Number of ANSAC-evaluated ABET-accredited programs in European countries (2025)

Countries	Associate	Bachelor's	Master's
Austria	0	0	0
Georgia	0	0	0
Germany	0	0	0
Netherlands	0	2	0
Poland	0	0	0
Portugal	0	0	0
Spain	0	0	0
Turkey	0	0	0
Total	**0**	**2**	**0**

Table 6 (ABET, 2025) displays the number of ABET-accredited programs under CAC in European countries as of 2025. In Poland, the two CAC-accredited programs are Computer Science and Information Technology. Similarly, in Georgia and Portugal, the accredited programs are Computer Science and Information Systems, respectively. Also, CAC-accredited programs constitute only 3.77% of all ABET-accredited programs in the 8 European countries compared.

Table 6. Number of CAC-evaluated ABET-accredited programs in European countries (2025)

Countries	Associate	Bachelor's	Master's
Austria	0	0	0
Georgia	0	1	0
Germany	0	0	0
Netherlands	0	0	0
Poland	0	2	0
Portugal	0	1	0

Spain	0	0	0
Turkey	0	0	0
Total	**0**	**4**	**0**

Table 7 (ABET, 2025) presents the number of ABET-accredited programs under EAC in European countries as of 2025. The data show that Turkey has the highest number of EAC-accredited bachelor's degree programs, while Spain leads in EAC-accredited master's degree programs. Also, EAC-accredited programs constitute 94.34% of all ABET-accredited programs in the 8 European countries compared.

Table 7. Number of EAC-evaluated ABET-accredited programs in European countries (2025)

Countries	Associate	Bachelor's	Master's
Austria	0	1	0
Georgia	0	3	0
Germany	0	0	0
Netherlands	0	0	0
Poland	0	2	1
Portugal	0	0	1
Spain	0	21	11
Turkey	0	73	0
Total	**0**	**100**	**13**

Table 8 (ABET, 2025) presents data on historically ABET-accredited programs in European countries as of 2025. The historical data show that Turkey has the highest number of previously accredited bachelor's programs, while Spain has the highest number of previously accredited master's programs.

Table 8. Historically ABET-accredited programs in European countries (2025)

Countries	Associate	Bachelor's	Master's
Austria	0	0	0
Georgia	0	0	0
Germany	0	0	1
Netherlands	0	0	0
Poland	0	0	0
Portugal	0	0	0
Spain	0	1	5
Turkey	0	8	0
Total	**0**	**9**	**6**

Table 9 (ABET, 2025) displays the number of higher education institutions with historically ABET-accredited programs in European countries as of 2025. The data show that Germany and Spain are tied, with one institution in each country offering historically accredited programs: a bachelor's degree program in Spain and a master's degree program in Germany.

Table 9. Institutions with historical ABET accreditation in European countries (2025)

Countries	Associate	Bachelor's	Master's
Austria	0	0	0
Georgia	0	0	0
Germany	0	0	1
Netherlands	0	0	0
Poland	0	0	0
Portugal	0	0	0
Spain	0	1	2
Turkey	0	3	0
Total	**0**	**4**	**3**

While the majority of Turkey's current ABET-accredited bachelor's programs are concentrated at Istanbul Technical University (25), it has only one historically accredited bachelor's program. This contrasts with Bogazici University, which has six of Turkey's eight historically accredited bachelor's programs.

Figure 1 illustrates the percentage distribution of ABET-accredited programs in European countries as of 2025. As shown in the figure, Turkey accounts for the highest percentage of active ABET-accredited bachelor's degree programs, while Spain holds the highest percentage of active ABET-accredited master's degree programs.

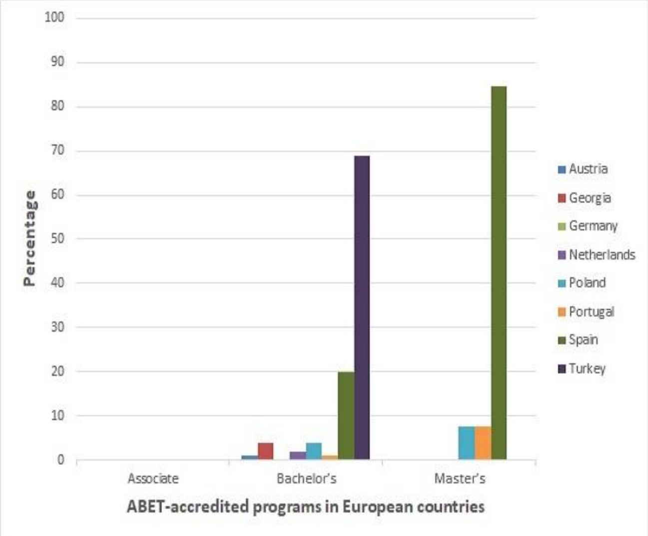


Figure 1. Percentage of ABET-accredited programs in European countries (2025)

Figure 2 presents the percentage distribution of historically ABET-accredited programs in European countries as of 2025. The figure shows that Turkey accounts for the highest proportion of historically ABET-accredited bachelor's degree programs, while Spain represents the highest percentage of historically ABET-accredited master's degree programs.

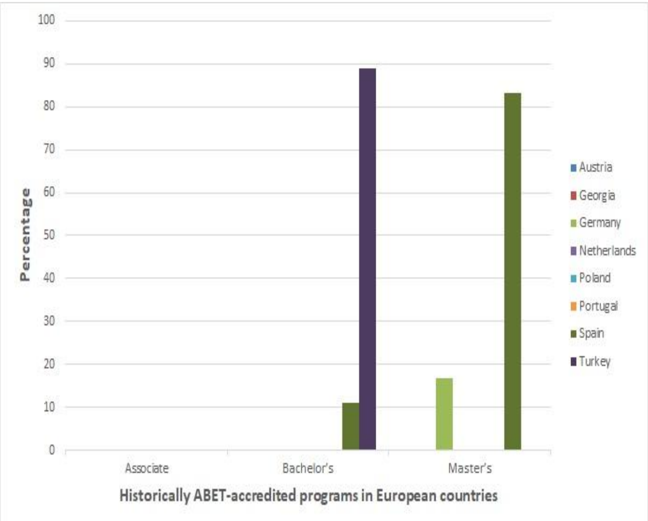


Figure 2. Percentage of historically ABET-accredited programs in European countries (2025)

The quantitative dominance of EAC-accredited programs (94.34%) and the complete absence of ETAC accreditation reveal a strategic prioritization within European ABET-seeking institutions. This pattern suggests that European HEIs pursue ABET not for technical or vocational program validation, which is likely covered by robust national frameworks, but specifically to gain a competitive edge in the globalized market for traditional engineering education. The concentration of accredited programs in a few countries (notably Turkey and Spain) and a handful of elite technical universities further indicates that ABET accreditation is a resource-intensive strategy employed by specific institutions aiming to signal international comparability and attract a global student body and faculty. Moreover, the scarcity of programs under international mutual recognition accords (only 3.77% under the Seoul Accord) highlights a potential misalignment or a lack of perceived need to integrate ABET's outcomes-based approach with other global qualification frameworks, underscoring that for most European institutions, ABET serves as a standalone mark of excellence rather than a component of a broader international credentialing strategy.

Discussion and Implications

This study's quantitative findings, when analyzed through the proposed framework, reveal distinct strategic models of ABET engagement in Europe, offering lessons for global audiences, including ASEAN countries.

1. **Strategic Accreditation as a Niche Differentiator:** The overwhelming dominance of EAC accreditation (94.34%) and its concentration in elite technical universities in Turkey and Spain suggests that ABET is not used for foundational quality assurance, a role filled by national agencies, but as a strategic tool for *international differentiation*. For ASEAN institutions, this underscores that ABET accreditation is likely not a mass-quality solution but a high-investment, high-reward strategy for flagship engineering programs aiming to compete for international students and research partnerships.
2. **The Limited Role of Technology and Computing Accreditation:** The complete absence of ETAC-accredited programs and the low share of CAC programs indicate a European alignment where "engineering" (EAC) holds more global prestige than "engineering technology" (ETAC). This presents a strategic consideration for ASEAN countries, where polytechnics and universities of applied sciences might find more value in ETAC. The choice of commission signals a specific institutional identity to the global market.
3. **Insights on Sustaining Accreditation:** The historical data revealing lapsed accreditations, particularly in Spain (5 master's programs) and Turkey (8 bachelor's programs), serves as a critical warning. It highlights the significant, ongoing resource commitment required beyond initial certification. For ASEAN policymakers and university leaders, this emphasizes the need for long-term financial and administrative planning, ensuring that the pursuit of accreditation is coupled with a sustainable plan for its maintenance.

4. **Broader Relevance for ASEAN Quality Assurance:** The European experience demonstrates that ABET accreditation coexists with, rather than replaces, robust regional (EUR-ACE) and national quality assurance systems. For ASEAN, which is developing its own quality assurance paradigms, this suggests that international accreditations like ABET can be a complementary, top-tier layer within a multi-level quality ecosystem, rather than a substitute for developing strong regional and national standards.

Conclusions

This study, employing a structured benchmarking analysis, has provided the first comprehensive overview of ABET accreditation in Europe, moving beyond descriptive counts to reveal the strategic rationales behind its adoption. Our findings demonstrate that ABET accreditation is not a broad-based quality assurance tool in Europe but a targeted, resource-intensive strategy for international differentiation. The overwhelming dominance of EAC accreditation (94.34%), coupled with its concentration in elite technical universities in Turkey and Spain, underscores its role as a niche marker of excellence aimed at enhancing global competitiveness and attracting talent. The complete absence of ETAC accreditation further signals that European institutions leverage ABET to validate traditional engineering programs, not to certify technology-focused curricula.

The analysis of historical data serves as a critical warning, revealing that the challenge of accreditation lies not only in its initial achievement but in its long-term sustainability. The significant number of lapsed programs in key countries highlights the substantial, ongoing commitment required. For global observers, particularly in regions like ASEAN, the European experience offers a clear lesson: pursuing ABET accreditation is a strategic decision that must be coupled with a sustainable, long-term plan for institutional support and resource allocation. Ultimately, this study illustrates that in mature educational ecosystems with robust national accreditation systems, ABET functions not as a replacement but as a complementary, top-tier credential for institutions seeking a distinct advantage in the globalized education market. These insights provide a valuable, evidence-based framework for institutions and policymakers worldwide when evaluating the strategic value of international accreditation.

Acknowledgement

The support provided by Lincoln University College, Malaysia is gratefully acknowledged by the authors.

Conflict of Interest Statement

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

References

ABET. (n.d.). *ABET accreditation*. https://amspub.abet.org/aps/category-search

Amashukeli, M., Lezhava, D., & Chitashvili, M. (2020). "Conditioned" quality assurance of higher education in Georgia: Talking the EU talk. *TalTech Journal of European Studies, 10*(2), 75–95. https://doi.org/10.1515/bjes-2020-0016

Bakhuis, J. (2019). *From convergence to divergence: The development of higher education quality assurance approaches in the Netherlands and Flanders* [Master's thesis, University of Twente]. https://purl.utwente.nl/essays/77305

Cardoso, S., Tavares, O., & Sin, C. (2015). The quality of teaching staff: Higher education institutions' compliance with the European Standards and Guidelines for Quality Assurance—the case of Portugal. *Educational Assessment, Evaluation and Accountability, 27*, 205–222. https://doi.org/10.1007/s11092-015-9211-z

Dursun, M., Goker, N., & Ünal, M. (2024). Decision-making method for the evaluation of success factors of ABET accreditation. *WSEAS Transactions on Business and Economics, 21*, 2021–2025. https://doi.org/10.37394/23207.2024.21.164

Enders, J., & Westerheijden, D. F. (2014). The Dutch way of new public management: A critical perspective on quality assurance in higher education. *Policy and Society, 33*(3), 189–198. https://doi.org/10.1016/j.polsoc.2014.07.004

Eryılmaz, M. E., Kara, E., Aydoğan, E., Bektaş, O., & Erdur, D. A. (2016). Quality management in the Turkish higher education institutions: Preliminary findings. *Procedia - Social and Behavioral Sciences, 229*, 60–69. https://doi.org/10.1016/j.sbspro.2016.07.114

Faiz, M. M. U. (2023). Curricula comparison of mechanical engineering technology and similarly named programmes. *World Transactions on Engineering and Technology Education, 21*(1), 32–37. http://www.wiete.com.au/journals/WTE&TE/Pages/Vol.%2021,%20No.1%20(2023)/05-Faiz-M.pdf

Faiz, M. M. U., & Almutairi, M. S. (2015). Assessment of a cooperative training course using faculty course assessment report in an ABET accredited engineering technology program. Proceedings of the 45th ASEE/IEEE Frontiers in Education International Conference (FIE 2015) (pp. 1–7). El Paso, TX, USA. https://doi.org/10.1109/FIE.2015.7344403

Faiz, M. M. U., & Almutairi, M. S. (2015). Engineering education for a resilient society: A case study of the Kingdom of Saudi Arabia. Proceedings of the 2015 World Engineering Education Forum (WEEF 2015)/18th IEEE International Conference on Interactive Collaborative Learning (ICL 2015) (pp. 82–88). Florence, Italy. https://doi.org/10.1109/ICL.2015.7317983

Faiz, M. M. U., & Almutairi, M. S. (2021). Assessment of student outcomes of an electrical and electronics engineering technology programme: A case study. *Global Journal of Engineering Education, 23*(3), 231–

239. http://www.wiete.com.au/journals/GJEE/Publish/vol23no3/10-Faiz-M.pdf
Faiz, M. M. U., & Almutairi, M. S. (2021). Curricula comparison of electrical and electronics engineering technology and similarly named associate degree programmes. *World Transactions on Engineering and Technology Education, 19*(4), 384–391. http://www.wiete.com.au/journals/WTE&TE/Pages/Vol.%2019,%20No.4%20(2021)/07-Faiz-M.pdf
Faiz, M. M. U., & Almutairi, M. S. (2021). On the ABET accreditation of academic programs and rankings of universities in Saudi Arabia. Proceedings of the 2021 World Engineering Education Forum/Global Engineering Deans Council (WEEF/GEDC 2021) (pp. 270–276). Madrid, Spain. https://doi.org/10.1109/WEEF/GEDC53299.2021.9657262
Faiz, M. M. U., Mansoor, U. B., Asad, S. M., & Mahmood, K. (2014). Using faculty course assessment report for the assessment of an associate degree course in engineering technology program. *Proceedings of the 6th IEEE International Conference on Engineering Education (ICEED 2014)* (pp. 73–78). Kuala Lumpur, Malaysia. https://doi.org/10.1109/ICEED.2014.7194691
Faiz, M. M. U., Oruganti, S. K., & Khekare, G. (2025). A comparative analysis of ABET accredited programs in the GCC countries. *SGS - Engineering & Sciences, 1*(1), 1–8. https://spast.org/techrep/article/view/5231
Faiz, M. M. U., Oruganti, S. K., & Khekare, G. (2025). ABET accreditation in Canada and Russia – A study of contrasting trends. *SGS - Engineering & Sciences*, *1*(4), 1–8. https://spast.org/techrep/article/view/5587
Faiz, M. M. U., Oruganti, S. K., & Khekare, G. (2025). ABET-accredited programs in non-GCC Muslim-majority countries: A comparative study. *SGS - Engineering & Sciences*, *1*(2), 1–13. https://spast.org/techrep/article/view/5359
Goldman, C. A., Karam, R. T., Migacheva, K., Cefalu, M., Rico, M., & Giglio, K. (2021). *Georgia II STEM higher education interim evaluation report*. RAND Corporation. https://www.rand.org/content/dam/rand/pubs/research_reports/RRA300/RRA363-1/RAND_RRA363-1.pdf
Kehm, B. M. (2013). The German system of quality assurance and accreditation in higher education. *Scuola Democratica,* 4(2), 628–633. https://doi.org/10.12828/74733
Marciniak, R. (2018). Quality assurance for online higher education programmes: Design and validation of an integrative assessment model applicable to Spanish universities. *International Review of Research in Open and Distributed Learning,* *19*(2), 125–154. https://doi.org/10.19173/irrodl.v19i2.3443
Mazurkiewicz, M., Liuta, O., & Kyrychenko, K. (2017). Internal quality assurance system for the higher education: Experience of Ukraine and Poland. *Business Ethics and Leadership,* *1*(4), 74–83. http://essuir.sumdu.edu.ua/handle/123456789/66357
Mukan, N., Shyika, O., & Shyika, J. (2020). Quality assurance system of the university education in Austria. *Mountain School of Ukrainian Carpaty,* *23*, 26–31. https://doi.org/10.15330/msuc.2020.23.26-31
Polmear, M., Bielefeldt, A. R., Knight, D., Canney, N., & Swan, C. (2019). Analysis of macroethics teaching practices and perceptions in engineering: A cultural comparison. *European Journal of Engineering Education, 44*(6), 866–881. https://doi.org/10.1080/03043797.2019.1593323
Reis, C. S., Formosinho, M., & Lobo, C. C. (2014). Higher education in Portugal: From expansion to quality assessment. *The Online Journal of New Horizons in Education, 4*(4), 57–66. https://core.ac.uk/download/pdf/151538005.pdf
Ríos, C. (2015). Quality assurance in higher education in Spain: An overview of the accreditation system. *International Research and Review,* *5*(1), 25–45. https://eric.ed.gov/?id=EJ1148966
Rocha, J. M. S., Costa, A. M. C., & Martins, A. M. R. S. (2010). CDIO as a foundation for program accreditation/certification in Portugal. *Proceedings of the 6th International CDIO Conference (CDIO 2010)* (pp. 1–11). Montreal, QC, Canada. https://doi.org/10.4018/ijqaete.2012040103
Suarez, B., Revilla, J. A., & Galan, L. (2011). Quality assessment in engineering education in Spain: Towards a new accreditation agency. *Proceedings of the 2011 EUCEET Conference (EUCEET 2011)* (pp. 1–8). Patras, Greece. http://www.euceet.upatras.gr/Content/Uploads/S6-2%20SUAREZ%20ET%20AL..pdf
United Nations. (n.d.). *Sustainable Development Goals (SDGs)*. https://sdgs.un.org/
Yilmaz, D. V. (2019). Quality assurance in Turkish higher education in the framework of policy process model. *SDU Faculty of Arts and Sciences Journal of Social Sciences, 46*, 37–60. https://doi.org/10.35237/sufesosbil.533996

Impact of Workplace Support on Career Advancement of Electrical Trade Teachers in Technical Colleges

Article history
Received
16 July 2025
Received in revised form
31 October 2025
Accepted
4 November 2025
Published online
27 December 2025

Abidemi Olufemi Shodeinde & Idowu Dare Aderinto*
Department of Industrial Technical Education
Tai Solarin University of Education, Ogun State, Nigeria
**aderintoid@tasued.edu.ng*

Abstract

One of the key factors for employee to reach the peak of their career is the level of support from colleagues or those around them. This is crucial for professional development and career progress. Hence, this study examines the impact of workplace support on the career advancement of electrical trade teachers in technical colleges in Ogun State, Nigeria. Descriptive survey research design was adopted for the study. The population for the study comprised all the thirty (30) electrical trade subject teachers across the 8 technical colleges in Ogun State. Structured questionnaire was used for data collection. Data were analyzed using mean and standard deviation, correlation and regression. The findings of the study revealed that no significant relationship exist between workplace support and career advancement of electrical trade teachers ($r=.033$; $p>0.05$). Also, workplace support significantly influences career advancement of electrical trade teachers ($\beta= .312$; $p<0.05$) in technical colleges in Ogun State. It was concluded and recommended that workplace support plays a crucial role in shaping professional growth and career progression of electrical trade teacher's. Therefore, educational stakeholders should collaborate with industries for regular workshops, training sessions, and certification programs to keep teachers updated with the latest industry trends and teaching methodologies.

Keywords: Workplace Support, Career Advancement, Electrical Trade Teachers, Technical Colleges.

Introduction

The contemporary workforce is experiencing substantial transition, driven by rapid technological advancements, evolving organizational structures, and the increasing complexity of global labor markets. These shifts have necessitated the development of diverse and adaptive vocational skills among employees, prompting organizations to raise expectations concerning workforce efficiency, innovation, and responsiveness to change to increase their level of productivity. Besides, multifaceted career characterized by individual self-direction, continuous skill acquisition, and adaptability has gained substantial relevance in the present-day career discourse (AlKhemeiri, Khalid, & Musa, 2020). Similarly, the globalization of economies has accelerated the restructuring of job roles, compelling employees to remain current with emerging knowledge and practices. (Musaigwa, 2023). Thus, the capacity for lifelong learning and strategic career self-management and has become indispensable in navigating the demands of modern vocational pathways for employees to maintain professional relevance and advance in their career.

Career advancement is the process by which each person develops their skills in order to pursue their intended career (Eko, 2015). It is a crucial component of professional development for workers in any organization. This is not an exemption to educators, since it is not only contributing to job satisfaction but also enhances their teaching strategies and bring more improvement to students' academic satisfaction and performance (Day & Gu, 2014). It is even more crucial for teachers in technical colleges who teaches skill-based subjects to engage in periodic professional development in order to stay relevant in their roles due to rapid changes in technology. Some of the skill-based subject under the tutelage of these teachers across various technical colleges includes: Agric-Mechanization, Motor-Mechanics, Building Construction, Woodworking, Metalworking, Plumbing, and Electrical trades among others (Hassan, Dauda and Badawi 2019).

Electrical trades is one of the programme offers at technical colleges which is geared towards gaining the practical skills, fundamental scientific knowledge, and mindset needed for those who are interested or are practicing electrical work at basic level (Oviawe, Uwameiye, and Uddin, 2017). The trade comprises of different areas such as surface wiring, conduit wiring, AC and DC machines, electrical equipment maintenance, and installation, among others. Therefore, due to protean nature of this trade and the emergent technology, electrical trade teachers are obliged to refresh their expertise on a regular basis in

Shodeinde, A.O. & Aderinto, I.D. (2025), Impact of Workplace Support on Career Advancement of Electrical Trade Teachers in Technical Colleges, *ASEAN Journal of Engineering Education*, 9(2), 96-103. https://doi.org/10.11113/ajee2025.9n2.196

order to keep their knowledge current and prevent it from becoming outdated. Besides, upgrading their knowledge and abilities is crucial to ensure that students receive the necessary training required in the world of work (Payne, 2021). In order to make this a reality, electrical trade teachers in technical colleges needs different kind of support related to their work including material resources, on-going training, among others. This will help them to sustain high standards for practical knowledge, and improve their professional growth (Akpan & Ita, 2015). Supporting these specialized teachers' professional development is therefore essential since the services they provide are vital to the nation's economic, human, and cultural advancement.

It is no doubt that at some point in life, everybody needs help, whether social, spiritual, or material. Furthermore, without assistance of any kind, no one can achieve tangible or professional success on their own. Support in this study is streamline to workplace. Workplace support is referred to as assistant rendered during interpersonal dealings, business transactions or one's job that make workers feel cared for, esteemed, and loved (Giao et al 2020). Workplace support has been found to be a major contributor to career advancement in a variety of professional domains since it is the supportive system that employees rely on for information, encouragement, and help in both personal and professional concerns. For electrical trade teachers, their career is shaped in a different way based on the type of support they receive, which in turn affects their resilience, motivation, job satisfaction, and prospects for growth. Additionally, this also determine how they will manage their job demands, overcome institutional obstacles, respond to opportunities for advancement as well as professional growth in their career. In light of this, this study investigates impact of workplace support on the career advancement of electrical trade teachers in technical colleges in Ogun State.

Statement of the Problem

Teachers of Electrical trade in technical colleges are crucial in producing qualified workers that are needed for industrial manpower and economic expansion. These educators are tasked with equipping students with technical knowledge and practical skills that are in high demand across a range of industries, including manufacturing, telecommunications, and power generation. However, a number of obstacles stand in the way of these teachers' work effectiveness and career advancement. This includes lack of opportunities for professional growth, unavailability of resources, and the need to stay current with changes in their field. As a result, professional growth is crucial for maintaining the quality and relevance of technical education as well as for motivating and retaining electrical trade teachers.

Numerous studies have demonstrated the importance of workplace support, which includes help from coworkers, management, and professional networks, in determining the degree of career advancement in a variety of fields, including education. This suggests that workplace assistance is crucial for electrical trade teachers' well-being and job productivity. But in the absence of this support, teachers are now experiencing a number of negative effects, including a decline in job satisfaction, stress on their mental health, reduction in the quality of their instruction, lack of creativity, poor emotional health, disruption in teamwork and collaboration, rise in absenteeism, loneliness and isolation, among others. In addition, the devastation caused due to lack of workplace support by instructors' is influencing the caliber of graduates produced at technical colleges, which remain a worrisome issue. All put together, prompted this study on impact of workplace support on the career advancement of electrical trade teachers in technical colleges in Ogun State.

Objectives of the Study

The main purpose of this study was to examine impact of workplace support on the career advancement of electrical trade teachers in technical colleges in Ogun State. Specifically, the objectives of this study are to determine:

1. If there are work place support received by electrical trade teachers in technical colleges in Ogun State.
2. Career advancement system in place for electrical trade teachers in technical colleges in Ogun State.
3. Relationship between workplace support and career advancement of electrical trade teachers in technical colleges in Ogun State
4. Impact of workplace support on career advancement of electrical trade teachers in technical colleges in Ogun State

Research Questions and Hypotheses

1. Is there workplace support received by electrical trade teachers in technical colleges in Ogun State?
2. What are the career advancement system in place for electrical trade teachers in technical colleges in Ogun State?
3. There is no significant relationship between workplace support and career advancement of electrical trade teachers in technical colleges in Ogun State?
4. There is no significant impact of work place support on career advancement of electrical trade teachers in technical colleges in Ogun State?

Literature Reviewed

Career advancement

The development and progression of a person's career path is known as career advancement. It is the process by which each person develops their skills in order to pursue their intended career (Eko, 2015). According to Ng and Feldman (2014) career advancement is define as an employee's upward movement in their professional trajectory, which is essential for job satisfaction, retention, and general professional growth. Individual improvement in their fields of expertise is the goal of professional advancement. The organization where an employee works will be greatly impacted by personal efforts for capacity building in their career. Similar to this, every organization is supposed to establish an atmosphere that fosters growth and development for both its employees and the organization as a whole (D'Netto, Tang, and Shen, 2014). This suggests that professional growth, particularly for educators, is not solely dependent on their own roles but also on the degree of support or provision received, which is a major factor in their career advancement and has a high propensity to increase their motivation and self-readiness for their work. Hence, support is very important for career advancement of electrical trade teachers.

Electrical Trade Teachers

Professional educators who have the requisite electrical technology subject-matter knowledge and abilities to support their theoretical understanding are known as electrical trade teachers (Mbaga et al., 2017). Electrical trade teachers are majorly found working at technical colleges. Majority of them are often trained in educational institutions that offer technical education or courses linked to electrical engineering in order to transmit electrical technology expertise to students after they graduate (Ezugu Bala & Muhammad, 2023). These educators are expected to constantly participate in on-the-job training and attend a number of workshops that will broaden their knowledge of their particular fields in order to stay relevant in their roles despite technological advancements. If these teachers are unable to pursue additional training, they may become irrelevant and their skill would become obsolete, which means that the students they are teaching would suffer as a result of their incompetency (Shetima, 2010). Consequently, there is a strong correlation between teachers' skill and how effective or bad their instruction is. Subtly, the dedication and technical proficiency of the teachers who carry out the educational program are crucial to its effectiveness (Mbaga, Wampana, and Shanga, 2017).

Workplace Support

Support is the help someone or anything needs to succeed. Among other things, the assistance could be social, psychological, or physical. According to Giao et al. (2020), workplace support is defined as assistance provided during commercial transactions, interpersonal interactions, or one's employment that makes employees feel valued, cared for, and appreciated. Support in the workplace is given and received by connections or professional networks with different levels of intimacy. According to Mack and Rhineberger-Dunn (2019), workplace support produce interpersonal work interactions, which can enhance the recipient's coping skills or general well-being. Support at work can come from a variety of sources, including coworkers, administrators or management of the company, and professional networks. For electrical trade teachers, workplace support plays a unique role in shaping their career and thereby influencing their job satisfaction, motivation, and prospects for growth. A study by Ogbuanya and Musa (2020) reported that collaborative arrangement of seminars and workshops together with the involvement of technical instructors in industry operations, greatly promotes skill learning among students. This collaboration ensures that educators remain current of technical innovations, which they may teach to their students. Similarly, Siddiky and Uh (2020) emphasized in their thematic literature analysis that fostering closer linkages between academia and industry reduces practice gaps in Technical and Vocational Education and Training (TVET). According to the review, these kinds of partnerships are essential for fostering the knowledge and abilities needed to satisfy the needs of the labor market which is essential for improvement and adequate growth of electrical trade teachers.

Theoretical Review - Self-Determination Theory (SDT)

According Deci and Ryan (1985), human need changes in a social setting with respect to intrinsic and extrinsic motivation. This implies that humans can achieve self-determination when their three essential psychological demands for autonomy (e.g., freedom), competence (e.g., confidence), and relatedness (e.g., connection) are met. SDT research has demonstrated that major education stakeholders, such as administrators and policymakers, can influence teacher motivation and well-being (Lee et al., 2020). As a result, school learning support (such as professional development activities) is critical to promoting teachers' career advancement. In the context of this study, workplace support that meet this need might increase job satisfaction and commitment among electrical trade teachers. For example, encouragement from school leaders and colleagues can boost instructors' sense of competence and relatedness, prompting them to incorporate new technologies or newly acquired skills into their teaching practices.

Methodology

The study adopted a descriptive survey research design. The study was conducted in Ogun State of Nigeria. The population for this study comprised all the thirty (30) teachers who specializes in electrical trade subject across the 8 technical colleges in Ogun State. Due to relatively manageable number of participants, the entire population were used for the study. Structured questionnaire which comprised of 30 items, rated on a 5-point Likert scale of (5 = Strongly agree, 4 = agree, 3 = disagree, 2 = strongly disagree and 1= undecided) was used as instrument for data collection. Validity of the instrument were carried out by experts to ensured appropriate vocabulary, sentence structure of the items is suitable for the intended purposes. Reliability of the instrument was established by administering 10 copies of the instrument to respondents outside the study area. Cronbach Alpha reliability technique was used to establish the internal consistency of the instrument and reliability coefficient of 0.74 was obtained. The instrument for data collection was administered by the researcher with support of a research assistant. The majority of the filled questionnaire items were collected on the spot by the researchers and co-assistant while the remaining few were collected one week after the day of the distribution of the items. Data was analyzed using descriptive statistics of mean and standard deviation, correlation matrix and regression respectively. Mean and standard deviation was used to answer the research questions while correlation and regression analytical tools were used for the hypothesis. For the research question any mean value above 3.00 was considered agreed, while any value below 3.00 was considered disagreed. For hypothesis, Null hypotheses with p-value that are less than or equal to 0.05 was Accepted while null hypotheses with p-values that are greater than 0.05 was rejected.

Data Analysis and Results

The results and discussion are presented in accordance with the objectives, research questions and hypothesis of the study.

Table 1: Mean responses on the workplace support received by electrical trade teachers in technical colleges in Ogun State.

S/N	ITEMS	MEAN	S.D	REMARK
	Extent of workplace Support received			
	Support from Colleagues			
1	My colleagues are willing to listen to work-related problems.	3.50	.50	Agreed
2	I can rely on my colleagues for help with teaching resources or ideas.	3.43	.57	Agreed
3	My colleagues share information about professional development opportunities.	3.47	.53	Agreed
4	I feel that I belong to a supportive community of teachers.	3.56	.50	Agreed
5	Colleagues provide useful feedback that helps me grow professionally.	3.40	.49	Agreed
	Average mean	3.47		
	Support from Superior/Management			
6	My supervisors/administrators are approachable and willing to discuss my career goals	3.40	.49	Agreed
7	Management provides clear pathways for promotion and career advancement.	3.46	.50	Agreed
8	Management supports my professional development through training and workshops	2.67	.48	Disagreed
9	I receive encouragement from my superiors to take on challenging tasks that enhance my skills.	3.57	.50	Agreed
10	My efforts are recognized and rewarded by the administration	3.46	.57	Agreed
	Average mean	3.31		
	Support from Professional Networks			
11	I am part of a professional network of technical educators outside my college	3.03	.18	Agreed
12	My professional network provides valuable resources for career advancement.	3.00	.69	Agreed
13	I have access to mentorship and guidance through my professional network.	3.16	.70	Agreed
14	Networking with other professionals has helped me stay updated with industry trends.	3.30	.65	Agreed
15	I feel encouraged to pursue career opportunities due to the support of my professional network.	3.26	.64	Agreed
	Average mean	3.15		
	Overall Average mean	**3.31**		

Table 1 presents mean responses on the workplace support available for electrical trade teachers in technical colleges in Ogun State. All the 15 items have their means ranges between 2.67 and 3.57. Based on the result shown in the table the teachers agreed that their colleagues are willing to listen to work-related problems, they can rely on their colleagues for help with teaching resources or ideas, supervisors/administrators are approachable and willing to discuss on career goals, management provides clear pathways for promotion and career advancement, they are part of a professional network of technical educators outside their college, their professional network provides valuable resources for career advancement among others. However, with an average mean of 3.31 which is greater than 3.00 the minimum level of agreement adopted in this study. It is therefore agreed that electrical trade teachers received workplace support from colleagues, management/superior and professional network in technical colleges in Ogun State.

Table 2 presents mean responses on the career advancement system in place for electrical trade teachers in technical colleges in Ogun State. All the 15 items have their means ranges between 2.67 and 3.57. Based on the result shown in the table the teachers agreed that their colleagues are willing to listen to work-related problems, they can rely on their colleagues for help with teaching resources or ideas, supervisors/administrators are approachable and willing to discuss on career goals, management provides clear pathways for promotion and career advancement, among others. However, with an average mean of 2.78 which is lesser than 3.00 the minimum level of agreement adopted in this study. It is therefore, concluded that majority of electrical trade teachers agreed that there is low level of career advancement system such as promotions, increased professional growth responsibilities in technical colleges in Ogun State.

Table 2: Mean responses on career advancement system in place for electrical trade teachers in technical colleges in Ogun State

S/N	ITEMS	MEAN	S.D	REMARK
	Career Advancement System in place			
	Promotions			
1	There are clear promotion pathways available for teachers in my institution.	3.20	.61	Agreed
2	Promotions occur frequently in my institution	3.10	.66	Agreed
3	I feel that management supports my promotion efforts.	2.13	.68	Disagreed
4	My career advancement is dependent on my performance and achievements.	2.00	.74	Disagreed
5	There are specific criteria set by management for promotion.	3.46	.50	Agreed
	Average mean	2.78		
	Professional Growth			
6	I have access to professional development opportunities within my institution.	2.16	.75	Disagreed
7	My institution provides opportunities for me to attend workshops or conferences related to my field.	2.00	.74	Disagreed
8	Management encourages me to further my education or acquire advanced certifications	3.50	.51	Agreed
9	There is a strong emphasis on professional growth within my institution	3.43	.50	Agreed
10	I receive adequate support (financial or otherwise) to pursue professional development.	1.97	.72	Disagreed
	Average mean	2.61		
	Increased Responsibilities			
11	I am given leadership roles or positions within my department	3.43	.50	Agreed
12	I have been assigned to develop or review the curriculum for my department	2.13	.73	Disagreed
13	I am involved in school-wide projects or initiatives that enhance my career experience	2.60	.89	Disagreed
14	I am given responsibilities that allow me to demonstrate my leadership skills	3.30	.53	Agreed
15	My responsibilities have increased over time in ways that support my career advancement	3.40	.49	Agreed
	Average mean	2.92		
	Overall Average Mean	**2.78**		

Testing of Hypotheses

Table 3: Correlation analysis showing the relationship between workplace support and career advancement of electrical trade teachers in technical colleges in Ogun State

Variables	Mean	Std.	1	2
1. Workplace Support	49.70	1.51	1	
2. Career Advancement	41.83	2.44	.033	1

**. Correlation is significant at the 0.05 level (2-tailed)

Table 4: Regression analysis showing the impact of workplace support on career advancement of electrical trade teachers in technical colleges in Ogun State

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	48.850	4.911		9.946	.000
Workplace Support	.020	.117	.312	.173	.003

Dependent Variable: Career Advancement

Table 3 presents the relationship between workplace support and career advancement of electrical trade teachers in technical colleges Ogun State. The table shows that there is a positive and weak relationship between workplace support and career advancement of electrical trade teachers (r = .033). The table further revealed that the relationship between workplace support and career advancement of electrical trade teachers is not significant ($p > 0.05$). Thus, the null hypothesis was accepted. Hence, there is no significant relationship between workplace support and career advancement of electrical trade teachers in technical colleges Ogun State.

Table 4 presents the regression analysis showing impact of work-place support on career advancement of electrical trade teachers in technical colleges in Ogun State. The table revealed that work place support (β = .312) has moderate influence on career advancement of electrical trade teacher. This suggest that changes in career advancement are is associated with changes in workplace support. The study also revealed that work place support has a statistically significant impact (.003; $p < 0.05$) on career advancement of electrical trade teachers in technical colleges. Thus, the null hypothesis was rejected. Hence, there is a significant influence of work place support on Career advancement of electrical trade teachers in technical colleges in Ogun State.

Discussion of Findings

The study's findings draw attention to important facets of workplace assistance and career promotion for electrical trade instructors in Ogun State's technical colleges. However, the survey found that technical colleges had few structures in place for career growth, such as promotions and more responsibility. This is consistent with the study of Mustapha, (2013) which reported that educators' discontent and decreased motivation are caused by a lack of options for career advancement

The study also found that management, professional networks, and coworkers provide workplace support to electrical trade instructors at Ogun State technical colleges. This agrees with the study of Slemp, Kern, and Patrick (2018) which points to the fact that workplace assistance will help in fostering collaboration, lowering job stress, and improving job performance. Besides, Support from superiors and colleagues can be crucial in helping instructors overcome obstacles and continue to perform their jobs. Also, professional networks, such as teacher forums and trade groups, offer chances for resource sharing, skill development, and exposure to market trends (Billett, 2016).

There is no significant relationship between workplace support and career advancement of electrical trade teachers in technical colleges in Ogun State. It's interesting to note that the study showed no significant correlation between the career advancement of electrical trade teachers in Ogun State and workplace support, even though it was visible. This implies that even while instructors receive assistance from their peers and supervisors, institutional barriers such a lack of promotions, professional development programs, and policy restrictions may prevent this assistance from directly resulting in career advancement. This result is in agreement with study of Baruch (2006) which reported that, when institutional impediments remain, workplace support which is essential for performance and job satisfaction does not necessarily ensure career progress.

However, the study also discovered that workplace support significantly influences career advancement of electrical trade teachers. This in line the study of De

Vos & Van der Heijden, (2017) which reported that collaborative settings, professional coaching, and mentoring may improve teachers' abilities and increase the eligibility of workers for promotions when they occur. This indicate that workplace support have a greater impact on career advancement in organizations with well-defined professional development policies and procedures.

Overall, the results indicate that legislative changes are necessary to close the gap between career advancement in technical institutions and workplace support. Creating clear promotion standards, professional development courses, and mentorship programs, will help to strengthen career advancement frameworks. By doing this, job satisfaction and workforce stability will be improved and workplace assistance will be translated into meaningful career advancement.

Conclusion

Teachers' career advancement and professional development are greatly influenced by workplace support. In particular, access to professional development opportunities, mentorship programs, institutional support, and a positive work environment are essential components in making this a reality. This suggests that the professional growth of electrical trade teachers will be hampered by the lack of formal mentorship and ongoing training programs, which will limit their capacity to impart pertinent skills to students. As a result, workplace assistance is crucial for both the professional development of electrical trade instructors and the general enhancement of Ogun State technical colleges curriculum.

Recommendations

Based on the result of these findings and literatures reviewed, the following recommended are therefore put forth:

1. The administration of technical colleges should set up official mentorship programs so that more experienced teachers can guide and assist the less experienced ones. This will enhance instructional strategies, offer career counseling, and foster a positive work atmosphere.
2. Educational stakeholders should collaborate with industries to organize frequent workshops, training sessions, and certification programs to keep teachers updated with the latest industry trends and teaching methodologies.
3. The public and private sectors ought to provide technical colleges with funding, sufficient instructional resources, and up-to-date teaching tools and equipment.
4. Technical teachers should have clear professional advancement pathways established by their employers, including promotions, salary increments, and recognition for outstanding performance.

Acknowledgement

The authors would like to express their sincere gratitude to the ASEAN Journal of Engineering Education editorial team for their timely feedback, and support that facilitated the successful review and publication of this article.

Conflict of Interest

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

References

Akpan, Charles & Ita, A. (2015). Teacher Professional Development and Quality Universal Basic Education in Lagos State, Nigeria. Global Journal of Arts, Humanities and Social Sciences. 3(9) 65-76.

AlKhemeiri, A & Khalid, K & Musa, N (2020). The role of career competencies and proactive personality in early-career employee career adaptability. European Journal of Training and Development. ahead-of-print. 10.1108/EJTD-05-2020-0081.

Baruch, Y. (2006). Career development in organizations and beyond: Balancing traditional and contemporary viewpoints. Human Resource Management Review, 16(2), 125-138.

Billett, S. (2016). Learning through practice: Beyond informal and towards a framework for learning through work. Springer.

Day, C., & Gu, Q. (2014). Resilient teachers, resilient schools: Building and sustaining quality in testing times. Oxon, UK: Routledge

De Vos, A., & Van der Heijden, B. I. (2017). Current thinking on career success: A review of the literature and implications for theory and practice. Career Development International, 22(5), 413-425.

Deci, E. L., & Ryan, R. M. (1985). Intrinsic motivation and self-determination in human behavior. New York: Plenum Press

Eko, W. S. (2015). Manajemen Pengembangan Sumber Daya Manusia. In Yogyakarta: Pustaka Pelajar

Ezugu, L. C., Bala, A. A, Muhammad Z. I (2023) Technical Skills Improvement Needs of Electrical Installation and Maintenance Work Trade Teachers for Effective Teaching in Technical Colleges in Kano State. International Journal of Multidisciplinary Research and Growth Evaluation 4(6) 425-431

Giao, H. N. K., Vuong, B. N., Huan, D. D., Tushar, H., & Quan, T. N. (2020). The effect of emotional intelligence on turnover intention and the moderating role of perceived organizational support: Evidence from the banking industry of Vietnam. Sustainability, 12(5),

Hassan MA, Dauda YA, Badawi HM (2019). Skills improvement need of woodwork teachers in technical colleges of Yobe State, Nigeria. Insertions Journal of Innovative Information Systems and Technology Research. 7(1):39-49.

Lee, A. N., Nie, Y., & Bai, B. (2020). Perceived principal's learning support and its relationships with psychological needs satisfaction, organisational commitment and changeoriented work behaviour: A Self-Determination Theory's perspective. Teaching and Teacher Education, 93, 103076.

Mack, K. Y., & Rhineberger-Dunn, G. (2019). Burnout among community corrections officers: Do supervisor and coworker support matter? Corrections, 6(1), 1–17. https://doi.org/10.1080/23774657.2019. 1593067

Mbaga VE, Wampana QD, Shanga BA. (2017) Assessment of technical skills competency needs of electrical installation and maintenance work trade teachers in skills acquisition centres of Yobe State. Journal of Education and Practice, 8(17):102-110.

Musaigwa, Misheck. (2023). The Role of Leadership in Managing Change. International Review of Management and Marketing. 13. 1-9. 10.32479/irmm.13526.

Mustapha, N. (2013). The influence of financial reward on job satisfaction among academic staffs at public universities in Kelantan, Malaysia. International Journal of Business and Social Science, 4(3), 244–248.

Ng, T. W., & Feldman, D. C. (2014). Subjective career success: A meta-analytic review. Journal of Vocational Behavior, 85(2), 169-179.

Ogbuanya, T. C., & Musa, T. J. (2020). Improving skill acquisition of electrical installation and maintenance work students through collaboration between technical colleges and industries in Plateau State. Vocational and Technical Education Journal, 2(2).

Oviawe JI, Uwameiye R, Uddin PS. (2017). Bridging skill gap to meet technical, vocational education and training school-workplace collaboration in the 21st century. International Journal of Vocational Education and Training Research, 3(1):7-14.

Payne C. T., (2021) Identifying the technical and teacher skills needed by in-service teachers to effectively teach an agricultural mechanics course in West Virginia. Department of Agriculture and Extension Education. Theses, dissertations, and problem reports, p. 8067.

Shen, J., Tang, N., & D'Netto, B. (2014). Linking diversity management to organizational culture and employee attitudes. International Journal of Human Resource Management, 25(12), 1720-1738.

Shetima A. (2010) Electrical installation competencies required by electrical/electronic teachers in Bauchi and Gombe States technical colleges. M.Ed thesis, University of Nigeria, Nsukka.

Siddiky, M. R., & Uh, S. (2020). A thematic literature review on industry-practice gaps in TVET. TVET@Asia, (15). https://tvet-online.asia/19/a-thematic-literature-review-on-industry-practice-gaps-in-tvet/

Slemp, G. R., Kern, M. L., & Patrick, K. J. (2018). Leader autonomy support in the workplace: A meta-analytic review. Motivation and Emotion, 42(5), 706-724.

Development and Validation of an Instrument Assessing Biomedical Engineering Competencies, AI Readiness, and Organisational Support

Article history
Received
28 July 2025
Received in revised form
23 October 2025
Accepted
27 October 2025
Published online
27 December 2025

Almi Mahmod[a]*, Maheza Irna Mohamad Salim[b], Beni Widarman Yus Kelana[a], Raimi Dewan[bc]
[a]Azman Hashim International Business School, Universiti Teknologi Malaysia, 54100 Kuala Lumpur, Malaysia.
[b]Department of Biomedical Engineering and Health Sciences, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
[c]IJN-UTM Cardiovascular Engineering Centre, Institute of Human Centered Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
**almi2@graduate.utm.my*

Abstract

This study presents the development and validation of a survey instrument designed to assess the competence of biomedical engineers in AI-integrated healthcare settings. Based on the KSAA (Knowledge, Skills, Abilities, and Attitudes) framework, the instrument incorporates AI readiness and perceived organisational support (POS) as mediators of job performance. The items were adopted and adapted from established studies and refined through expert opinion analysis involving five experts from academia and industry, followed by feedback from 10 postgraduate reviewers. A pilot study was conducted with 40 biomedical engineers in this study group using the same criteria as the intended full-scale study. Data were analysed using SPSS version 30.0, focusing on internal consistency through reliability analysis. Results showed strong reliability across all dimensions, with Cronbach's alpha values ranging from 0.823 to 0.897. This paper only reports the validation phase of the instrument; testing of the mediation hypothesis will be conducted in a subsequent full-scale study. Validated instruments provide a reliable foundation for future workforce development, training programmes, curriculum enhancements, and large-scale data collection in AI-driven healthcare environments.

Keywords: AI readiness, Biomedical engineering, Competency assessment, Mediators, POS, Psychometric validation.

Introduction

In the era of digital transformation, biomedical engineers are no longer confined to ensuring the safety, functionality, and compliance of medical equipment alone. Their roles now encompass broader responsibilities, including planning, procurement, installation, maintenance, and disposal within increasingly complex and AI-driven healthcare environments (Topol, 2019; Ibrahim & Karim, 2020). These evolving functions demand not only technical expertise but also digital literacy, analytical agility, and the ability to collaborate across interdisciplinary teams (Olanrewaju & Hamid, 2021).

The emergence of smart healthcare systems underscores the need for a robust set of competencies among biomedical engineers. However, existing competency models still tend to prioritise technical knowledge over the essential cognitive, interpersonal, and attitudinal domains (Mulder 2014). The KSAA framework stands for knowledge, skills, abilities, and attitudes and offers a more holistic foundation to assess these multidimensional attributes, especially in digitally enhanced work contexts(Mahmod et al., 2025).

Importantly, the translation of individual competencies into actual workplace performance may be influenced by contextual factors such as organisational support. POS is defined as employees' perceptions of how much their organisation values their contribution and well-being, which has been linked to improved motivation, engagement, and job performance, particularly in technology adaptive roles (Eisenberger et al., 1986). Job performance, in turn, serves as a key indicator of how effectively individuals apply their competencies in practice. Complementing these relationships, AI readiness, defined as one's preparedness and confidence to work with AI systems, is gaining recognition as a critical enabler of

Mahmod, A., Mohamad Salim, M.I., Yus Kelana, B.W., Dewan, R. (2025), Pilot Study on Biomedical Engineering Competencies and AI Readiness: Development and Validation of Instrument, *ASEAN Journal of Engineering Education*, 9(2), 104-111. https://doi.org/10.11113/ajee2025.9n2.197

performance in AI-integrated settings (Parasuraman & Colby, 2015).

Despite the significance of these constructs, there remains a lack of validated instruments that collectively examine the relationships between KSAA, POS, AI readiness, and job performance, especially within the biomedical engineering field in emerging economies like Malaysia (Olanrewaju & Hamid, 2021).

Existing engineering competency frameworks such as ABET and CDIO offer strong foundations in technical and design-orientated outcomes, particularly in areas such as problem solving, system integration, experimentation, teamwork, and design thinking. These models effectively support core engineering education and practice; however, they provide limited attention to emerging and non-technical competencies required in AI-driven work environments. Specifically, they do not adequately address digital literacy, AI readiness, behavioural adaptability, or organisational support mechanisms that influence technology adoption in modern healthcare settings. ABET's outcome criteria remain largely centred on general engineering capabilities, while CDIO highlights innovation and system integration without considering contextual enablers such as workplace culture or institutional support. To address these gaps, the present study extends these traditional frameworks by incorporating psychological and organisational constructs, namely AI readiness and POS, to better reflect the competencies needed by biomedical engineers working in AI-integrated hospitals.

Drawing from the work of van Berkum et al. (2024), who highlighted the importance of aligning graduate competencies with curriculum design in food technology education, this study adopts a similar lens within the biomedical engineering domain. It provides empirical evidence and a validated measurement instrument to support the development of competency-based curricula tailored to AI-integrated healthcare.

Therefore, this study aims to develop and validate a measurement instrument that evaluates the influence of KSAA on job performance, with AI readiness and POS modelled as dual mediators supporting educators, employers, and policymakers in aligning biomedical engineering talent with the demands of future healthcare systems.

This pilot study focuses on the development and validation of an instrument to assess competencies among biomedical engineers. The mediation effects of AI readiness and POS are not examined at this stage; these hypotheses will be tested in a subsequent full-scale study.

Conceptual Framework

This study is based on the conceptual framework (Figure 1) that integrates the knowledge, skills, abilities, and attitudes (KSAA) model with AI readiness and POS as mediating variables influencing job performance. This framework draws on well-established theories of professional competence, technology acceptance, and organisational behaviour and is adapted to the context of biomedical engineering in AI-integrated healthcare systems.

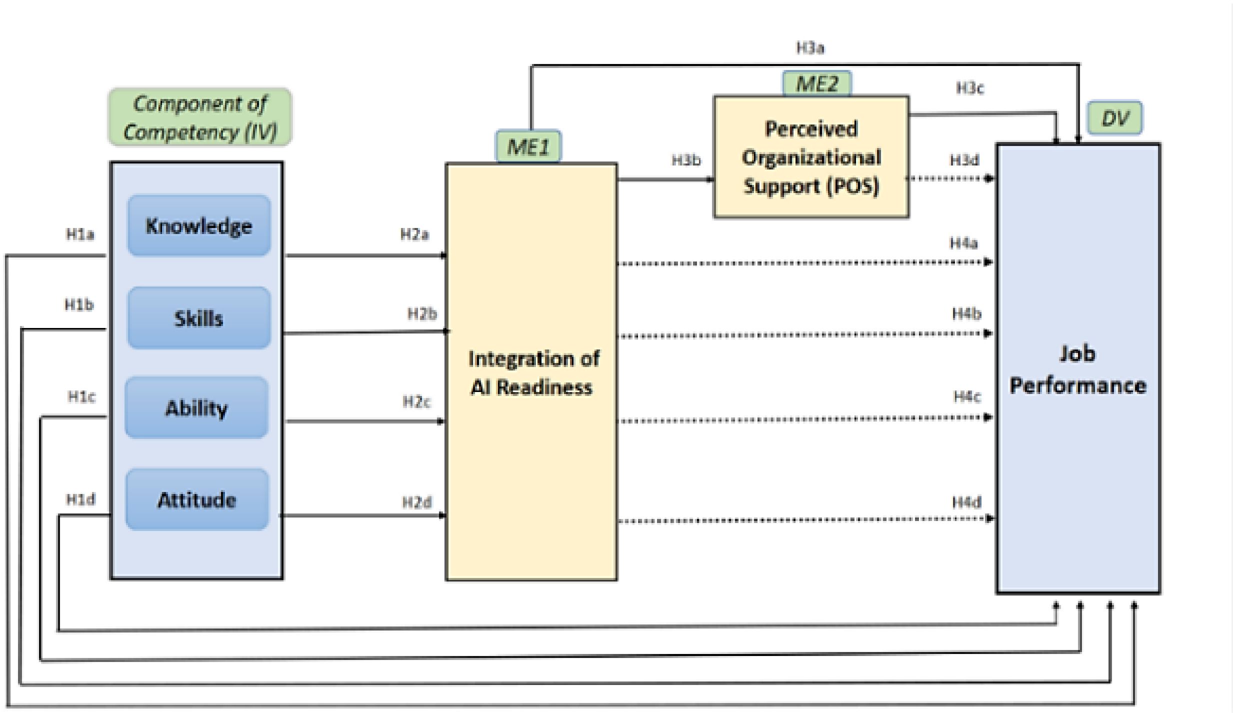


Figure 1. Conceptual framework

KSAA Competency Model

The KSAA model serves as the foundation for understanding the core attributes required by biomedical engineers to function effectively in digital healthcare environments (Mahmod et al., 2025)KSAA stands for knowledge, skills, abilities, and attitudes. It is a comprehensive framework widely used in competency modelling. Knowledge refers to the theoretical understanding of concepts, such as biomedical systems and AI applications in healthcare. Skills are the practical capabilities to apply this knowledge, including operating medical devices or interpreting AI-generated data (Mulder, 2014). Abilities encompass the cognitive and physical capacities to perform tasks, such as analytical thinking, problem-solving, and adaptability to new technologies (Spencer & Spencer, 1993). Attitudes involve behavioural and emotional dispositions that influence how tasks are approached, including motivation, responsibility, and openness to innovation (Boyatzis, 2008). Bartram (2005) explains that competence includes not just knowledge and skills but also deeper ways of thinking and attitudes that help people adapt and perform well.

AI Readiness

Malaysia offers a timely and relevant setting for this investigation. The national healthcare sector is rapidly digitalising through initiatives such as the Ministry of Health's MyDigital Healthcare Blueprint, yet structured competency models for biomedical engineers remain underdeveloped. Existing research, including Olanrewaju and Hamid (2021), has highlighted persistent digital-skills gaps and uneven AI adoption across public and private hospitals. Moreover, current professional and institutional frameworks in Malaysia have not fully integrated AI readiness as a core competency requirement. Validating an AI-related competency instrument within this context directly addresses a pressing workforce and educational need while also generating insights that may be transferable to other emerging economies undergoing similar transitions.

AI readiness refers to an individual's preparedness, willingness, and confidence to work with artificial intelligence tools and systems (Parasuraman & Colby, 2015). It encompasses digital literacy, technological optimism, and perceived self-efficacy in using AI. In engineering environments, AI readiness functions as a psychological enabler that influences how effectively individuals can apply their competencies in AI-driven settings. Accordingly, it is positioned as a mediator between KSAA and job performance, reflecting its role in translating core attributes into technology-enhanced outcomes (Marques & Ferreira, 2020). In the Malaysian healthcare context, where AI implementation is accelerating but workforce preparedness remains inconsistent, this construct is particularly significant for understanding competency gaps and informing targeted capacity building.

Perceived Organisational Support (POS)

POS is conceptualised as the extent to which employees believe that their organisation values their contributions and supports their professional development (Eisenberger et al., 1986). In the context of technological change, POS enhances individual motivation, reduces uncertainty, and facilitates continuous learning. This study hypothesises that POS mediates the relationship between KSAA and job performance by providing an enabling organisational environment that fosters skill application and professional growth (Chow et al. 2018). It complements AI readiness by addressing the social and structural aspects of technology adoption.

Job Performance

Job performance is treated as the outcome of the conceptual model and includes both task-based and adaptive dimensions. Drawing from Campbell & Wiernik (2015), performance in dynamic environments such as AI-integrated healthcare involves not only technical execution but also innovation, continuous learning and responsiveness to digital transformation. Biomedical engineers' job performance is thus influenced by both internal (KSAA) and external (AI readiness and POS) factors.

Method

This study was conducted in five sequential stages to develop and validate a competency measurement instrument for biomedical engineers in AI-integrated healthcare settings.

In Stage 1, the questionnaire was designed based on the objectives of the study, using the method of adaptation and adoption from previous validated instruments related to knowledge, skills, abilities, and attitudes (KSAA), AI readiness, POS, and job performance (Boyatzis, 2008; Hung et al., 2020).

In Stage 2, the Expert Opinion Analysis (EOA) instrument was reviewed by a panel of five subject matter experts, comprising academic professionals and industry practitioners, to evaluate the content, clarity, and relevance of each item.

Next, in Stage 3, the refined questionnaire underwent a validation process and was submitted for ethical review and approval by the Universiti Teknologi Malaysia (UTM) ethics committee to ensure adherence to research integrity and ethical guidelines (Universiti Teknologi Malaysia, 2022).

Following this, in Stage 4, a user feedback session was conducted with 10 postgraduate students who reviewed the instrument to establish face validity and provided feedback regarding the clarity and comprehensibility of the items (DeVellis, 2017).

Finally, in Stage 5, a pilot study was conducted with 40 biomedical engineers who fulfilled the sampling criteria. The pilot data were analysed using SPSS Version 30.0, where Cronbach's Alpha (CA) was used to assess the internal consistency and reliability of each construct. According to Song (2020), the CA coefficient is appropriate for determining the homogeneity of Likert-scale items. Additionally, descriptive statistics were used to analyse Section A, which comprised the demographic profile of the respondents.

This study employed a quantitative pilot approach with an embedded validation framework for instrument development. The validation process was conducted in several structured phases to ensure both content and construct validity prior to full-scale deployment. Instrument Development and Validation Process:

The development of the survey instrument followed a five-phase process:

Stage 1: Item Construction

The development of the survey instrument began with the item construction phase, guided by a comprehensive review of relevant literature and supported by well-established theoretical frameworks, namely the KSAA competency model (Boyatzis, 2008; Mulder, 2014), the Technology Readiness Index for AI readiness (Parasuraman & Colby, 2015), Social Exchange Theory underpinning Perceived Organisational Support (Eisenberger et al., 1986), and the performance model by Campbell et al. (1993) for job performance. The instrument was designed to investigate the relationship between the key variables in this study: KSAA the independent variable, job performance as the dependent variable, and AI readiness, along with POS as dual mediators (Boyatzis, 2008; Campbell et al., 1993; Hung et al., 2020). This theoretical foundation reflects the critical competencies and organisational support factors required for biomedical engineers to perform effectively in AI-integrated healthcare environments. An initial pool of items was developed by adapting and adopting validated measures from prior studies to ensure conceptual clarity and content relevance (DeVellis, 2017).

The survey instrument was structured into five main sections as follows:

i. Section A: Demographic Information is collecting background data on respondents, including age, gender, years of professional experience, and highest level of education (Fink, 2017).
ii. Section B: Competency Components (KSAA) assesses respondents' knowledge, skills, abilities, and attitudes related to biomedical engineering in digital healthcare settings (Boyatzis, 2008; Mulder, 2014).
iii. Section C1: AI Readiness is measuring the extent of respondents' preparedness and confidence in working with AI technologies (Parasuraman 2015).
iv. Section C2: POS and evaluating the level of support respondents perceive from their organisations in adopting AI-related tasks (Eisenberger 1986).
v. Section D: Job Performance is capturing self-reported measures of effectiveness and work outcomes in AI-integrated tasks (Koopmans 2013).

All items in Sections B through D were measured using a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree", adopted from Song (2020). This structured instrument served as the foundation for subsequent expert validation and psychometric testing.

Stage 2: Expert Opinion Analysis (Content Validity)

To ensure content validity, the draft instrument was assessed by a panel of five subject matter experts, consisting of academic experts in biomedical engineering, artificial intelligence, competency, and job performance, and industry professionals with experience in the healthcare technology sector. These experts were selected for their domain knowledge and practical insights relevant to the study context. The assessment focused on key aspects such as item relevance, wording clarity, and subject matter expertise. Each expert provided qualitative ratings and comments. Quantitative assessment was conducted using the Content Validity Index (CVI), allowing for a structured assessment of the appropriateness of each item (Zamanzadeh et al., 2015). Based on the CVI scores and expert feedback, several items were revised, refined, or removed to improve the conceptual accuracy and linguistic clarity of the instrument before moving on to the next validation phase.

Stage 3: Ethical Review

In the third stage, the refined version of the questionnaire underwent a formal validation and ethical review process. This involved ensuring that the instrument met the necessary standards for research quality, participant protection, and data confidentiality. The complete set of questionnaire items is finalised after expert review is submitted to the Universiti Teknologi Malaysia (UTM) Research Ethics Committee. The purpose of this submission was to obtain ethical clearance in accordance with institutional protocols and national research ethics guidelines (Universiti Teknologi Malaysia, 2022). Therefore, the researcher obtained confirmation from UTM Ethics Approval on July 30, 2025, Bill 8/2025. Approval number: UTMREC-2025-160 verbal and written feedback. The approval process ensured that the study adhered to principles of research integrity, including informed consent, voluntary participation, and the ethical handling of participant data. Only after receiving official ethical approval was the study allowed to proceed to the next phase of data collection.

Stage 4: User Review (Face Validity)

To ensure clarity, readability, and practical interpretability of the survey instrument, the revised questionnaire was reviewed by 10 postgraduate students who represented the target population. Their feedback focused on the wording, item sequencing, and overall usability of the instrument. Based on their input, necessary adjustments were made to improve the phrasing and flow of the questionnaire. This process helped establish face validity, ensuring that the instrument was understandable and appropriate for use in the actual data collection phase (DeVellis, 2017).

Stage 5: Pilot Study (Construct Validation)

The finalised version of the survey instrument was pilot-tested with a sample of 40 biomedical engineers working in private hospitals across Malaysia. These participants were purposefully selected to reflect characteristics similar to the intended study population, ensuring contextual relevance to AI-integrated healthcare environments. A sample size of 30 to 50 participants is generally considered adequate for pilot testing of survey instruments, as recommended by Johanson and Brooks (2010), who state that a minimum of 30 respondents is sufficient to identify preliminary validity and reliability issues. Similarly, Hertzog (2008) supports the use of 10–40 participants for pilot studies aimed at refining instruments and assessing feasibility.

The primary objective of the pilot study was to evaluate the instrument's construct validity and internal consistency prior to its full-scale administration (DeVellis, 2017; Boateng et al., 2018). During this phase, the researchers examined the dimensional structure of the instrument and assessed whether the items were interpreted consistently and meaningfully by respondents. The pilot also helped detect any issues related to item clarity, response bias, or scale performance (Netemeyer et al., 2003).

To assess reliability, Cronbach's Alpha values were used as the benchmark. According to Hair et al. (2020), values above 0.70 indicate acceptable reliability, values between 0.80 and 0.90 reflect very good internal consistency, while values above 0.90 may suggest redundancy. Since all constructs in this study exceeded the acceptable threshold, a repeated measure such as test–retest was not deemed necessary at the pilot stage.

The results of the pilot study provided the empirical foundation to confirm the psychometric robustness of the instrument, ensuring it was suitable for broader data collection and further statistical analysis.

Data Analysis

The data analysis in this study involved two key approaches: psychometric evaluation and preliminary conceptual modelling. Several statistical methods were employed to assess the quality of the instrument and to explore the relationships between study constructs, including descriptive statistics and reliability analysis (DeVellis, 2017).

Firstly, descriptive statistics were used to analyse Section A of the questionnaire, which captured respondents' demographic information. This section consisted of four key elements: age, gender, working experience and education level. This analysis provided an overview of the respondent profile and ensured that the sample was representative of the target population.

Next, to assess internal consistency, Cronbach's alpha coefficients were calculated for each construct. The results indicated high reliability, with all constructs achieving alpha values above 0.80, which is considered very good according to Hair et al. (2020). This confirmed that the items within each construct consistently measured the intended dimension.

The interpretation scale for Cronbach's Alpha used in this study is shown in Table 1.

Table 1. Scale for Cronbach's Alpha

Alpha Coefficient Range	Strength of Association
< 0.6	Poor
0.6 to < 0.7	Moderate
0.7 to < 0.8	Good
0.8 to < 0.9	Very Good
0.9	Excellent

Source: (Hair *et al.*, 2020)

Results

These results are from the findings of the pilot study conducted among 40 biomedical engineers in the group of the study. The results encompass demographic profiles, descriptive statistics of key constructs, and internal consistency reliability testing for the developed instrument.

Respondent Demographics

The sample consisted of 40 biomedical engineers from both public and private hospitals (Table 2). The gender distribution was relatively balanced, with 21 female respondents (52.5%) and 19 male respondents (47.5%). In terms of age, the majority were between 31 and 40 years old (62.5%), followed by those aged 22–30 years (22.5%) and 41–50 years (15%).

Table 2. Gender Demographics

Category	Count	Percentage
Male	19	47.5
Female	21	52.5
	40	100%

Descriptive Statistics

The pilot study findings revealed consistently high mean values across all seven measured constructs are knowledge, skills, ability, and attitude (KSAA), AI Readiness, POS, and Job Performance are accompanied by relatively low standard deviations. This suggests a high degree of response consistency and a generally positive perception among participants regarding the measured domains.

Specifically, the core KSAA components recorded mean scores ranging from 21.18 to 21.90 on a 25-point scale. AI Readiness recorded a mean of 57.72 (SD = 8.34), POS recorded a mean of 42.45 (SD = 6.89), and Job Performance scored a mean of 68.40 (SD = 8.41). These results indicate that the instrument is well-understood, contextually appropriate, and capable of capturing the key constructs relevant to biomedical engineers in AI-integrated healthcare environments.

Overall, the pilot phase supports the instrument's suitability for full-scale deployment in the next phase of the study.

Reliability Analysis

To assess internal consistency reliability, Cronbach's Alpha coefficients were computed for each construct. All seven constructs exceeded the acceptable threshold of 0.80, indicating strong internal reliability and coherence among items. The highest reliability was recorded for the Attitude dimension (α = 0.897), followed by Knowledge (α = 0.884) and POS (α = 0.877). These results affirm the stability and consistency of the instrument's measurement properties across constructs.

The summary of reliability results is presented in Table 3 below.

Table 3. Reliability Statistics of Constructs (n = 40)

Construct	No. of Items	Cronbach's Alpha	Mean	Std Dev.
Knowledge	5	0.884	21.70	2.38
Skills	5	0.854	21.33	2.44
Ability	5	0.823	21.18	2.35
Attitude	5	0.897	21.90	2.52
AI Readiness	16	0.854	57.72	8.34
POS	12	0.877	42.45	6.89
Job Performance	18	0.853	68.40	8.41

(Source: Author)

Comparison with Previous Studies

The reliability coefficients obtained in this pilot study align well with prior research that has examined similar constructs within the domains of engineering competencies, AI readiness, and POS. The KSAA domains, the Cronbach's Alpha values ranging from 0.823 to 0.897 are consistent with findings by Mulder (2014) and Bartram (2005), who emphasised the robustness of multi-domain competency models in professional settings. In the engineering education context, van Berkum et al. (2024) reported Cronbach's Alpha values between 0.82 and 0.89 across cognitive, interpersonal, and technical clusters in a competency validation study for food technology graduates, supporting the structural integrity of similar constructs.

Regarding AI readiness, the internal consistency of 0.854 matches values observed in recent adaptations of the Technology Readiness Index (TRI 2.0) and AI for specific instruments. For instance, Parasuraman & Colby (2015) reported alpha values between 0.83 and 0.87 for constructs such as optimism and innovativeness in AI adoption. Similarly, Marques & Ferreira (2020), who measured digital readiness in STEM professionals, documented an internal consistency of 0.85–0.88, reinforcing the reliability of digital and AI readiness dimensions in technical environments. Meanwhile, for POS, the result of 0.877 is within the range of prior studies. According to Eisenberger et al. (2002), they originally reported alpha values above 0.80 in their POS scale development. More recent studies in healthcare and engineering domains, such as Chow et al. (2018), also observed reliability coefficients between 0.83 and 0.89, confirming the stability of POS as a mediating variable influencing job performance and learning engagement.

The Job Performance construct, with a reliability of 0.853, is similarly supported by research in engineering and healthcare workforce evaluations. Campbell & Wiernik (2015) identified consistent reliability levels when job performance was assessed through multi-dimensional behavioural indicators. In sum, the internal consistency reliability demonstrated in this pilot study is in strong agreement with earlier validated scales, confirming the suitability of the instrument for subsequent empirical studies in biomedical engineering and AI-integrated workplace settings.

Discussion

The findings of this pilot study provide empirical support for the reliability and preliminary construct validity of the developed instrument to assess biomedical engineering competencies and AI readiness. The strong internal consistency across all constructs indicates that the questionnaire items are coherent, relevant, and well-understood by professionals working in AI-integrated healthcare environments. These results offer important insights into the preparedness of biomedical engineers for evolving technological demands, with implications for curriculum development, workforce training, and policy planning.

Firstly, the consistently high reliability coefficients for the KSAA constructs knowledge (α = 0.884), skills (α = 0.854), ability (α = 0.823), and attitude (α = 0.897) demonstrate that the instrument effectively captures the multidimensional nature of professional competence. This aligns with well-established competency frameworks in engineering and education literature, such as those proposed by Bartram (2005) and Mulder (2014), which emphasise the integration of technical, cognitive, and attitudinal domains. The inclusion of attitudinal elements is particularly relevant in AI-driven contexts, where adaptability, openness to innovation, and digital confidence are increasingly recognised as enablers of performance.

Secondly, the reliability of the AI Readiness construct (α = 0.854) reflects growing awareness among biomedical engineers of the need to engage with AI-enabled systems. This aligns with previous research by Parasuraman and Colby (2015) and Marques and Ferreira (2020), which frame readiness as a cognitive-emotional state that influences effective technology use. The high reliability score in this study suggests that the instrument is appropriately designed and easily interpreted for subsequent large-scale use.

Thirdly, the findings reinforce the importance of POS, which recorded a Cronbach's alpha of 0.877. This highlights POS as a critical mediating factor shaping engineers' confidence, performance, and retention, particularly in sectors experiencing technological transition. Consistent with Eisenberger et al. (2002), organisational investment in employee development and digital upskilling is essential in high-technology environments such as biomedical engineering.

The Job Performance construct also demonstrated strong reliability (α = 0.853), validating the behavioural indicators used in the instrument. The inclusion of both technical execution and adaptability to AI-enhanced settings allows for a comprehensive assessment of engineering outcomes. This dual focus supports data-driven improvements in curriculum design, performance appraisal, and professional accreditation.

Although this pilot was conducted among biomedical engineers in Malaysia, the theoretical constructs underpinning the instrument KSAA, AI readiness, and POS are globally relevant. Overall, the validated instrument demonstrates strong potential to inform empirical research, curriculum enhancement and policy development in biomedical engineering education and workforce planning. Its ability to capture competencies, contextual enablers, and performance outcomes positions it as a timely contribution to AI-integrated healthcare practice.

Limitations of the Study

This pilot study has several limitations. The sample was small and drawn exclusively from private hospitals in Malaysia; thus, the findings cannot be generalised to biomedical engineers in public healthcare institutions or other countries. Nevertheless, the Malaysian context is a relevant setting to explore this gap, as it represents a developing healthcare system progressively integrating artificial intelligence into biomedical engineering practice. The reliance on self-reported data also introduces the risk of social desirability bias, where participants may overstate their competencies or readiness levels. Future studies should incorporate supervisor ratings, peer evaluations, or objective performance indicators to mitigate such bias. A larger and more diverse sample, combined with triangulated data sources, would strengthen the robustness, reliability, and generalisability of future research outcomes.

Conclusion

This pilot study has successfully developed and validated a multidimensional measurement instrument that evaluates biomedical engineering competencies, AI readiness, POS, and job performance. The findings demonstrate strong internal consistency across all constructs, confirming the reliability of the instrument for use in AI-integrated healthcare environments. The high mean scores across KSAA domains suggest that biomedical engineers in Malaysia perceive themselves as well-equipped with core competencies, particularly in technical, cognitive, and attitudinal areas. Furthermore, the strong reliability of the AI readiness and POS constructs reinforces their relevance as mediating variables that influence how individual attributes translate into actual job performance.

From an educational perspective, this instrument provides a valuable tool for curriculum designers, educators, and policymakers to assess and align graduate competencies with industry needs. The inclusion of AI readiness and POS offers a novel contribution to engineering education by accounting for both individual preparedness and contextual enablers. This supports the broader shift toward competency-based education and digital transformation in STEM fields. The validated instrument may now be deployed in a full-scale study to examine the mediating effects of AI readiness and POS on the relationship between KSAA and job performance. Such research can inform national talent development strategies and workforce planning in the biomedical engineering sector.

Acknowledgement

The authors would like to express their sincere appreciation to Universiti Teknologi Malaysia (UTM) for the continuous support provided throughout this research. We also extend our heartfelt thanks to all the biomedical engineers who participated in the study for their valuable time, contributions, and cooperation.

Conflict of Interest Statement

The author declares that there is no conflict of interest associated with the conduct of this research or the preparation of this manuscript.

References

Bartram, D. (2005). The Great Eight Competencies: A Criterion-Centric Approach to Validation. Journal of Applied Psychology, 90(6), 1185–1203.

Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quiñonez, H. R., & Young, S. L. (2018). Best practices for developing and validating scales for health, social, and behavioral research: A primer. Frontiers in Public Health, 6, 149.

Boyatzis, R. E. (2008). Competencies in the 21st century. Journal of Management Development, 27(1), 5–12.

Campbell, J. P., & Wiernik, B. M. (2015). The Modeling and Assessment of Work Performance. Annual Review of Organizational Psychology and Organizational Behavior, 2, 47–74.

Campbell, J. P., McCloy, R. A., Oppler, S. H., & Sager, C. E. (1993). A theory of performance. In N. Schmitt & W. C. Borman (Eds.), Personnel selection in organizations (pp. 35–70). Jossey-Bass.

DeVellis, R. F. (2017). Scale development: Theory and applications (4th ed.). Sage Publications.

Eisenberger, R., et al. (2002). Perceived Organizational Support: A Review of the Literature. Journal of Applied Psychology, 87(3), 698–714.

Eisenberger, R., Huntington, R., Hutchison, S., & Sowa, D. (1986). Perceived organizational support. Journal of Applied Psychology, 71(3), 500–507.

Fink, A. (2017). How to conduct surveys: A step-by-step guide (6th ed.). Sage Publications.

Hair, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., & Danks, N. P. (2023). *A primer on partial least squares structural equation modeling (PLS-SEM)* (3rd ed.). SAGE Publications.

Haynes, S. N., Richard, D. C. S., & Kubany, E. S. (1995). Content validity in psychological assessment: A functional approach to concepts and methods. Psychological Assessment, 7(3), 238–247.

Hertzog, M. A. (2008). Considerations in determining sample size for pilot studies. Research in Nursing & Health, 31(2), 180–191.

Hinkin, T. R. (1998). A brief tutorial on the development of measures for use in survey questionnaires. Organizational Research Methods, 1(1), 104–121.

Hung, W. H., Lin, C. P., & Yu, T. K. (2020). Determinants of hospital staff continuance of the use of artificial intelligence-assisted diagnosis and treatment. Technology in Society, 63, 101383.

Ibrahim, R., & Karim, A. (2020). Developing core competencies for biomedical engineers in the era of digital healthcare. Journal of Engineering Science and Technology, 15(2), 47–59.

Johanson, G. A., & Brooks, G. P. (2010). Initial scale development: Sample size for pilot studies. Educational and Psychological Measurement, 70(3), 394–400.

Koopmans, L., Bernaards, C. M., Hildebrandt, V. H., van Buuren, S., van der Beek, A. J., & de Vet, H. C. W. (2013). Development of an individual work performance questionnaire. *International Journal of Productivity and Performance Management, 62*(1), 6–28.

Lynn, M. R. (1986). Determination and quantification of content validity. Nursing Research, 35(6), 382–386.

Mahmod, A., Dewan, R., Yus Kelana, B. W., & Salim, M. I. M. (2025). Improving Industry Readiness: Insights from a Pilot Study of Biomedical Engineering Program. *International Journal of Academic Research in Business and Social Sciences*, *15*(4).

Marques, C., & Ferreira, J. J. (2020). Digital Readiness in STEM Education: A Technological Capabilities Perspective. Journal of Engineering and Technology Management, 55, 101562.

Md. Lazim et al. (2023). Validation Assessment of a Relationship between Teaching Practice and Professional Engineer Certification: A Pilot Study and Survey Evaluation, 1- 11

Mulder, M. (2014). Conceptions of Professional Competence. International Handbook of Research in Professional and Practice-Based Learning, 107–137.

Netemeyer, R. G., Bearden, W. O., & Sharma, S. (2003). Scaling procedures: Issues and applications. Sage Publications.

Olanrewaju, R. F., & Hamid, S. (2021). Bridging digital skill gaps in Malaysia's healthcare sector: The role of engineering education. International Journal of Emerging Technologies in Learning (iJET), 16(9), 148–160.

Parasuraman, A. (2015). Reflections on gaining competitive advantage through customer value. Journal of the Academy of Marketing Science, 43(2),159–164.

Parasuraman, A., & Colby, C. L. (2015). An updated and streamlined technology readiness index: TRI 2.0. Journal of Service Research, 18(1), 59–74.

Spencer, L. M., & Spencer, S. M. (1993). Competence at work: Models for superior performance. Wiley.

Topol, E. (2019). Deep Medicine: How Artificial Intelligence Can Make Healthcare Human Again. Basic Books.

Universiti Teknologi Malaysia. (2022). *Research Ethics Committee Guidelines*. Johor Bahru: UTM

Van Berkum, M., et al. (2024). Measuring Graduate Competence in Food Technology: Development of a Competency-Based Survey Instrument. European Journal of Engineering Education.

W. C. Borman (Eds.), Personnel selection in organizations (pp. 35–70).

Yusoff et al. (2024), Assessing the Reliability and Validity of a Survey Questionnaire for Online Laboratory Courses in Mechanical Engineering Programs, 70 - 75

Zamanzadeh, V., Ghahramanian, A., Rassouli, M., Abbaszadeh, A., Alavi-Majd, H., & Nikanfar, A. R. (2015). Design and implementation content validity study: Development of an instrument for measuring patient-centered communication. Journal of Caring Sciences, 4(2), 165–178.

Evaluating the Effectiveness of an Intensive CCIE Bootcamp: A Case Study from Indonesia

Article history
Received
11 June 2025
Received in revised form
29 June 2025
Accepted
5 July 2025
Published online
27 December 2025

Zamrin Md Zin[a,b,*], Izurrochman Aziz[c], Heri Susanto[d], Andi Muhammad Bintang Fadhilah[e], Nur Fatihah Najwa Zamrin[f], Hanafi Ahmad[f], Rosnani Sarkarsi[g], Farah Hussan Sahib[h]
[a]Technical and Vocational Faculty, University Pendidikan Sultan Idris, Tanjung Malim, Malaysia.
[b]ICT Department, Johor Port Berhad, Johor, Malaysia.
[c]Infrastructure Department, PT. Hanasta Dakara, Indonesia.
[d]IT Network Department, PT Fastrata Buana, Indonesia.
[e]IT Network Department, PT. Mastersystem Infotama TBK, Indonesia.
[f]Industrial Logistic Department, Universiti Kuala Lumpur, Malaysia.
[g]Department of Special Care Nursing, International Islamic University, Malaysia.
[h]Centre for Fundamental and Continuing Education, Universiti Malaysia Terengganu, Malaysia.
** zamrinmz@gmail.com*

Abstract
This study examines the instructional design, delivery, and educational impact of the Cisco Certified Internetwork Expert (CCIE) Bootcamp organized by IDN Networkers Indonesia. The problem addressed is the limited access to affordable, intensive CCIE certification preparation in Southeast Asia, where traditional training costs (USD 2,000-7,000) remain prohibitive for many professionals. Held over six consecutive days with training hours extending from 8:00 AM to 12:00 AM, the program represents an ultra-intensive technical training model. Using a qualitative case study approach with document analysis and thematic coding of participant testimonials (n=25), official program documentation, and autoethnographic observations, we evaluate the extent to which the bootcamp supports learning outcomes relevant to Cisco's CCIE certification through experiential learning theory (Kolb) and constructive alignment (Biggs frameworks. Data collection included structured interviews, participant feedback surveys, and systematic observation protocols. Our findings show that comprehensive content, immersive learning, and aligned support mechanisms significantly enhance participants' skill readiness and confidence with initial certification success rates of 12% (3 of 25 participants) within six months post-training. This paper contributes recommendations for integrating bootcamp models in formal engineering curricula in ASEAN.

Keywords: CCIE, engineering education, experiential learning, bootcamp, intensive training, Indonesia, Cisco certification.

Introduction

The Cisco Certified Internetwork Expert (CCIE) certification is widely recognized as one of the most prestigious and technically demanding qualifications in the field of networking. Introduced by Cisco Systems in 1993, the CCIE certification is designed to validate expert-level knowledge and skills in network engineering, covering areas such as routing and switching, security, data center, and service provider operations (Cisco, 2023). Achieving a CCIE not only demonstrates deep technical competence but also signifies the ability to design, implement, diagnose, and troubleshoot complex enterprise networks.

The importance of CCIE certification is well established in both industry and academia. For employers, it serves as a benchmark of technical excellence and commitment to professional development. Studies have shown that certified professionals tend to earn higher salaries, enjoy greater job mobility, and are more likely to be involved in strategic infrastructure projects (Global Knowledge, 2021). For network engineers, CCIE certification offers a path to career advancement and leadership roles in IT infrastructure, especially in mission-critical environments such as telecommunications, financial services, and large enterprise networks.

Md Zin, Z., Aziz, I., Susanto, H., Fadhilah, A.M.B., Zamrin, N.F.N., Ahmad, H., Sarkarsi, R., Hussan Sahib, F. (2025), Evaluating the Effectiveness of an Intensive CCIE Bootcamp: A Case Study from Indonesia, *ASEAN Journal of Engineering Education*, 9(2), 112-120. https://doi.org/10.11113/ajee2025.9n2.189

Despite its high value, the CCIE certification remains elusive for many professionals due to its intensive requirements, which include a rigorous written examination and an eight-hour practical lab exam. The financial burden—ranging from USD 450 for the written exam to USD 1,600 for the lab exam, excluding the cost of training and travel—poses a significant barrier, particularly for professionals in developing countries (Cisco, 2023). Additionally, the self-study nature of CCIE preparation can be overwhelming without structured guidance and access to real-world lab environments.

In this context, CCIE bootcamps have emerged as an effective solution to bridge the gap between self-study and certification success. Bootcamps are intensive, instructor-led training programs that provide focused, hands-on experience in a controlled learning environment. They offer structured coverage of the CCIE syllabus, access to advanced lab equipment or simulations, and opportunities to engage with expert instructors and peers. According to Simpson (2020), bootcamp-style learning can accelerate skills acquisition and improve certification outcomes by offering immersive, distraction-free training tailored to the demands of professional certification.

Intensive bootcamps are an emerging modality in professional and technical education. Within Southeast Asia, programs that compress technical content into short, high-impact sessions are increasingly used to prepare candidates for globally recognized certifications. The CCIE Bootcamp, initiated by Mr. Dedi Gunawan through the IDN Foundation, serves as a model for such efforts. The institution provides government-recognized IT diplomas while offering tuition-free secondary education.

Internationally, CCIE bootcamps are offered by various training providers including Internetwork Engineering (INE), Global Knowledge, and Netmetric Solutions (INE, 2023; Global Knowledge, 2023). These programs are typically run in North America, Europe, and India, offering both online and in-person formats. While comprehensive in content, they often lack the cultural immersion and residential nature exemplified by the IDN Bootcamp in Indonesia.

Another notable feature of the CCIE Bootcamp is its setting amidst nature, specifically in Pamijahan, Bogor—a location surrounded by mountains and forested terrain. Participants live, eat, and study in a serene and focused environment, which contributes to reduced stress levels and improved concentration (Figure 1). The natural surroundings also facilitate spiritual routines and encourage reflection, thus supporting the experiential learning cycle (Kaplan & Kaplan, 1989).

This paper evaluates the CCIE Bootcamp to understand how its pedagogical structure facilitates learning and prepares students for real-world challenges. It explores how the program's rigorous scheduling and immersive design align with foundational theories of engineering education. Specifically, this study aims to describe the pedagogical structure of the CCIE Bootcamp, evaluate its design through the lens of Kolb's Experiential Learning Theory and Biggs' Constructive Alignment, assess participant outcomes and experiences, and offer recommendations for engineering educators in ASEAN seeking to adopt similar models.

Figure 1. CCIE Bootcamp participants eat and study in a serene environment

Literature Review

Bootcamps in Engineering and Technical Education

Bootcamps are increasingly employed in technology and engineering education due to their ability to provide focused, competency-based training (Teague et al., 2020). Research shows that bootcamps create effective learning environments when tightly aligned with certification standards and supported through mentoring and peer collaboration (Chen et al., 2018).

The theoretical foundation for bootcamp effectiveness lies in cognitive load theory and spaced learning principles. Sweller (1988) demonstrates that structured, intensive learning environments can optimize cognitive processing when properly designed with appropriate breaks and scaffolding. In technical education, this translates to alternating periods of theory, practice, and reflection that prevent cognitive overload while maximizing retention.

Global and Regional Bootcamp Initiatives

Globally, coding and networking bootcamps have grown as alternative pathways to employment. In the United States, programs like General Assembly and Flatiron School have shown strong placement outcomes (Zhao, 2019). These programs typically focus on intensive, immersive learning experiences that compress traditional degree content into accelerated timeframes.

In Singapore, institutions such as NTUC LearningHub run short-term IT certification courses for working adults.

In Malaysia, bootcamp-style training is offered by MyDigitalMaker and Telekom Malaysia's Digital Workforce Institute, focusing on digital and network certifications (Hasan et al., 2021). Regional academic institutions have also recognized the value of intensive training models, with studies published in the ASEAN Journal of Engineering Education highlighting innovative approaches to engineering education that incorporate practical, hands-on methodologies (Pauzi & Kasim, 2023; Sarkawi et al. 2024).

However, these programs are typically shorter (1-3 days) or modular in format and do not often follow the immersive residential model used in the Indonesian CCIE Bootcamp.

The residential bootcamp model represents a distinct approach that combines intensive technical training with community building and peer support. This model has shown particular effectiveness in developing regions where access to high-quality technical education is limited by geographic and economic barriers.

Importance of CCIE Certification

The CCIE certification is one of the highest-level credentials offered by Cisco Systems. It is designed for senior networking professionals who design, implement, and troubleshoot complex enterprise networking environments. The certification has global prestige and is seen as a differentiator in the job market, often leading to higher-level roles and significantly improved salary prospects. CCIE certification not only builds credibility but also fosters in-depth understanding of emerging technologies such assoftware-defined networking (SDN) and cybersecurity], making it a future-proof credential (Scispace, 2023).

Learning Theory Adoption

Kolb (1984) proposed that learning is a cyclic process consisting of four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. In technical bootcamps, learners engage with real-time problem-solving, which facilitates this cyclical learning, especially through repeated practice and feedback cycles.

Biggs (1996) introduced the concept of constructive alignment, where learning activities, intended outcomes, and assessment tasks are aligned to foster deeper learning. The CCIE Bootcamp aligns theory, practice, and evaluation tightly, thus adhering to the principles of constructive alignment.

Long-duration, immersive training like that found in the CCIE Bootcamp also ties into Sweller's Cognitive Load Theory (Sweller, 1988). The bootcamp’s design attempts to mitigate overload through structured routines and supportive learning scaffolds (snack breaks, shared meals, reflection times).

CCIE Bootcamp Module Overview

- Layer 2 Technologies
- Redundancy Protocol
- OSPF EIGRP
- IPv6 EIGRP/OSPF
- BGP MPLS
- MPLS VPNv4/VPNv6
- DMVPN
- Multicast
- Cisco DNA Center
- Virtual Network DNA Center
- SD-WAN
- SD-WAN VPN Route Leaking
- Network Programming
- Python
- Automated Configuration Backup Script

Each module was carefully sequenced to build upon previous knowledge while introducing increasingly complex networking concepts and technologies relevant to modern enterprise and service provider environments.

Research Methods

Research Approach

This study adopts a qualitative case study approach to explore and evaluate the effectiveness of an intensive CCIE Bootcamp conducted in Indonesia. The case study design was selected to provide an in-depth, contextualized understanding of the bootcamp's structure, content delivery, and perceived impact on participants.

Participants: The bootcamp involved 25 participants (ages 24-38, mean=29.2 years) representing diverse backgrounds:

- Network engineers (n=15, 60%)
- IT support specialists (n=6, 24%)
- University lecturers (n=3, 12%)
- IT managers (n=1, 4%)

Inclusion criteria: Minimum 2 years networking experience, basic Cisco certification (CCNA or equivalent), and commitment to full program participation.

Data Collection Protocol: Multiple data sources were employed to ensure rich triangulation and strengthen the credibility of findings. These sources included:

1. Structured participant interviews (n=15, 30-45 minutes each)
2. Daily reflection surveys (Likert scale 1-5 +open-ended questions)
3. Focus group discussions (3 sessions, 8-10 participants each)
4. Autoethnographic observations by researcher-Participant
5. Document analysis of the publicly available "Rundown CCIE Bootcamp 2023" tentative

program and official bootcamp website (https://www.idn.id/ccie-bootcamp/)

The collected data were subjected to document analysis and thematic coding, with emerging patterns and themes systematically aligned to established educational frameworks, particularly those related to experiential learning, adult education, and bootcamp-based pedagogy. Triangulation was achieved through multiple data sources, member checking with participants, and peer debriefing with educational researchers.

Bootcamp Structure and Delivery

The bootcamp ran from 30 June to 6 July 2023 in Pamijahan, Bogor, Indonesia. The program employed a structured four-phase daily learning cycle designed to maximize knowledge retention and practical skill development:

Phase 1: Morning Theory & Review Session (2 hours: 08:00-10:00)

- Theoretical foundations: Introduction of new concepts and technical principles
- Previous day review: Systematic recap and reinforcement of prior learning
- Interactive Q&A sessions: Participant-driven clarification and discussion
- Learning objective setting: Clear daily goals and outcome expectations

Phase 2: Guided Practice Session (2-4 hours: 10:00-14:00)

- Instructor-led demonstrations: Step-by-step technical explanations
- Hands-on laboratory practice using network simulation software:
    i. VirtualBox 7.0 / VMware Workstation: Industry-standard virtualization platform for network device emulation
    ii. EVE-NG Community Edition: Professional-grade network emulation providing Cisco IOS, NX-OS, and ASA simulation
- Progressive complexity: Gradual increase in scenario difficulty and scope

Phase 3: Independent Testing & Troubleshooting (2-3 hours: 15:00-18:00)

- Practical skill assessment: Individual lab exercise completion
- Real-world troubleshooting scenarios: Problem-solving under time constraints
- Peer collaboration: Guided group problem-solving activities
- Instructor feedback: Immediate performance evaluation and improvement guidance

Phase 4: Advanced Module Progression (4-6 hours: 18:30-24:00)

- Next module introduction: Sequential progression through CCIE curriculum
- Complex scenario integration: Multi-technology lab environments
- Extended practice sessions: Deep-dive technical implementation
- Continuous learning cycle: Seamless transition to following day's content

Daily Schedule Components:

- 08:00 – 24:00: CCIE Lab (divided into focused learning phases)
- 06:30 – 08:00: Breakfast
- 12:00, 18:30: Lunch and dinner
- 10:00, 15:00, 21:00: Snack breaks

This structure encouraged full cognitive immersion in networking practice while maintaining wellness through communal meals and spiritual practice. The bootcamp location, nestled in a natural mountainous area, was intentionally chosen to reduce distractions and foster a tranquil, focused learning environment.

Results and Discussion

Participant Feedback and Learning Experience

One of the key findings from this case study is the overwhelmingly positive reception of the intensive CCIE bootcamp model delivered in Indonesia, particularly with respect to cost-effectiveness, pedagogy, and community-driven learning. The bootcamp provided a unique opportunity for aspiring IT network engineers to access high-quality CCIE preparation in a setting that was financially, logistically, and culturally tailored to the needs of the local context. To systematically evaluate participant experiences, daily satisfaction surveys were conducted using a 5-point Likert scale across seven learning dimensions.

Quantitative feedback data collected through daily surveys revealed consistently high satisfaction levels across all evaluated aspects (Table 1):

Table 1. CCIE Participant Satisfaction Survey Results

Learning Aspect	Mean Score (1-5)	Standard Deviation
Content Comprehensiveness	4.3	0.8
Instructor Effectiveness	4.6	0.6
Laboratory Quality	4.1	0.9
Peer Collaboration	4.7	0.5
Overall Satisfaction	4.4	0.7
Exam Readiness (Post)	4.2	0.8
Confidence Level (Post)	4.0	0.9

The survey results demonstrate exceptional participant satisfaction across all learning dimensions, with mean scores ranging from 4.0 to 4.7 on the 5-point scale. Peer Collaboration achieved the highest satisfaction rating (M=4.7, SD=0.5), indicating the effectiveness of the community-driven learning approach. Instructor Effectiveness scored 4.6 (SD=0.6), reflecting the quality of expert-led instruction. Notably, both Exam Readiness (M=4.2, SD=0.8) and Confidence Level (M=4.0, SD=0.9) showed substantial improvement, directly addressing the bootcamp's primary objective of CCIE certification preparation.

Financial Accessibility and Value for Money

A significant barrier to CCIE certification in Indonesia, as echoed by one of the participants, is the high cost of examination and study materials. The official costs for the CCIE written and lab exams amount to approximately USD 450 and USD 1,600 respectively. Additionally, the cost of self-study materials often ranges from USD 500 to as much as USD 5,000, making it inaccessible for many individuals without corporate sponsorship or substantial personal investment.

Recognizing this challenge, the bootcamp organizer offered a highly subsidized program at a cost of only IDR 8.5 million (approximately USD 560 based on June 2023 exchange rates), inclusive of 6 full days of instruction, accommodation, meals (breakfast, lunch, dinner, and tea breaks), and training facilities. This inclusive pricing model made the program not only affordable but highly attractive to participants, especially when benchmarked against conventional CCIE training providers.

The value proposition becomes even more compelling when considering that comparable commercial CCIE bootcamps typically charge between USD 3,000 to USD 8,000 for similar duration programs, excluding accommodation and meals.

This represents a cost reduction of approximately 85-90% compared to market rates. Furthermore, the subsidized model enabled participation from diverse economic backgrounds, including junior network engineers and IT professionals from smaller organizations who would otherwise be unable to afford such premium training. The democratization of access to high-quality CCIE preparation has significant implications for professional development equality within Indonesia's IT sector, potentially reducing the certification gap between corporate-sponsored and self-funded professionals.

The training modules were supported with comprehensive CCIE coursebooks and structured lab simulation materials. Each participant received the "CCIE Bootcamp Enterprise Infrastructure" textbook (346-page hardcopy), published exclusively by IDN Indonesia and written entirely in Indonesian (Figure 2). This localized resource provided detailed tutorials, technical explanations, network diagrams, and hands-on exercises specifically adapted for Indonesian networking professionals. All participants retained their textbooks as permanent reference materials, eliminating the typical USD 500-2,000 cost of international CCIE study resources.

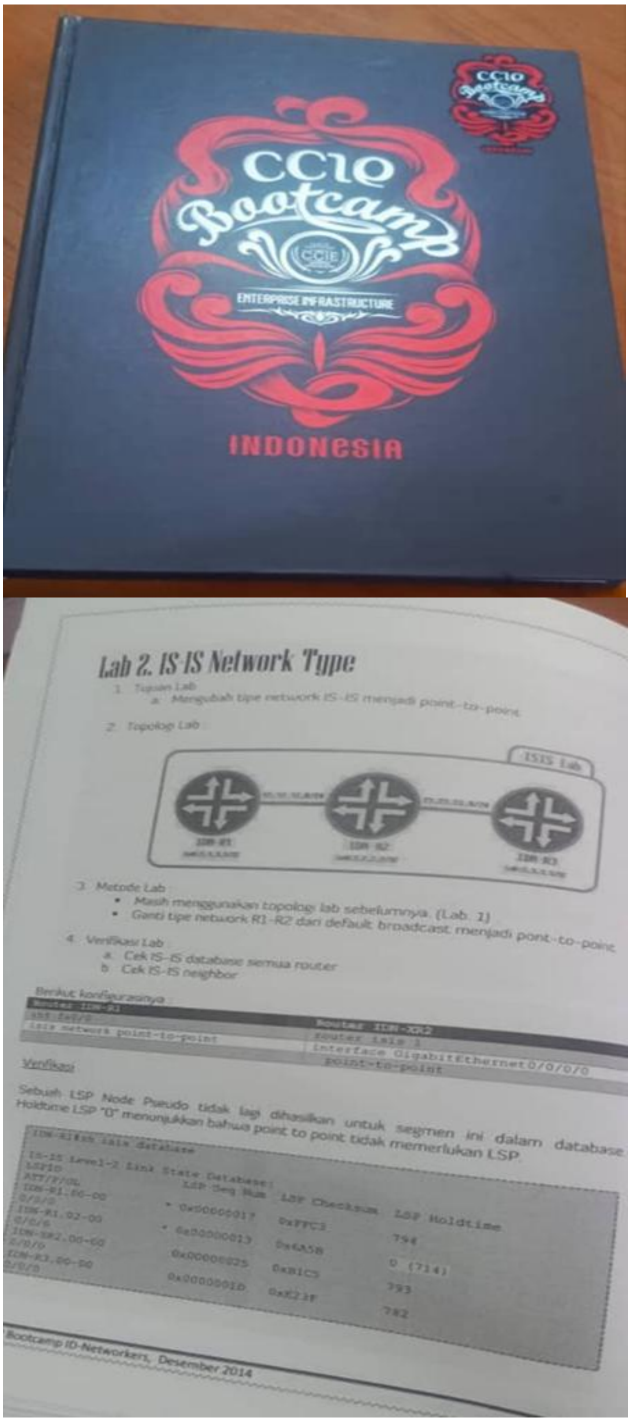


Figure 2. CCIE Bootcamp Study Materials by IDN Written in Indonesian

The lab scenarios were developed around real-world use cases, many of which were based on issues raised directly by the participants. This responsive, participant-centered approach enhanced engagement and relevance. The extended daily schedule allowed learners to deeply immerse themselves in solving networking problems, and all participants were able to complete the given tasks with support from instructors. Participants also engaged in activities aimed at mental relaxation, such as riverside breakfasts, barbecues, and recreational river bathing on the fifth day (Figure 3).

Figure 3. CCIE Bootcamp participants enjoying barbeque by the river

Learning Experience and Environment

The learning environment was intentionally informal and relaxed, set in a scenic valley near a river and away from city noise (Figure 4). Despite the remote location, high-speed internet was available, enabling participants to access external resources and documentation in real time. Such a setting contributed to a stress-free yet productive learning atmosphere. Participants also engaged in activities aimed at mental relaxation, such as riverside breakfasts, barbecues, and recreational river bathing on the fifth day.

Figure 4. Informal, relaxed, casual and away from the city CCIE Bootcamp

Additionally, the bootcamp incorporated spiritual elements such as congregational prayers and Quranic recitation sessions, aligning with the cultural and religious values of many attendees. This holistic approach to learning—addressing technical, emotional, and spiritual well-being—was a distinctive feature of the bootcamp.

The program was delivered by experienced instructors, including the bootcamp founder, Mr. Dedi Gunawan, a certified CCIE holder. Remarkably, some facilitators were alumni or current students of the IDN Polytechnic, fostering a peer-learning culture that helped to break down hierarchical barriers in the classroom. A sense of camaraderie was further enhanced through nightly lab sessions, often extending until midnight or even 3 a.m., with trainers working alongside participants.

Moreover, alumni of previous bootcamp batches voluntarily returned to share their success stories, providing motivational support and actionable advice (Figure 5).

Figure 5. CCIE Alumni success story sharing session

The presence of a WhatsApp support group post-bootcamp ensured ongoing peer-to-peer mentoring, reinforcing the sense of community and sustained learning.

Outcomes and Impact

As of the conclusion of this bootcamp batch, 3 out of 25 participants (12%) had successfully passed their CCIE certification exams within six months of bootcamp completion, with additional 8 participants (32%) successfully passing the written examination component. These outcomes highlight the bootcamp's role not just in training but also in professional advancement and employability. Historically, from 2012 until 2023, the IDN bootcamp has produced over 100 CCIE-certified professionals, many of whom have gone on to work with leading companies.

Testimonials gathered from the website and social platforms revealed the following themes:

Satisfaction: "*Sangat padat dan sangat daging semua materinya*." ("Very dense and packed with useful material.") This indicates the program's comprehensive and relevant content.

Confidence: "*Setelah bootcamp ini saya merasa lebih siap menghadapi ujian CCIE*." ("After this bootcamp, I feel more prepared to face the CCIE exam.") Participants gained a significant boost in self-efficacy and exam readiness.

Peer Support: "*Lingkungan belajar sangat positif, saling bantu antar peserta*." ("The learning environment is very positive, with participants helping each other.") The residential and communal setup created strong peer learning and collaboration.

Motivation: "*Bootcamp ini membangkitkan semangat belajar dan mengejar sertifikasi.*" ("This bootcamp reignited my passion for learning and pursuing certification.") Suggests intrinsic motivation was renewed during the immersive experience.

These sentiments support the notion that experiential and socially-supported learning frameworks contribute positively to knowledge retention and learner engagement. They also reinforce the idea that well-designed bootcamps can not only transfer skills but also inspire long-term professional development.

The bootcamp's success lies in its intensive, supportive learning ecosystem. By integrating Kolb's learning cycle, students are exposed to practice, reflect through shared discussion, abstract through theory review, and experiment via repeated labs. This cyclical instructional design directly implements Kolb's Experiential Learning Theory:

- *Concrete Experience (35% of daily time):* Hands-on laboratory practice using VirtualBox and EVE-NG simulation environments
- *Reflective Observation (15% of daily time):* Morning review sessions and peer discussion activities
- *Abstract Conceptualization (25% of daily time):* Theoretical foundations and instructor-led demonstrations
- *Active Experimentation (25% of daily time):* Independent troubleshooting and advanced scenario testing

Constructive alignment is achieved through clear intended outcomes (CCIE readiness), relevant activities (hands-on labs), and reinforcement (peer feedback, trainer mentoring).

Summary of Key Strengths

The bootcamp model presented in this case study offers several distinctive advantages:

- Comprehensive syllabus and lab simulations aligned with CCIE objectives.
- Extended contact hours (16 hours/day over 6 days) promoting deep engagement
- Affordable cost structure including accommodations and meals (USD 560 vs. USD 2,000-7,000 for international alternatives)
- High-quality instruction from CCIE-certified trainers.
- Localized instructional materials (346-page Bahasa Indonesia textbook)
- Professional simulation environment (VirtualBox 7.0, EVE-NG Community)
- Mentorship and peer-learning opportunities via alumni engagement.
- Post-program support through active online groups.
- A balanced focus on technical rigor, mental wellness, and spiritual grounding.

Overall, the bootcamp model presented in this case study offers a compelling example of how intensive, community-oriented, and affordable training can democratize access to high-level certifications like the

CCIE, particularly in developing regions where cost remains a prohibitive factor.

Study Limitations

Several limitations should be acknowledged in this study.

First, the case study design limits generalizability to other contexts, geographic regions, or different bootcamp models. The findings are specific to the Indonesian CCIE Bootcamp and may not apply to other intensive training programs or cultural settings.

Second, the sample size (n=25) and single-cohort focus restricts statistical power and broader applicability of the quantitative findings.

Third, the autoethnographic component may introduce researcher bias despite triangulation efforts through multiple data sources and member checking.

Fourth, the study's timeframe did not allow for long-term career impact assessment, limiting understanding of sustained professional benefits and certification maintenance over time.

Fifth, the absence of a control group or comparison with alternative CCIE preparation methods (self-study, online courses, traditional classroom training) limits claims about relative effectiveness.

Finally, the success rate measurement (12% within six months) may not reflect the full impact, as some participants may achieve certification beyond the study period.

Future research should address these limitations through longitudinal studies, larger sample sizes, and comparative analyses with alternative preparation methods.

Conclusion

The CCIE Bootcamp conducted by IDN Networkers Indonesia provides a compelling example of how intensive, immersive, and experiential learning environments can effectively support high-level technical certification preparation. Through a thoughtfully structured schedule, cultural immersion, and strong peer and mentor support, the program aligns with key educational theories including Kolb's Experiential Learning and Biggs' Constructive Alignment.

Quantitative and qualitative participant feedback confirms high levels of satisfaction, motivation, and exam readiness, with a 12% initial certification success rate within six months. The bootcamp's integration of localized instructional materials, professional simulation environments, and affordable access presents a holistic model that supports cognitive, emotional, and motivational aspects of learning—factors often underrepresented in traditional training models.

Given the increasing need for IT certified networking professionals across ASEAN, institutions should consider adopting similar approaches that combine academic rigor with experiential engagement and cultural relevance. Future research should investigate long-term outcomes such as certification success rates and career advancement of alumni to further validate the bootcamp's effectiveness and scalability across different regional contexts**.**

Acknowledgement

The authors wish to express sincere gratitude to Dedi Gunawan from IDN Networkers Indonesia for kindly granting permission to use images from the bootcamp sessions as material for this publication.

Conflict of Interest

The authors declare no conflict of interest.

References

Biggs, J. (1996). Enhancing teaching through constructive alignment. Higher Education, 32(3), 347–364.
Chen, X., Zhang, Y., & Zhou, Y. (2018). Understanding learners' experiences in coding bootcamps. ACM Transactions on Computing Education (TOCE), 18(4), 1-29.
Cisco. (2023). CCIE certification overview. Retrieved from https://www.cisco.com/c/en/us/training-events/training-certifications/certifications/expert/ccie-enterprise-infrastructure.html
Fröschl, K. A., & Goldberg, M. (2017). Realization possibilities for virtual networking labs in higher education courses. In 13th Annual International Conference on Computer Science and Education in Computer Science (CSECS), pp. 1-10.
Global Knowledge. (2021). IT Skills and Salary Report. Retrieved from https://www.globalknowledge.com/us-en/resources/resource-library/reports/it-skills-and-salary-report/
Global Knowledge. (2023). Cisco CCIE training programs. Retrieved from https://globalknowledge.com/cisco-training
Hasan, N. M., Yusof, N., & Ghazali, A. (2021). Upskilling Malaysia's digital workforce: Bootcamp initiatives and challenges. Journal of Human Capital Development, 14(2), 55–68.
IDN Indonesia (2023). CCIE Bootcamp 2023 Rundown. Retrieved from https://www.idn.id/ccie-bootcamp/
INE. (2023). CCIE Enterprise Infrastructure Bootcamp. Retrieved from https://ine.com/learning/certifications/cisco/ccie
International Journal of Computer Science and Information Security. (2015). Virtualization and Live Migration in VirtualBox. IJCSIS, 13(5), 45-52.
Kaplan, R., & Kaplan, S. (1989). The experience of nature: A psychological perspective. Cambridge University Press.
Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. Prentice Hall.
Kumar, S., & Patel, R. (2023). Comparative analysis of network simulation tools in engineering education: EVE-NG, GNS3, and Packet Tracer. International Journal of Engineering Education Technology, 15(3), 234-248.
Mendes, J., Silva, A., & Santos, R. (2023). Interactive Network Learning: An Assessment of EVE-NG Platform in Educational Settings. Acta Electrotechnica et Informatica, 23(3), 1-10.

Nakivo. (2023). VMware vs VirtualBox: Comprehensive comparison for enterprise virtualization. Virtualization Technology Review, 8(2), 45-62.

Oliveira, V. C. (2020). Eve-NG simulator in projects of heterogeneous networks: a study on the importance of simulation in computer networks. Research, Society and Development, 9(11), e1199119562.

Oracle. (2023). VirtualBox 7.0: Virtualization software. Retrieved from https://virtualbox.org/

Pauzi, A., & Kasim, F. H. (2023). Review on Chemical Engineering Capstone Design Teaching Model to Drive Continuous Improvement and Achieving Program Outcomes. Asean Journal of Engineering Education, 7(1), 24–33. https://doi.org/10.11113/ajee2023.7n1.121

Rosado, T., & Bernardino, J. (2014). An overview of openstack architecture. Proceedings of the 18th International Database Engineering & Applications Symposium, 366-367.

Sarkawi, M. S., Mohamed, M., Shamjuddin, A., Alias, H., & Mohamad, Z. (2024). Project-based Experiential Learning in Designing Truss Structure for First Year Chemical Engineering Students. Asean Journal of Engineering Education, 8(1), 49–55. https://doi.org/10.11113/ajee2024.8n1.149

Scarfone, K., Souppaya, M., & Hoffman, P. (2011). Guide to enterprise telework, remote access, and bring your own device (BYOD) security. NIST Special Publication, 800(46), 1-82.

Scispace. (2023). Cisco Certified Internetwork Expert (CCIE) certification exam. Retrieved from https://scispace.com/papers/cisco-certified-internetwork-expert-ccie-certification-exam-2qshv3hzqn

Simpson, R. (2020). The value of IT bootcamps in modern certification paths. Journal of Network Education, 17(2), 45–52.

Smith, J., & Anderson, K. (2010). Selecting and using virtualization solutions: our experiences with VMware and VirtualBox. Journal of Computing Sciences in Colleges, 25(3), 123-129.

Sosinsky, B. (2009). Virtualization and cloud computing. In Cloud Computing Bible (pp. 45-67). Wiley Publishing.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. Cognitive Science, 12(2), 257-285.

Teague, D., Lister, R., & Whalley, J. (2020). Engineering bootcamps: Pedagogical considerations and design. Australasian Journal of Engineering Education, 25(1), 43–56.

Thomas, M., Mitchell, M., & Joseph, R. (2020). Virtualization and cloud computing: A comprehensive technical research survey. International Journal of Computer Applications, 176(37), 15-22.

Uhlig, R., Neiger, G., Rodgers, D., Santoni, A. L., Martins, F. C., Anderson, A. V., ... & Smith, L. (2005). Intel virtualization technology. Computer, 38(5), 48-56.

VMware. (2024). VMware Workstation Pro virtualization platform for professional development. VMware Technical Documentation. Retrieved from https://docs.vmware.com/

Walters, R. (2012). A summary of virtualization techniques. Procedia Technology, 4, 267-272.

Zhang, L., Wang, H., & Chen, M. (2022). Network simulation environments for engineering education: A comparative study of EVE-NG and traditional approaches. Asian Journal of Engineering Education, 6(2), 78-85.

The Doctor of Efficiency: Philosophical Reflections on Knowledge and Meaning in the Age of AI

Article history
Received
2 November 2025
Received in revised form
2 December 2025
Accepted
8 December 2025
Published online
27 December 2025

Faical Mnif
Department of Electrical and Computer Engineering,
Sultan Qaboos University, Muscat, Oman.
mnif@squ.edu.om

Abstract

Artificial intelligence has accelerated knowledge production while quietly redefining what counts as knowing. Within universities, this transformation is most visible in the PhD; traditionally a Doctor of Philosophy devoted to slow inquiry and reflective understanding. As AI systems generate research outputs, structure arguments, and even simulate reasoning, the doctoral identity risks mutating into that of a Doctor of Efficiency: a figure of technical productivity optimized for metrics rather than meaning. This essay traces the philosophical genealogy of that shift, from Weber's instrumental rationality to contemporary algorithmic epistemology, arguing that AI represents the culmination, not the cause, of a long drift from wisdom to calculation. Drawing on Arendt, Simondon and Floridi, it diagnoses how automation displaces comprehension and how academia's fixation on speed undermines intellectual responsibility. The paper concludes by proposing an alternative ethos for the digital university grounded in cognitive authenticity, epistemic humility and reflective effort; the virtues through which intelligence regains its human depth.

Keywords: Artificial Intelligence, PhD, Knowledge, Cognitive authenticity.

Introduction: The Paradox of Intelligence

Artificial intelligence promises cognition without consciousness and reasoning without reflection. The very term intelligence, once bound to deliberation and meaning, has become shorthand for computational capacity. In laboratories and lecture halls alike, algorithms now accomplish tasks that once defined human scholarship: summarising texts, generating code, reviewing literature, simulating arguments. Yet as machines appear to think, human thought risks being redefined as what machines do efficiently. The paradox is not that AI thinks, but that it teaches us to value thinking less.

The modern PhD sits at the centre of this paradox. Conceived in nineteenth-century Germany as a Doctor of Philosophy, it symbolised the unity of disciplined inquiry and reflective judgement. Today, under the pressure of metrics and automation, it risks becoming the Doctor of Efficiency; an expert in accelerating knowledge production through computational means. The transformation is not merely pedagogical; it is civilisational. When universities equate learning with throughput, they convert understanding into a performance indicator. The question therefore arises: what remains of philosophy when intelligence is measured in iterations per second?

Within engineering doctoral education, the tension becomes decisive. The PhD has never been merely a credential of expertise but a commitment to understand the consequences of one's own knowledge. When automation accelerates inquiry, comprehension risks being displaced by output, as if knowing why could be postponed until after the results are achieved. But a scholar who produces without understanding risks contributing to a future they cannot interpret. If efficiency becomes the primary virtue of research, intelligence collapses into performance. Preserving the depth of the doctorate therefore means defending the spaces where understanding remains the measure of work, where reflection is not a delay but the condition of knowledge. The future of the doctorate will not be secured by faster thinking machines but by researchers who refuse to let speed outrun meaning.

The Figure of the Doctor of Efficiency

To speak of a Doctor of Efficiency is to describe a new scholarly archetype. This figure is fluent in the languages of automation, able to manipulate code and data, yet often estranged from the slower arts of reasoning. The doctoral candidate who relies on large language models to draft reviews or summarise theories gains speed but loses apprenticeship in thought. The machine becomes the first reader of every text, the silent co-author of every idea.

Academic structures reinforce this metamorphosis. Funding cycles reward deliverables; citation indices quantify influence. The culture of publish-or-perish treats knowledge as a continuous

Mnif, F. (2025), The Doctor of Efficiency: Philosophical Reflections on Knowledge and Meaning in the Age of AI, *ASEAN Journal of Engineering Education*, 9(2), 121-124. https://doi.org/10.11113/ajee2025.9n2.204

production line. Within such a system, AI does not corrupt scholarship, it completes it. Automation becomes the final form of the logic universities already serve.

The ethical consequence is profound. The scholar's responsibility shifts from truth to throughput. Where the philosopher once asked whether an argument was valid, the efficient researcher asks whether it is accepted. In the mirror of AI, academia confronts its own mechanisation.

Automation and the Erosion of Understanding

Understanding differs from information as listening differs from hearing. It requires duration, hesitation, and error; the very qualities automation is designed to eliminate. AI systems such as large neural networks excel at correlation, not comprehension; they operate within statistical rather than semantic space. Their successes seduce us into mistaking prediction for explanation. When researchers delegate interpretation to algorithms, they inherit that epistemic shallowness.

The philosopher Gilbert Simondon (1958) viewed technology as the concretisation of human thought: each machine embodies a schema of reasoning. Yet when machines begin to reason autonomously, they mirror not our understanding but our abstraction. The opacity of deep learning, described by Burrell (2016), makes results reproducible but not interpretable. In science and scholarship alike, reproducibility without intelligibility undermines the very notion of knowledge.

Efficiency thereby becomes an epistemic criterion: if it works, it is true. The consequence, as Judea Pearl and Dana Mackenzie (2018) observe, is the eclipse of causality by correlation. Knowledge shifts from knowing why to knowing how well. This epistemic inversion, caused by the cult of efficiency, marks the true revolution of AI.

Reclaiming Philosophy in the Age of Automation

If automation reveals the limits of comprehension, philosophy reveals its necessity. The remedy to mechanised intelligence is not romantic rejection but reflective integration. To philosophise amid machines is to recover the human capacity for understanding as responsibility; to insist that knowing entails answering for what one knows. The modern university, if it is to remain more than a knowledge factory, must transform AI from an instrument of acceleration into a mirror for reflection.

Reclaiming philosophy therefore begins with epistemic humility. Where AI produces certainty by volume, philosophy cultivates uncertainty by design. To recognise the boundaries of one's understanding is to reopen the space of wonder that automation tends to close. Humility is not the absence of knowledge but its condition of possibility: only those aware of ignorance can meaningfully inquire. In an environment saturated with computational assurance, humility becomes a revolutionary virtue.

A second virtue is cognitive authenticity; the alignment between what the scholar produces and what the scholar truly understands. In an age of automated authorship, authenticity requires explicit reflection on how digital tools participate in thought. When a doctoral candidate uses AI to draft, simulate or analyse, the ethical question is not whether such use is legitimate but whether it is understood. Authenticity thus redefines originality: not as independence from tools but as transparency in reasoning with them.

Finally, there is reflective effort. The ease of automation tempts intellectual passivity. Reflection resists this by reinstating effort as a moral value. The time taken to understand, to wrestle with ambiguity and failure, is not inefficiency; it is the very process through which meaning emerges. To think slowly in the age of AI is not nostalgia but resistance to superficiality. It is the deliberate preservation of depth in an accelerating world.

The University as Moral Technology

The call to re-philosophise knowledge cannot remain abstract. Universities are not neutral infrastructures; they are moral technologies; systems that encode particular visions of the good. When they prioritise metrics over meaning, they operationalise instrumental reason. When they cultivate reflection, they embody ethical intelligence. The curriculum, assessment, and doctoral training are therefore sites of moral engineering.

Within doctoral education, this means redefining success. Instead of measuring progress by publication counts or algorithmic performance, institutions might evaluate the quality of understanding. Supervisory dialogues could include not only technical feedback but ethical questioning: What does this model assume? What does it exclude? Who benefits from its accuracy? Such questions return the human dimension to inquiry. They also make visible what automation conceals; the interpretive choices behind every dataset and the moral weight of every conclusion.

Philosophy in this sense becomes the conscience of research. It does not slow science; it stabilises it. Just as engineers build safety factors into bridges, scholars must build epistemic safety factors into knowledge; margins of reflection that prevent collapse under the weight of efficiency.

Beyond Efficiency: Re-Humanising Intelligence

To re-humanise intelligence is not to diminish machines but to elevate humanity. AI extends human capability; it should not replace human curiosity. The challenge is to maintain a dialogue between machine precision and human purpose. As Luciano Floridi (2023) argues, the digital revolution demands an infosphere ethics: a framework where information processes are judged by their contribution to human flourishing. Efficiency, within such an ethic, becomes secondary to significance.

Hannah Arendt's warning in The Human Condition (1958) resonates here. When thought becomes labour and labour becomes automatic, action, the realm of freedom and meaning, disappears. The Doctor of Efficiency embodies that disappearance: an intellect that acts without thinking, producing without reflecting. Re-humanising intelligence means restoring action to thought; reintroducing deliberation where automation offers completion.

This restoration is not merely individual but collective. The community of scholars must cultivate slow spaces; seminars, retreats, and colloquia where ideas are developed without immediate deliverables. Slowness is not resistance to technology but architecture for wisdom. In a world where AI compresses time, philosophy must expand it.

The Ethics of Understanding

The ultimate task of philosophy in the digital university is to transform understanding from an epistemic achievement into an ethical obligation. Knowledge divorced from responsibility becomes power without direction. The doctoral oath, implicit or explicit, should therefore include not only commitment to truth but commitment to meaning; to ensure that the expansion of intelligence serves human comprehension rather than eclipses it.

Miranda Fricker's (2016) notion of epistemic injustice, the harm done when someone's capacity as a knower is undermined, extends poignantly to AI. When algorithms mediate what counts as knowledge, they risk committing systemic epistemic injustice by excluding interpretive depth itself. The Doctor of Efficiency participates unwittingly in this harm by valuing performance over understanding. Philosophical reflection becomes an act of repair, restoring the dignity of knowing as a human practice.

Håvard Sætra (2022) identifies an "ethics of effort" as essential in automated societies: moral worth arises not from outcomes alone but from the commitment of attention. This insight reframes doctoral work. The candidate who labours to comprehend, even inefficiently, performs an ethical act. In contrast, effortless mastery, whether delivered by machine or borrowed text, diminishes moral agency. Understanding is valuable not because it is productive, but because it is earned.

Philosophy's Technological Turn

If the nineteenth century industrialised matter, the twenty-first industrialises thought. Philosophy's task is therefore no longer to interpret technology from without but to think through it. The digital medium reshapes not only what we know but how we think; philosophy must inhabit this new terrain without surrendering its critical distance. This means using AI as a philosophical instrument; testing its reasoning, exposing its assumptions, and learning from its failures.

Such engagement transforms both partners. AI becomes a lens through which philosophy re-examines its own claims about reason, mind and autonomy. Conversely, philosophy becomes a means by which AI research confronts questions it cannot compute: What is meaning? What is responsibility? The encounter between philosophy and AI thus revives the very dialogue that the Doctor of Efficiency had silenced.

Gilbert Simondon's concept of individuation offers a useful metaphor. Just as a machine evolves through successive concretisations, so knowledge evolves through successive reflections. Each iteration of understanding refines not only what is known but who knows. The doctoral journey, when re-philosophised, mirrors this process: it is not the production of data but the formation of self through thought.

Efficiency in Engineering Doctoral Education

In engineering doctoral education, the transformation of scholarship into efficiency becomes starkly visible. The closer research is tied to technological progress and industrial expectation, the more the doctoral journey is recast as a race; toward publications, toward patents, toward measurable innovation. Artificial intelligence intensifies this logic by accelerating the very tasks that once defined intellectual apprenticeship: reading, modelling, composing, even critiquing. What once demanded patience and reflection now appears as mere friction. When speed becomes proof of intelligence, the doctoral scholar risks being trained not to understand more, but simply to achieve faster.

This acceleration reshapes supervision itself. The apprentice model, grounded in dialogue and slow maturation of ideas, is pressured by timelines, grants, deliverables. The machine increasingly becomes the silent supervisor; offering suggestions, rewriting sentences, simulating outcomes, while the human mentor becomes a project manager tracking milestones. The doctoral candidate may emerge technically skilled yet epistemically fragile, able to operate with tools whose meanings they no longer have time to grasp. Knowledge risks becoming a form of automation; functional, impressive, and strangely hollow.

The danger is not that engineers will become ignorant, but that they will become successful without understanding. Efficiency promises mastery without reflection, capability without conscience. Engineering doctoral education therefore stands at a threshold: either it defends the intellectual depth that gives technology meaning, or it allows automation to define intelligence as throughput alone. The doctoral engineer, entrusted with shaping the world, must remain capable of questioning what the machine performs; otherwise, innovation becomes a momentum without direction, and progress itself loses its purpose.

The pressures driving this acceleration are acutely felt in ASEAN universities, where engineering research is often tied to national development agendas and the rapid expansion of technological capacity. Doctoral candidates are encouraged to deliver outcomes that advance industry, infrastructure, and innovation, leaving little time to dwell on the meaning of what is produced. As AI becomes embedded in research practices, the temptation grows to value productivity over comprehension, speed over synthesis. Here, the question of what it means to understand is not abstract; it is a matter that shapes the foundations on which emerging societies build their futures.

Towards an Ethos of Reflective Intelligence

What, then, might replace efficiency as the governing value of intelligence? An ethos of reflection; a disposition that prizes comprehension over completion and dialogue over data. In practical terms, this ethos would cultivate interdisciplinary literacy, ethical deliberation and the patience to dwell with complexity. It would celebrate curiosity as much as competence.

Such an ethos does not oppose AI but orients it. Machines can accelerate discovery; they cannot supply direction. Direction arises from value, and value is a human invention. When the Doctor of Efficiency remembers this, efficiency itself regains moral significance; it becomes the means by which understanding travels, not the measure of its worth.

Conclusion: The Return of Philosophy

Artificial intelligence has not abolished thinking; it has revealed how fragile thinking is. The danger lies not in machines that know too much, but in humans who forget why they know at all. The cure is reflection slower, deeper, more deliberate engagement with the meanings that computation cannot reach. The next revolution in intelligence will not be artificial; it will be reflective.

The future of the doctorate, and by extension of knowledge, depends on restoring philosophy to its rightful place as the conscience of intelligence. The Doctor of Philosophy and the Doctor of Efficiency are not enemies but phases of the same evolution. Efficiency made possible the scientific progress that now threatens to overwhelm understanding; philosophy must provide the counter-force that keeps progress human.

The modern doctorate stands where thought becomes action, where ideas acquire material force in the world. Its task is not only to extend knowledge but to shape the very structures through which society moves, communicates and lives. When understanding gives way to acceleration, creation risks outpacing comprehension, and innovation arrives unaccompanied by meaning. What is produced begins to matter more than what is understood. To preserve the dignity of research, the doctorate must remain a place where the power to transform the world is always met by the responsibility to interpret it; where the ability to build is inseparable from the obligation to know why and for whom we build.

Acknowledgments

This work was supported by Sultan Qaboos University. The authors take full responsibility for the views and arguments expressed herein. Assistance from AI tools (e.g., ChatGPT) was limited strictly to language refinement and did not contribute to the intellectual content or structure of the manuscript.

Conflict of Interest

The author declares no conflict of interest.

References

Arendt, H. (1958) The Human Condition. University of Chicago Press, Chicago.
Burrell, J. (2016) How the machine “thinks”: understanding opacity in machine learning algorithms. Big Data & Society 3(1).
Dignum, V. (2023) Responsible Artificial Intelligence. Springer, Cham.
Floridi, L. (2023) The Ethics of Artificial Intelligence. Oxford University Press, Oxford.
Fricker, M. (2016) Epistemic Injustice: Power and the Ethics of Knowing. Oxford University Press, Oxford.
Hayles, N. K. (2017) Unthought: The Power of the Cognitive Nonconscious. University of Chicago Press, Chicago.
Pearl, J., Mackenzie, D. (2018) The Book of Why: The New Science of Cause and Effect. Basic Books, New York.
Rosa, H. (2013) Social Acceleration: A New Theory of Modernity. Columbia University Press, New York.
Sætra, H. S. (2022) The ethics of effort in artificial intelligence and automation. AI & Society 37(2):495–506.
Simondon, G. (1958) Du mode d’existence des objets techniques. Aubier, Paris.
Verbeek, P. P. (2011) Moralizing Technology: Understanding and Designing the Morality of Things. University of Chicago Press, Chicago.

A Scoping Review of Diversity, Equity, and Inclusion in Energy Engineering Education

Article history
Received
17 November 2025
Received in revised form
27 November 2025
Accepted
29 November 2025
Published online
27 December 2025

Yie Hua Tan[a,b]*, Ummul Hasanah Haji Hassan[a], Mohammad Hazwan Bin Azri[a], Rama Rao Karri[a], Shyang-Pei Hong[c], Reddy Prasad[a], Pui Vun Chai[b]
[a]Chemical and Energy Engineering, Faculty of Engineering, Universiti Teknologi Brunei, Jalan Tungku Link Gadong, BE1410, Brunei Darussalam
[b]Department of Chemical and Petroleum Engineering, Faculty of Engineering, Technology and Built Environment, UCSI University, Cheras, 56000, Kuala Lumpur, Malaysia
[c]Department of Agrotechnology, School of Applied Sciences and Mathematics, Universiti Teknologi Brunei, Brunei Darussalam, Bandar Seri Begawan BE1410, Jalan Tungku Link, Brunei Darussalam
**yiehua.tan@utb.edu.bn*

Abstract
A diversity, equity, and inclusion (DEI) problem persists in undergraduate programming, despite energy engineering receiving increasing attention as a critical field in addressing sustainability and global energy challenges. This paper examines the current situation of energy engineering education on DEI worldwide based on the areas of gender, race, and socioeconomic inclusion. This discussion examines the challenges and explores inclusive pedagogy, curriculum structure, faculty development, student mentoring, and institutional commitment. The review concludes that, although some of these initiatives are promising, integration is cursory and inconsistent. Embedding DEI in teaching pedagogy, institutional frameworks, and policy to enhance the undergraduate students' learning outcomes and equity in energy engineering is recommended.

Keywords: Energy Engineering, Diversity, Equity, Inclusion, Engineering education.

Introduction

Engineering education has come to acknowledge that learning in all its forms can be enhanced through diversity of talent and inclusive learning environments as being crucial in innovation and societal advancement. The purpose of Equity, Diversity, and Inclusion (DEI) initiatives is to eliminate structural inequalities, which have hampered the ability of women and racial/ethnic minorities, along with low-socioeconomic-status (SES) students, to pursue engineering in the past (Amer et al., 2024; Direito et al., 2021). Identities are usually defined in terms of DEI as the presence of diverse identities (race, gender, culture, etc.) and a set of institutional practices that guarantee equitable access (equity) or a sense of belonging (inclusion) (Direito et al., 2021). Diverse teams have been shown to increase creativity and innovation in engineering; however, there remains a leaky pipeline, where certain groups still leave the programs or careers out of proportion regarding undergraduate groups (Ridgway et al., 2023; Smith et al., 2023). Energy engineering is a sub-discipline of engineering that lies on the borders of technology, the environment, and society, and thus, should represent the multiplicity of people all over the world. Lying at the crossroads of mechanical, electrical, chemical, and environmental engineering, energy engineering is aimed at developing, integrating, and optimizing energy systems, such as renewable energy, energy efficiency, power generation, and energy storage (Thumann & Mehta, 2020). Therefore, it is central in regard to net-zero ambitions, decarbonization, and energy access equity around the world. In spite of the significance, the deficit in representation is still notable, especially when it comes to gender, racial or ethnic minorities, and students of disadvantaged socioeconomic statuses. Creativity, equity, and inclusion in energy engineering education are valid as diversity encourages the generation of new ideas, equity maintains a fair involvement, and inclusion maintains engagement, but their practices are still uneven (Pellissier et al., 2022). The restricted representation of women, minorities of color, and students of low socioeconomic status decreases the level of diversity and innovation in intricate energy

Tan, Y.H., Hassan, U.H., Azri, M.H., Karri, R.R., Hong, S.P., Prasad, R., Chai, PV. (2025), A Scoping Review of Diversity, Equity, and Inclusion in Energy Engineering Education, *ASEAN Journal of Engineering Education*, 9(2), 125-132. https://doi.org/10.11113/ajee2025.9n2.206

issues (Stephens, 2020). The effects of energy transitions vary when this happens across communities; hence, a diversified workforce in energy engineering must exist to establish inclusive and sustainable solutions. This review examines the global strategies to promote DEI in undergraduate energy engineering education. The issues concerning gender, race/ethnicity, and SES were discussed. Also, gather information related to pedagogical strategies, curricular improvement, and policies that have taken place across the globe.

Methodology

The scoping review has been carried out with the use of academic databases (Scopus, Web of Science, Google Scholar) and the reports of professional bodies dated between 2010 and 2024 (Amer et al., 2024). The searching keywords included “diversity”, “equity”, “inclusion”, “energy engineering,” and “undergraduate groups in STEM,” with a specific focus on energy engineering, gender, race, and socioeconomic status. Amer et al. (2024). Amer et al. (2024) gave an example of how the systematic keyword searching (equity, diversity, engineering education) and thematic analysis of DEI in engineering faculties could be performed (Smith et al., 2023). Documents were chosen on the basis of their relevance to undergraduate energy engineering and their inclusion of DEI themes. There were 42 sources examined in the review, which include journal articles (20), conference papers (7), governmental reports (4), institutional policy reports (5), books and book chapters (4) and dissertations (2). A qualitative thematic analysis was conducted by reviewing each selected source systematically and identifying recurrent themes around topics pursued for diversity, equity and inclusion in energy engineering education. The articles were reviewed in detail, and prominent observations pertaining to sex, race/ethnicity, or socioeconomic status were recorded. Words with similar ideas were then grouped together, and patterns in the literature were compared to ascertain common themes. This recursive process permitted the identification of larger, thematic categories to emerge from among the analysed sources, which allowed for a structured review of DEI concerns and practices in the field.

DEI in Energy Engineering Education

DEI in energy engineering education is identified into several categories. Diversity consists of the representation of identity (gender, race, socioeconomic status, ability, and culture) (Fernández et al., 2023). Equity addresses the barriers that keep individuals in an unfair situation by allowing inclusion in the learning environment that makes individuals feel appreciated and welcomed (Ainscow, 2020). These principles are critical in the development of solutions in energy engineering that are socially just, technically, and culturally responsive. The energy engineering field of study has an immense scope of disciplines and technologies that are essential to the creation of a sustainable future. They consist of a clean energy system like solar, wind, hydro, and biomass, intelligent electrical grids, and efficient building and industrial energy systems, carbon capture and utilization and storage (CCUS), and emerging technologies such as hydrogen energy and the advanced nuclear system (Thumann & Mehta, 2020). The technical, social, and international nature of these fields requires a skilled and socially responsible workforce.

University of Toronto has started to incorporate Indigenous knowledge as well as environmental justice in energy systems design curricula (*Integrating Indigenous Perspectives into the UC Curricula,* 2025; Kanu, 2011). Electrical and information engineering technology (EIET) program at the University of Northern Iowa (UNI) is incorporating social equity aspects into college-level capstone projects in renewable energy, where they would encourage students to design technologies that would consider an environmental and social payoff (Pecen et al., 2003). United States TRIO and LSAMP programs are federal initiatives that subsidize, mentor, and provide undergraduate students in STEM and energy access to research opportunities (Donovan et al., 2021). These programs have enjoyed great success when it comes to the low-income, first-generation, and minority students. African Centre of Excellence in Energy for Sustainable Development (ACE-ESD) in Rwanda is an example of inclusive energy education regionally in Africa (Khundi-Mkomba et al., 2021). The center attracts both academic excellence and social responsibility through its gender balance targets and interaction with the immediate communities.

The practitioners in this sector should be capable of traversing the vicinity of energy technology, environmental impact, and the overall welfare of society. Therefore, DEI is fundamental in the process of energy engineering education because it ensures that students across the board can engage, join, and contribute to the resolution of energy problems through incessant creation. A multicultural classroom environment adds texture to classroom discussions and promotes teamwork, as well as increasing the insights into social aspects of engineering solutions (Akintayo et al., 2024). This subsequently translates to more efficient energy systems, which are fair and fulfill the requirements of various populations.

Gender Equity

Gender imbalance remains stark in energy-related engineering programs globally. In most jurisdictions, less than one-third of the engineering graduates are female (Ali et al., 2025; Krishnannair & Krishnannair, 2024). In Sub-Saharan Africa (SSA), less than 30 percent of tertiary engineering graduates are female (Obonyo, 2024), for example. This male-dominated culture promotes stereotyping about the ideal engineer and helps in the attrition of women (Baird, 2018; Smith et al., 2023). To deal with this, curbing measures have been implemented by institutions and governments. In India, since 2018, a supernumerary reservation (quota) of 20 % female students in top institutes (Indian Institutes of Technology and National Institutes of Technology) has been added to their current 14 % reservation (Choudhury, 2016). A number of state and privately owned colleges in India, too, have reservations of 5 to 33 % of the seats for women, and the All India Council for Technical Education has given 10,000 Pragati scholarships to girl students in engineering every year (Das, 2025). Such policies succeeded in increasing the number of women enrolled in colleges somewhat (e.g. the female share in Indian Institutes of Technology increased to ~20% versus 8% before) (Das, 2025). Pragati scheme has been introduced to provide scholarships and reserved seats for girl students in technical disciplines such as energy engineering with the support of All India Council for Technical Education (AICTE) (Priyadarshini & Latha, 2019). The results of such efforts are reflected as there are now observed more women venturing into institutions of excellence like the Indian Institutes of Technology (IITs).Top-down policies of this type are seen elsewhere (e.g. quotas of women in Brazil, which are not described here).

Beyond admissions, universities build support structures. Inclusive policy is established through dedicated diversity offices or committees (e.g. the Engineering Equity, Diversity, Inclusion, & Decolonization steering committee at Western University (Amer et al., 2024)), and community is fostered through campus networks (e.g. chapter-based women-in-engineering, mentoring circles). In Spain, the 54 universities in Spanish Universities for University Excellence (RUIGEU) network of Gender Equity Units established it as a way to communicate and exchange best practices to increase the success of women (Amer et al., 2024). Spain has implemented the RUIGEU network that brings together gender equity offices at over 50 universities, providing a platform where DEI policies are developed and implemented in a consistent manner. Action plans and targets can assist as well: e.g. some faculties are now monitoring gender disparities in enrolment/retention and establishing targets they want to achieve. In the classroom, inclusive pedagogy supports women's success. Some of these strategies are active-learning strategies (which empirically reduce gender gaps in performance), teaching methods that involve the Universal Design for Learning to address various needs of students, and incorporating topics about female engineers and gender issues into the courses (Witcher, 2020). As an example, culturally-responsive curriculum could emphasize the work of female engineers or include gender biases in case studies, thus enhancing relevance and belonging in women students (Lux et al., 2024).

Racial and Ethnic Diversity

Students who are undergraduate ethnic/racial minorities usually face more challenges in engineering studies. According to U.S. research, programs "are less likely to retain women and students of color at all levels". The stereotypes and microaggressions against the identities of minority students may undermine self-efficacy and the sense of belonging among them. Latine and Black engineering students, as an example, state that they feel like outsiders in white-dominated programs. In addition, minority students are overrepresented as low-income students (e.g. many Latinx students have low-income families), thereby adding to access challenges (Smith et al., 2023).

Institutions combat these challenges through targeted recruitment and support. The outreach programs collaborate with a high school in the underserved communities to motivate minority youth. As an example, the U.S. universities are involved in such programs as TRIO Talent Search and Upward Bound that select low-income, first-generation, Science, Technology, Engineering, and Mathematics (STEM) talent and offer them college-preparatory experiences. These programs are connected with engineering camps and mentorship, such that one student recalled that a TRIO mentor showed her around aerospace labs and discussed scholarship options, which in effect builds technical capital and demystifies college engineering (Martin et al., 2020). Pathways to entry (e.g., link or foundation years, or higher offers to undergraduate groups) are also used in many schools to admit minority students as well as to provide bridging courses as part of the solution to the lack of preparation.

Institutional action plans and affinity groups are common on campus. Peer support and professional development opportunities in engineering are common in North American engineering schools through the presence of chapters of NSBE (National Society of Black Engineers), Society of Hispanic Professional Engineers (SHPE), and American Indian Science and Engineering Society (AISES), among others. Other faculties use the appointment of EDI champions or committees to direct efforts against racism. As an example, the Faculty of Engineering of McGill University developed an Action Plan Against Anti-Black Racism, some of the goals of which include expanding the presence of Black students and diversifying its faculty. Another model is the government-led approach of Spain, where the country has national networks of universities (e.g. Conference of Rectors of the Spanish Universities (CRUE)-Diversity and Disability of CRUE-Students Affairs) that coordinate disability and diversity policies in 66 universities, and a Network for Diversity (RUD) comprises 30 universities that explicitly proclaim to promote inclusion of sexual/gender diversity, cultural and religious backgrounds, etc. (Amer et al., 2024). Such networks support the exchange of policies (e.g., anti-discrimination training, inclusive facilities) and allow universities to teach one another.

Canadian universities use decentralized action together with specific plans. According to Amer et al. (2024), numerous engineering institutions have their equity programme. As an illustration, McMaster University has developed a Faculty of Engineering Equity Plan and McGills above-mentioned anti-racism plan. McGill University (Canada) is one example that has implemented an anti-Black racism action plan in the Faculty of Engineering, which includes the review of hiring practices, curricula change, and collaboration with local communities (Burke et al., 2021). In Spain, the national policy, on the other hand, secures harmonization of efforts. These are two varying models that run in context: Canadian higher education is institution-centered, whereas the Spanish system can have government-funded and nationwide programme. The lesson is that bottom-up (institution-led) approaches, as well as top-down (policy-driven) approaches, can promote racial inclusion when coordinated with the local needs.

Socioeconomic Inclusion

There are unique challenges that confront low-income or first-generation college engineering students with respect to energy engineering. Quite a number arrive unprepared because of unequal K-12 resources (Smith et al., 2016). Especially math-intensive and rigorous, engineering programs can leave unprepared students struggling (Kopparla, 2019). Tuition and living costs are another cause of financial stress that prevents persistence. Numerous schools provide financial support to STEM students, specifically on a need-based basis. The above-mentioned Pragati scheme in India provides the scholars with scholarships for girls (Priyadarshini & Latha, 2019). In some countries, there exist stipend programs for low socio-economic status STEM students (Baldwin et al., 2022). In Canada, the U.S., and elsewhere, grants (e.g., Pell Grants, NSERC bursaries) and programs (TRIO Student Support Services) for disadvantaged students are funded by governments (Diehl, 2024; Grants, 2019). Canadian Scholarship for Persons with Disabilities (CSEP) scholarships and Engineers Canada scholarships typically have lower-income candidates who are underrepresented as their target audience (Harrison & McCarron, 2023; Ross et al., 2020). Engineering cohorts of disadvantaged backgrounds are also financed by nonprofits and industry foundations. On analyzing Southern Africa, a UNESCO survey suggested both campaigning and funding (stipends, scholarships) to increase female numbers in STEM (Unterhalter et al., 2024).

Many effective interventions on all levels of DEI are supported by inclusive classroom teaching and teaching according to the relevant curricula. Extensive research on engineering education demonstrates that the student-centered, active-learning method has multiple advantages, including the disproportionate benefits to the underrepresented learners. To clarify, a meta-study investigating the effects of high-quality active learning concluded that the high-quality active learning decreased the gap in exam scores between majority and minoritized students majoring in STEM by approximately 33% and in passing rates by approximately 45% (Witcher, 2020). This has been aligned to an active-learning inclusive approach, and the fact that active-learning depends on scaffolded practices, regular feedback, and group interaction, and does not condescend to the students (Witcher, 2020). Energy engineering courses, therefore, where the primary teaching tool is experiential (hands-on projects, small group problem solving, and peer instruction), enable minority, female, and lower-SES students to close the gap and feel appreciated. Instructors would be advised to use Universal Design for Learning (UDL) principles (Lux et al., 2024), including providing more than one presentation of material (visual, verbal, collaborative); delivering low-stakes forms of assessment; and creating a classroom environment that shows belonging.

DEI is also facilitated through reforms in the curricular content. Incorporating issues of energy that are germane to a variety of communities (e.g., rural electrification or the gendered effects of energy policy) can be used to engage students with a variety of backgrounds. Assignments and case studies designed to profile the contributions inflicted by engineers of color and women broaden layer models. Units on ethics and social justice in engineering (requiring DEI and global development modules) raise all students to the level of consciousness of equity issues. As an example, there exists a teaching module that provides engineering people with an introduction to the concept of the ethics of diversity and inclusion (Sabat, 2023). Some institutions provide clear teaching regarding implicit bias, how to cooperate in multidisciplinary teams, and the power of diversity (Diaz et al., 2020). All these curricular strands are indications of institutional good intentions and provide students who are underrepresented with a sense that their identities are applicable to the engineering task.

Faculty development is also very important. Classroom climate may be improved by training and preparing instructors in inclusive pedagogy, e.g. how to prevent disrespectful collaboration, express clear and encouraging language, or include inclusive examples (Dessel, 2010). Workshops on inclusive teaching and other resources are currently provided by engineering education communities (American Society for Engineering Education (ASEE) and the European Society for Engineering Education (SEFI)) (Direito et al., 2021). A similar program allowed faculty to incorporate equity issues into STEM curriculum and was reported to have increased engagement rates in students (Desing & Clayton, 2025). In short, curriculum changes that focus on active, culturally relevant, and student-centered learning have some of the most empirical support in changing diversity outcomes (Lux et al., 2024).

Challenges in DEI

The minority group and women are still underrepresented among students and faculty. DEI material is seldom considered in the engineering courses, resulting in curriculum gaps. Skepticism of the DEI and institutional inertia still persists; thus, the institute is resistant to change. The majority of teachers have not been trained professionally with regard to inclusive pedagogy. A small number of programs employ indicators to examine DEI practices. Few of the energy engineering programs employ measurements to analyze DEI programs; thus, there is insufficient evaluation. Also, the majority of the strategies target DEI only with one dimension of either gender, race, or income, without acknowledging that identities intersect in complicated ways. This restricts how effective interventions and actions can be in relation to learners with multiple and overlapping forms of disadvantage.

Partly due to structure and culture, there are several structural and cultural issues that constrain DEI in energy engineering education. First, the area to this day experiences a major lack of representation of women, as well as racial and ethnic minorities and low-income students. The percentage of female engineering graduates throughout the world is not even at 20 percent, and this is even lower in the disciplines that major in energy. There are also other setbacks, including the lack of quality STEM education and role models, that minority students experience. The institutions lack the ability to collect and disaggregate data regarding demographics and experiences of students, hence it is hard to see whether progress is being achieved or not, and to adapt interventions accordingly.

The DEI measures that sometimes prove to be ineffective include integration of DEI into technical curriculum, which is there only to add to elective programs, but is not incorporated into the general curriculum. The majority of curricula are still aligned to technical content without paying much attention to the social and ethical aspects of energy systems. Other subjects like energy justice, gender effects of energy transitions, or the contribution of engineering in solving energy poverty are instead given the status of peripheral to the field. This disjoint causes weakness in the ability of the students to think through the societal implications of what they are undertaking.

Thirdly, it can be a significant barrier to DEI initiatives because of certain resistance in some institutions. Certain faculty and administrators might view DEI as politically excessive, or they believe it has nothing to do with technical learning. This opposition will be furthered by a lack of awareness and training of instructors in inclusive teaching. Scalability of mentorship and training programs is restricted by resource-related limitations, especially in institutions that do not have significant funds. Consequently, most DEI activities are either isolated, informal, or low-funded.

Strategies and Recommendations for DEI in Energy Engineering Education

The most promising way of enhancing DEI is to include the societal issues of social justice and ethical consideration in the energy engineering curricula. This incorporates case studies about marginalized communities that are affected by energy projects, an analysis of the distributional effects of energy policies, and the incorporation of Indigenous and local knowledge systems in the design considerations. Technical knowledge and human knowledge can be connected through courses in energy and society, or global energy justice, or ethics in energy engineering.

Another important strategy is active and inclusive pedagogy. The enhancement of outcomes regarding undergraduate energy engineering students has been revealed to foster pedagogical strategies based on problem-based learning, a flipped classroom, and group projects. Assignments need to be culturally related or based on the community to make students relate to the material in a better way. Lecturers are supposed to speak inclusively, accommodate different styles, and be flexible to the different needs and backgrounds of students (Vásquez et al., 2025).

Mentorship and support networks will play an important role in guiding the undergraduate students through energy engineering programs. Peers in the form of peer mentorship groups, industry mentorships, and/or affinity networks, i.e., Women in Renewable Energy (WIRE) or the National Society of Black Engineers (NSBE), can offer academic, professional, and emotional support (McPherson, 2024). Such networks can be further enhanced through the support of alumni and industry partners who can frame role models and career access into oil and gas occupations.

Inclusive learning environments need the development of their faculty and staff. Academic staff should be trained to become aware of implicit bias, learn to address diverse learners, and interact in a respectful manner with DEI issues. Institutions ought to also reward such inclusive teaching using prizes, grants, and promotion guidelines that consider the contributions made to DEI. Interdisciplinary relations and continuous professional development courses are areas that can contribute to the capacity of faculty to work with DEI (Impedovo et al., 2025). Inclusive environments have to be continuously supported in the long term by faculty training and mentorship infrastructure. They should also encourage community-building and visibility through student-led DEI events and activities that institutions should support.

Institutions have to declare DEI a priority at an institutional level. This can be done by carrying out strategic planning where measurable diversity objectives are established to recruit, retain, and graduate students. To build a pipeline of DEI leadership positions and offices could be created where Engineering faculties would organize those initiatives and progress, and would hold people accountable. The metrics of DEI also ought to be integrated into the assessment models of accrediting bodies like ABET and EUR-ACE, so that equity can become one of the educational quality standards (Adăscăliţei & Arădoaiei, 2019; Putman et al., 2024). The bodies awarding accreditation ought to call on programs to contain learning outcomes revolving around equity and inclusion. Curriculum developers ought to come up with open-access material that mirrors diverse opinions and experiences.

DEI principles should become the core of educating engineers in the energy sector. Engineering, social sciences, and humanities offer transdisciplinary opportunities to complement and even transform curricula and to lead to more comprehensive views of energy systems. The national and regional organizations of the DEIs should provide a standard DEI reporting platform that will ensure the benchmarking of the different performances and the exchange of best practices. These systems have the potential to guide more specific funding, policy decisions, and accountability to the public on DEI in the engineering education field.

Conclusion

Inclusion, equity, and diversity in undergraduate energy engineering education are set to require complex responses. Bringing diversity, equity, and inclusion to energy engineering education is not only the right thing to do but a practical one as well. Since energy systems define economies, ecosystems, and the general lifestyles, they need to be modelled and developed by professional individuals who reflect and perceive the differences in the global society. There are shared principles to be discovered, and proactive recruitment of underrepresented populations, inclusive teaching, financial and social assistance to students, and program responsibility for achieving equity are some of them. With stakeholders moving into convergence on sustainable development priorities, DEI in energy engineering education is not just a social responsibility but a technical one: It opens the full range of human creativity to the clean-energy transition and well beyond. A broader energy engineering education makes engineering more innovative, increases access to opportunities, and empowers students to meet the energy challenges of our era. Incorporating DEI as a component of curriculum, pedagogy, faculty development, and institutional policy, energy engineering programs will be able to graduate individuals who can be the technical experts and paragons of social responsibility in the clean energy transformation.

Acknowledgement

The authors thank Universiti Teknologi Brunei and UCSI for realizing the current work.

Conflict of Interest

The authors affirm that they do not have any known conflicting financial interests or personal ties that may have given the appearance of influencing the work that is presented in this publication.

References

Adăscăliţei, A., & Arădoaiei, S. T. (2019). Blended teaching and learning solutions for electrical engineering study programs. 2019 International Conference on Electromechanical and Energy Systems (SIELMEN).

Ainscow, M. (2020). Promoting inclusion and equity in education: lessons from international experiences. *Nordic journal of studies in educational policy*, *6*(1), 7-16. https://doi.org/10.1080/20020317.2020.1729587

Akintayo, O. T., Eden, C. A., Ayeni, O. O., & Onyebuchi, N. C. (2024). Cross-cultural instructional design: A framework for multilingual and interdisciplinary education. *International Journal of Applied Research in Social Sciences*, *6*(5), 785-800. https://doi.org/10.51594/ijarss.v6i5.1101

Ali, K. S., Islam, Q. T., & Talukder, M. S. (2025). Empowering Change: The Role of Women in STEM for Achieving Sustainable Development Goals. In *African Women Trailblazers in STEM* (pp. 120-145). CRC Press. https://doi.org/dx.doi.org/10.1201/9781003540618-9

Amer, A., Sidhu, G., Alvarez, M. I. R., Ramos, J. A. L., & Srinivasan, S. (2024). Equity, diversity, and inclusion strategies in engineering and computer science. *Education Sciences*, *14*(1), 110. https://doi.org/10.3390/educsci14010110

Baird, C. L. (2018). Male-dominated stem disciplines: How do we make them more attractive to women? *IEEE Instrumentation & Measurement Magazine*, *21*(3), 4-14. https://doi.org/10.1109/MIM.2018.8360911

Baldwin, G. L., Booth-Womack, V., LaRose, S. E., Stwalley, C. S., & Stwalley III, R. M. (2022). Using support networks as a predictor of success for STEM degrees: preliminary results detailing a selection process for test subjects engaged in a longitudinal study of low socio-economic status American undergraduate students. *International Journal of Engineering Pedagogy (iJEP)*, *12*(6). https://doi.org/10.3991/ijep.v12i6.25547

Burke, M., Hanson, C., & Abraham, C. (2021). Addressing Black inclusivity within a Canadian post-secondary engineering faculty: A critical perspective. *Canadian Journal of Science, Mathematics and Technology Education*, *21*(2), 257-272. https://doi.org/10.1007/s42330-021-00155-5

Choudhury, P. K. (2016). Growth of engineering education in India: Status, issues and challenges. *Higher Education for the future*, *3*(1), 93-107. https://doi.org/10.1177/2347631115610223

Das, S. C. (2025). *Gender Reservation in Indian Engineering Education: Policies, Progress, and Perspectives*. https://alltogether.swe.org/2025/07/gender-reservation-indian-engineering-education/

Desing, R. M., & Clayton, R. N. (2025). Enhancing engineering faculty implementation of inclusive pedagogy through an inclusive excellence faculty development program. 2025 ASEE Annual Conference & Exposition.

Dessel, A. (2010). Prejudice in schools: Promotion of an inclusive culture and climate. *Education and Urban Society*, *42*(4), 407-429. https://doi.org/10.1177/0013124510361852

Diaz, T., Navarro, J. R., & Chen, E. H. (2020). An institutional approach to fostering inclusion and addressing racial bias: implications for diversity in academic medicine. *Teaching and learning in medicine*, *32*(1), 110-116. https://doi.org/10.1080/10401334.2019.1670665

Diehl, S. V. (2024). *Bridging the Gap Between Inputs and Outcomes: Pell-Eligible Students' Usage and Perceptions of Aid and Support at Community Colleges* Northeastern University].

Direito, I., Chance, S., Clemmensen, L., Craps, S., Economides, S. B., Isaac, S. S., . . . Wint, N. (2021). Diversity, Equity, and Inclusion in Engineering Education: An Exploration of European Higher Education Institutions' Strategic Frameworks, Resources, and Initiatives. SEFI 49th annual conference proceedings 2021.

Donovan, L. J., Bugallo, M., Woodson, T., Foley, C. J., Kent, S. N., London, B., . . . McInnis, M. (2021). An NSF-LSAMP model for the successful transition of underrepresented students into STEM majors and beyond. 2021 ASEE virtual annual conference content access.

Fernández, D. P., Ryan, M. K., & Begeny, C. T. (2023). Recognizing the diversity in how students define belonging: Evidence of differing conceptualizations, including as a function of students' gender and socioeconomic background. *Social Psychology of Education*, *26*(3), 673-708. https://doi.org/10.1007/s11218-023-09761-7

Grants, U. (2019). Research Matters.

Harrison, A. G., & McCarron, M. (2023). Supports and services for students with disabilities in postsecondary education in Canada. In *Handbook of higher education and disability* (pp. 52-63). Edward Elgar Publishing. https://doi.org/10.4337/9781802204056.00011

Impedovo, M. A. A., Ungureanu, E., & Marty, O. (2025). Faculty and Staff Development: Professional development programs to gain a deeper understanding of diversity, equity, and inclusion (EDI) issues. https://doi.org/https://hal.science/hal-05103744v1

Integrating Indigenous Perspectives into the UC Curricula. Retrieved 15 Nov 2025 from https://www.uc.utoronto.ca/indigenous-uc-living-commitment-ucs-response-trc-integrating-indigenous-perspectives-uc-curricula

Kanu, Y. (2011). *Integrating Aboriginal perspectives into the school curriculum: Purposes, possibilities, and challenges*. University of Toronto Press. https://doi.org/10.3138/9781442611320

Khundi-Mkomba, F., Saha, A. K., & Wali, U. G. (2021). Examining the state of energy poverty in Rwanda: An inter-indicator analysis. *Heliyon*, *7*(11). https://doi.org/10.1016/j.heliyon.2021.e08441

Kopparla, M. (2019). *Experiences of Freshmen Enrolled in Math-Intensive STEM Majors* Texas A&M University].

Krishnannair, S., & Krishnannair, A. (2024). Empowering Tomorrow's Scientists:'Girls In Control'Workshop Promotes STEM Education For Young Girls. *IFAC-PapersOnLine*, *58*(25), 37-42. https://doi.org/10.1016/j.ifacol.2024.10.234

Lux, N., Hammack, R., Gannon, P., Windchief, S., Taylor, S., Richards, A., & Hacker, D. J. (2024). Culturally Responsive Energy Engineering Education: Campus-Based Research Experience for Reservation and Rural Elementary Educators. *Journal of STEM Outreach*, *7*(2), n2. https://doi.org/10.15695/jstem/v7i2.07

Martin, J. P., Stefl, S. K., Cain, L. W., & Pfirman, A. L. (2020). Understanding first-generation undergraduate engineering students' entry and persistence through social capital theory. *International Journal of STEM Education*, *7*(1), 37. https://doi.org/10.1186/s40594-020-00237-0

McPherson, D. S. (2024). *Nevertheless, She Persisted: Examining the Structural and Individual Barriers Impacting NSBE, SHPE, and SWE Professional's Engineering Careers* Northeastern University].

Obonyo, R. (2024). *Empowering girls in Africa to embrace STEM*. https://africarenewal.un.org/en/magazine/empowering-girls-africa-embrace-stem

Pecen, R., Hall, T., Chalkiadakis, F., & Zora, A. (2003). Renewable energy based capstone design applications for an undergraduate engineering technology curriculum. 33rd Annual Frontiers in Education, 2003. FIE 2003.

Pellissier, R., Siluk, F., Flynn, C., & Kanaan, M. (2022). Approaching equity, diversity, inclusion, and social justice education as imperative to engineering curricula. *Proceedings of the Canadian Engineering Education Association (CEEA)*. https://doi.org/10.24908/pceea.vi.15924

Priyadarshini, P., & Latha, N. (2019). Initiatives in Higher Education: Government of India. *Date Fac. Dep. Coord*, *2*, 107.

Putman, B. J., Al-Sahili, K. A., Khader, A., & Gilbrecht, A. (2024). Assessing ABET Student Outcomes Through International Virtual Exchange. 2024 ASEE Annual Conference & Exposition,

Ridgway, M., Oldridge, L., Edwards, M., Kougiannou, N., Pass, S., Lawley, S., & Caven, V. (2023). Equality, diversity, and inclusivity in engineering, 2013 to 2022: a review. https://doi.org/10.17631/RD-2024-0002-DREP

Ross, R., Chaput, J.-P., Giangregorio, L. M., Janssen, I., Saunders, T. J., Kho, M. E., . . . McLaughlin, E. C. (2020). Canadian 24-hour movement guidelines for adults aged 18–64 years and adults aged 65 years or older: an integration of physical activity, sedentary behaviour, and sleep. *Applied physiology, nutrition, and metabolism*, *45*(10), S57-S102. https://doi.org/10.1139/apnm-2020-0467

Sabat, M. P. a. I. (2023). *Diversity, Ethics, and Engineering*. Retrieved 15 Nov 2025 from https://onlineethics.org/cases/diversity-ethics-and-engineering

Smith, K. C., Poleacovschi, C., Feinstein, S., & Luster-Teasley, S. (2023). Ethnicity, race, and gender in engineering education: The nuanced experiences of male and female Latinx engineering undergraduates targeted by microaggressions. *Psychological Reports*, *126*(5), 2345-2382. https://doi.org/10.1177/00332941221075766

Smith, P. S., Trygstad, P. J., & Banilower, E. R. (2016). Widening the gap: unequal distribution of resources for K-12 science instruction. *Education Policy Analysis Archives*, *24*(8), n8. https://doi.org/10.14507/epaa.24.2207

Stephens, J. C. (2020). *Diversifying power: why we need antiracist, feminist leadership on climate and energy*. Island Press.

Thumann, A., & Mehta, D. P. (2020). *Handbook of energy engineering*. River Publishers. https://doi.org/10.1201/9781003151715

Unterhalter, E., Howell, C., Longlands, H., Malloy, M., Vieira do Nascimento, D., & Sigamoney, R. (2024). Women's Participation in Higher Education in Southern Africa: STEM, Leadership, and Enrollment. https://doi.org/10.54675/VSIE5438

Vásquez, M. L. M., Ramírez, L. C. C., Bernaola, M. L. Y., Torrealva, J. R. Y., Torrealva, Z. M. R., Cárdenas, D. M. C., & Altamirano, S. F. S. (2025). Inclusive pedagogy and active learning in higher education: Cluster and dimensional insights into teaching competency integration. *Social Sciences & Humanities Open*, *12*, 102060. https://doi.org/10.1016/j.ssaho.2025.102060

Witcher, T. R. (2020). *Active learning helps diverse groups with STEM subjects*. Retrieved 15 Nov 2025 from https://www.asce.org/publications-and-news/civil-engineering-source/civil-engineering-magazine/article/2020/11/active-learning-helps-diverse-groups-with-stem-subjects

Designing Better Engineering Education Through Assessment: A Book Review

Article history
Received
23 November 2025
Received in revised form
27 November 2025
Accepted
29 November 2025
Published online
27 December 2025

Mohamad Syahrul Nizam Ibrahim [a*] ***& Norazman Shahar*** [b]**,**
[a] *Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia*
[b] *Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia*
**syahrul@ums.edu.my*

Abstract
Designing Better Engineering Education Through Assessment: A Practical Resource for Faculty and Department Chairs on Using Assessment and ABET Criteria to Improve Student Learning, edited by Joni E. Spurlin, Sarah A. Rajala, and Jerome P. Lavelle, provides a comprehensive guide to enhancing engineering education through effective assessment practices aligned with ABET accreditation standards. Aimed at faculty members and department chairs, this book focuses on the practical application of assessment methods to improve student learning and meet accreditation criteria. It explores the role of both formative and summative assessments in evaluating student outcomes at various stages of the engineering curriculum, from introductory courses to capstone projects and graduate education. The book is divided into four main parts: the basics of assessment, barriers and challenges to effective implementation, assessing student learning across the educational continuum, and the future of assessment in engineering education. The first part introduces fundamental assessment concepts and the importance of aligning assessments with desired learning outcomes. The second part addresses common obstacles, such as faculty resistance and institutional inertia, and provides strategies for overcoming these challenges. Part three discusses the integration of assessment throughout the engineering education experience, emphasizing methods used at different educational stages. The final part looks ahead, examining emerging trends and technologies that could transform the future of assessment. Through its practical examples, case studies, and expert insights, this book serves as a valuable resource for those seeking to improve engineering programs by ensuring that student learning is effectively measured and continuously enhanced. It offers actionable strategies for creating a culture of assessment that supports the ongoing improvement of engineering education.

Keywords: ABET, student learning, accreditation, curriculum improvement, program outcomes, formative assessment.

Spurlin, J., Rajala, S.A., & Lavelle, J.P. (Eds.). (2008). Designing Better Engineering Education Through Assessment: A Practical Resource for Faculty and Department Chairs on Using Assessment and ABET Criteria to Improve Student Learning (1st ed.). Routledge. https://doi.org/10.4324/9781003444107

Introduction

Designing Better Engineering Education Through Assessment serves as an essential guide for engineering faculty and department chairs looking to enhance the quality of their educational programs through effective assessment practices. Edited by Joni E. Spurlin, Sarah A. Rajala, and Jerome P. Lavelle, the book offers a practical, evidence-based approach to applying assessment methods that align with the Accreditation Board for Engineering and Technology (ABET) criteria. As engineering education continues to evolve in response to global challenges and industry demands, this book provides a comprehensive roadmap for institutions aiming to improve student outcomes and meet accreditation standards.

The editors bring extensive expertise in engineering education and assessment, with Spurlin, Rajala, and Lavelle all holding significant academic and leadership roles in engineering education reform. Their combined experience ensures that the book not only offers theoretical insights but also practical, real-world applications that are vital for institutional leaders. Spurlin's work in engineering education assessment, Rajala's experience as a former dean, and Lavelle's focus on curriculum design and program evaluation make the book an authoritative resource for improving the quality of engineering education.

This book is divided into four key sections, each addressing different aspects of assessment. The first part explores the fundamentals of assessment, introducing readers to the concepts and tools necessary for measuring student learning outcomes.

The second part tackles the challenges and barriers to implementing effective assessment, particularly focusing on overcoming resistance from faculty and institutional constraints. In the third part, the book looks at how assessment can be integrated throughout the engineering educational experience, from introductory courses to capstone projects. The final section examines emerging trends and technologies in assessment, offering a vision for the future of engineering education assessment.

By providing both a theoretical understanding of assessment and practical examples of its application across different stages of the engineering curriculum, the editors ensure that the book is not only a tool for meeting ABET's accreditation requirements but also a comprehensive guide to fostering continuous improvement in engineering programs (Raza et al., 2024). With contributions from experienced educators and assessment professionals, Designing Better Engineering Education Through Assessment is an invaluable resource for anyone looking to enhance the effectiveness of their engineering education program.

Summary and opinions

Designing Better Engineering Education Through Assessment provides an in-depth exploration of how assessment practices can be used to improve engineering education at both undergraduate and graduate levels. The book offers both theoretical insights and practical guidance, making it a valuable resource for faculty, department chairs, and academic administrators

Part One: Basics of Assessment

The first section introduces the core principles of assessment, focusing on its importance in improving student learning, curriculum, and teaching practices. Linda Suskie's chapter, *Understanding the Nature and Purpose of Assessment*, provides a thorough overview of assessment theory, emphasizing how it should be linked to clear and important educational goals. This section will appeal to faculty members who are new to assessment or looking to strengthen their understanding of its role in improving program outcomes. The book stresses that assessments must be used to inform decisions about curriculum design, teaching methods, and overall program improvement, making this section particularly relevant for faculty who are involved in program design or accreditation processes.

Part Two: Barriers and Challenges

The second part of the book addresses the barriers that often prevent effective assessment in engineering education, such as faculty resistance and institutional inertia. In *Barriers and Challenges to Assessment in Engineering Education*, J. Joseph Hoey and Eleanor W. Nault explore the challenges institutions face in establishing a culture of assessment, such as resource constraints and lack of professional development. One of the most compelling aspects of this section is its focus on strategies to overcome these barriers. This is especially useful for department chairs and faculty leaders who may be tasked with guiding their institutions through the process of implementing or improving assessment practices. The book suggests that fostering a collaborative environment, building trust among faculty, and securing administrative support are essential for successful assessment adoption which is similar to approach by Fiore & Koverola (2021). Faculty members can benefit from understanding how to overcome resistance and implement practical solutions within their own departments.

Part Three: Learning Along the Continuum of the Educational Experience

Part three focuses on the integration of assessment across the entire educational experience, from first-year courses to graduate programs. One of the highlights of this section is Jerome P. Lavelle and Sarah A. Rajala's chapter on Assessing the First Year of Engineering Education. This chapter presents innovative assessment methods for first-year engineering courses and discusses how early assessment can help improve retention rates and address the unique challenges faced by first-year students. The use of longitudinal tracking, pretest/post-test assessments, and attitudinal surveys is discussed as part of a broader effort to assess the foundational stages of engineering education. Faculty teaching introductory courses can find this section particularly valuable, as it provides evidence-based strategies for assessing the effectiveness of first-year curricula and identifying areas for improvement. The goal is to better equip students from the outset, ensuring that they are on track for success throughout their academic careers.

In our view, the integration of assessment across the educational continuum is crucial not only for improving retention but also for fostering a deeper understanding of the material. By implementing early assessments, educators can identify and address challenges before they become insurmountable, helping students build a strong foundation for their future courses (Imran et al., 2023). Moreover, these assessments encourage a proactive approach to learning, empowering students to take ownership of their educational journey (Ibrahim & Julius, 2024). It is essential that this kind of thoughtful and data-driven assessment continues to evolve, ensuring that every student, regardless of their entry point into the program, has the support they need to thrive academically and professionally.

Part Four: The Future of Assessment

The final section of the book looks ahead to the future of assessment in engineering education. This part explores emerging assessment technologies, including the use of concept maps, model-eliciting activities (MEAs), and e-portfolios, and how these tools can provide richer, more dynamic insights into student learning. The chapter on *The Future of Assessment*, written by Mary Besterfield-Sacre and Larry J. Shuman, presents the evolving landscape of assessment tools that are likely to shape the next generation of engineering education. This forward-thinking chapter will be of particular interest to faculty and administrators who are looking for innovative ways to measure student learning and adapt to the changing needs of both the engineering profession and educational accreditation bodies.

Highlighted Sections of Interest

Chapter 3: Assessment Methods Used in Undergraduate Program Assessment by Joni E. Spurlin

This chapter presents practical approaches to assessment in undergraduate engineering programs, including how course-based assessments can be used to evaluate student learning outcomes. It is particularly valuable for faculty members, as it provides a comprehensive framework for integrating assessment methods into everyday teaching practices. By focusing on the alignment of assessment methods with program objectives and educational outcomes, this chapter helps faculty understand how assessments can drive program improvements. It also introduces the concept of assessing educational objectives through multiple constituencies, such as faculty, alumni, and employers, making it an invaluable tool for those seeking to improve both their teaching practices and the quality of their engineering programs.

Chapter 9: Assessment for Improving Teaching and Student Learning within a Course by C. Dianne Raubenheimer

This chapter addresses how engineering faculty can use Classroom Assessment Techniques (CATs) to evaluate and improve their own instructional methods. The chapter categorizes CATs into techniques for assessing course knowledge, learner attitudes, and reactions to teaching, offering a range of tools for faculty to assess the effectiveness of their teaching. The use of action research in the classroom is also discussed as a way for instructors to continuously assess and improve their teaching practices. For faculty members who are looking to refine their own teaching strategies and engage students more effectively, this chapter is an excellent resource, providing actionable techniques for real-time assessment and feedback.

Educational Theories and Models in Engineering Assessment

"Designing Better Engineering Education Through Assessment" offers a comprehensive approach to assessment in engineering education, grounded in two pivotal educational theories/models: Formative and Summative Assessments and Assessment for Continuous Improvement.

Formative and Summative Assessment Framework

One of the central themes in the book is the use of both formative and summative assessments. The authors highlight how formative assessments used to monitor student progress throughout a course, are critical for providing ongoing feedback that informs teaching practices. Summative assessments, in contrast, evaluate students at the end of the learning period, serving as a final judgment of their achievement. This dual approach ensures that assessments are not only used for evaluation but also for the continuous enhancement of both teaching methods and student outcomes. The book emphasizes that these assessments must align with clear, predefined educational goals, ensuring that they contribute meaningfully to student learning.

Assessment for Continuous Improvement

Another key educational framework discussed in the book is the idea of assessment as a tool for continuous improvement. The authors argue that assessments should not be viewed solely as final evaluations of student performance but as integral components of the broader educational process. Through continuous assessment, educators can refine teaching strategies and adapt curricula based on student feedback and performance trends. This approach not only enhances the immediate learning experience but also fosters long-term improvements in educational quality and program design. The book underscores that assessments must be a dynamic, iterative process, one that evolves as both students and educational practices progress.

These educational frameworks provide the theoretical foundation for the practical strategies presented in the book. By emphasizing the role of assessment in both improving immediate learning outcomes and ensuring ongoing educational development, the book offers a valuable guide for engineering educators looking to foster a culture of continuous improvement within their programs.

Conclusion

Designing Better Engineering Education Through Assessment serves as a crucial guide for faculty, department chairs, and academic administrators who are dedicated to improving the quality of engineering education through effective assessment practices.

Edited by Joni E. Spurlin, Sarah A. Rajala, and Jerome P. Lavelle, the book provides an extensive framework for aligning assessment strategies with ABET accreditation criteria, addressing both the theoretical underpinnings of assessment and its practical application in real-world educational settings. The book's comprehensive approach offers readers valuable insights into how assessment can be integrated into engineering curricula at all stages of student development, from first-year courses to graduate education. The editors emphasize that assessment should not be viewed merely as a means of evaluating student performance but as an ongoing, dynamic process that informs curriculum design, teaching practices, and continuous program improvement. This focus on assessment as a tool for fostering educational development rather than a mere compliance measure aligns with the broader goals of engineering education, to ensure that graduates are equipped with not only technical knowledge but also the problem-solving, critical thinking, and teamwork skills essential for success in the modern engineering workforce.

One of the most significant contributions of the book is its discussion on the barriers and challenges to implementing effective assessment. The chapters on overcoming faculty resistance and institutional inertia provide actionable strategies for creating a culture of assessment within engineering programs. The emphasis on collaborative efforts, professional development, and fostering trust among faculty members ensures that institutions can build a supportive environment for adopting assessment practices that lead to continuous improvement. Faculty members and administrators will find these sections particularly useful in navigating the often complex and resource-intensive process of implementing assessment in higher education. The book also emphasizes the importance of integrating assessment throughout the entire engineering education experience. From introductory courses to capstone projects and graduate-level work, the book provides a clear framework for using formative and summative assessments to track and improve student progress. This holistic view ensures that assessment is not a one-time event but an integral component of the learning process that adapts to students' evolving needs as they progress through their education (Amini et al., 2024)

Moreover, the book looks to the future, presenting innovative assessment techniques and tools, such as e-portfolios, concept maps, and adaptive learning systems, that will play an increasingly important role in shaping how student learning is measured. As the engineering field becomes more interdisciplinary and complex (Van den Beemt et al., 2020), these new assessment methods offer opportunities to capture a broader spectrum of student competencies, including collaboration, creativity, and problem-solving. This forward-thinking approach ensures that engineering programs can remain responsive to industry needs and societal challenges, preparing graduates for a rapidly changing global workforce. Ultimately, *Designing Better Engineering Education Through Assessment* is an essential resource for anyone involved in the improvement and accreditation of engineering programs. Its clear, evidence-based strategies provide a comprehensive toolkit for creating and sustaining high-quality educational programs that are both innovative and effective. By focusing on continuous improvement, overcoming barriers, and preparing for the future of assessment, the book provides a roadmap for institutions committed to advancing the quality of engineering education. Whether a faculty member looking to refine their teaching methods or a department chair seeking to enhance program outcomes, this book offers invaluable insights that will help shape the future of engineering education, ensuring that graduates are prepared to meet the evolving challenges of the profession.

Acknowledgement

The authors extend gratitude to the Centre for Engineering Education, Universiti Teknologi Malaysia, Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah and Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia for the support and resources that facilitated the completion of this book review. Appreciation is also given to colleagues and peers for their insightful discussions and feedback, which helped shape the perspectives presented in this work.

Conflict of Interest

The authors declare no conflict of interest.

References

Amini, M., Ravindran, L., & Lee, K.-F. (2024). Adapting education shifts in Malaysia after COVID-19: A comprehensive review of flexible assessments, lifelong learning initiatives, and diversified learning trajectories. *Asian Journal of Assessment in Teaching and Learning*, *14*(1), 1–14.

Fiore, L. B., & Koverola, C. (2021). *Building trust between faculty and administrators: An intercultural perspective*. Routledge.

Ibrahim, M. S. N., & Julius, A. (2024). Book Review: Instructional Scaffolding in STEM Education–Strategies and Efficacy Evidence. *Asean Journal of Engineering Education*, *8*(2), 110–113.

Imran, M., Ahmad, N., Al-Harthy, A. A. Q., & Jat, Z. G. (2023). Early identification and intervention: Amplifying the voice of slow learners. *AITU Scientific Research Journal*, *2*(2).

Raza, K., Li, S., & Chua, C. (2024). A conceptual framework on imaginative education-based engineering curriculum. *Science & Education*, *33*(4), 923–936.

Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., Van Baalen, S., Klaassen, R., & Boon, M. (2020). Interdisciplinary engineering education: A review of vision, teaching, and support. *Journal of Engineering Education*, *109*(3), 508–555.

The Implementation of Book-end Division Approach using ClassPoint in Digital Electronics Courses

Article history
Received
27 November 2025
Received in revised form
12 December 2025
Accepted
18 December 2025
Published online
27 December 2025

Nurul Wahidah Arshad*, Nurulfadzilah Hasan, Mohd. Shafie Bakar, Rohana Abdul Karim, Yasmin Abdul Wahab
Engineering Education Research Group,
Faculty of Electrical and Electronics Engineering Technology,
Universiti Malaysia Pahang Al-Sultan Abdullah, Pekan, Malaysia
**wahidah@umpsa.edu.my*

Abstract

This paper explores the integration of the Book-End Division Approach with ClassPoint within the Technology-Enhanced Learning (TEL) framework to enhance student engagement in Digital Electronics courses at the Faculty of Electrical and Electronics Engineering Technology (FTKEE), Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA). Conventional teaching methods frequently face challenges to engage students, particularly in technical disciplines like electrical and electronic engineering. The study leverages a student engagement framework to foster an interactive learning environment, utilizing ClassPoint's interactive features to promote active participation, and collaboration among students. The Book-End Division Approach divides class sessions into advanced organizing, intermittent discussions, and closure. Results indicate significant impacts in student participation and motivation, with over than 90% of the students agree ClassPoint TEL made the classroom environment more motivating.

Keywords: Collaborative learning, book-end division, student engagement, engineering education, ClassPoint.

Introduction

Effective student engagement in class is important for successful learning. Some students face challenges in understanding course content, especially in the fields of engineering. To address this issue, our study aims is to enhance the learning experience for students in the Digital Electronics course at the Faculty of Electrical and Electronics Engineering Technology (FTKEE), Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA). We have implemented the student engagement framework proposed by (Bond & Bedenlier, 2019) as illustrated in Figure 1.

Student engagement is shaped by multiple elements. Within the Technology-Enhanced Learning (TEL) environment (Bond & Bedenlier, 2019), technology serves as a powerful driver for promoting active learning. Effective integration of technology within both the learning environment and classroom community encourages active student involvement, leading to a range of short-term and long-term academic and social benefits. In the short term, these benefits include enhanced higher-order thinking, increased motivation, and stronger interpersonal relationships, all of which are supported by peer learning and collaboration. Over the long term, these outcomes support lifelong learning, personal growth, and greater engagement in the wider educational community. Consequently, the effort and dedication that students invest are reciprocated within the TEL framework, creating a dynamic and evolving learning system.

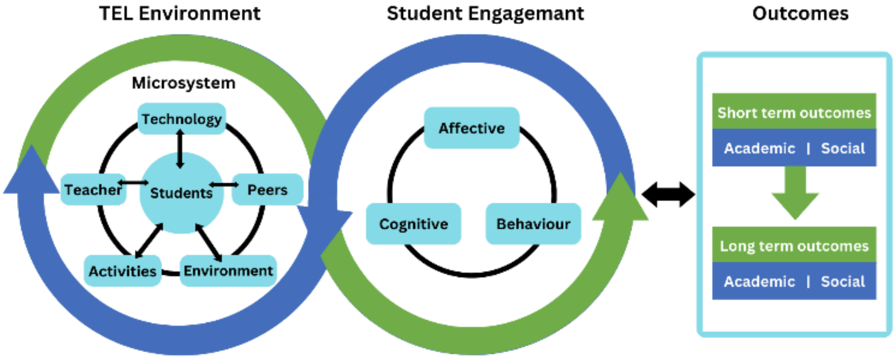


Figure 1. Student Engagement Framework

Arshad, N.W., Hasan, N., Bakar, M.S., Abdul Karim, R., Abdul Wahab, Y. (2025), The Implementation of Book-end Division Approach using ClassPoint in Digital Electronics Courses, *ASEAN Journal of Engineering Education*, 9(2), 137-143. https://doi.org/10.11113/ajee2025.9n2.208

Conventional teaching methods often fall short of effectively engaging students, particularly in technical and engineering disciplines. Traditionally, "chalk and talk" teaching often struggles to capture students' attention, especially in engineering disciplines. The motivation to create an engaging and interactive learning environment comes from the desire to ensure that students actively participate in their learning journey, rather than receiving information passively. Therefore, educators' ability to design and create classes that welcome student engagement is crucial.

The limitations of traditional pedagogical approaches in engineering education are well-documented and varied. The transmission model of instruction, where an instructor broadcasts information to passive recipients, is increasingly viewed as inadequate for the complexities of modern engineering curricula (Prince, 2004). One of the primary deficits of this method is the lack of immediate feedback mechanisms. In a standard lecture hall, misconceptions regarding complex theoretical concepts, such as circuit analysis or signal processing often go undetected until high-stakes assessments occur. Prince notes that without the interruption of active learning intervals, students' attention spans wane significantly after just 10 to 15 minutes, leading to a phenomenon known as cognitive drift.

Furthermore, engineering courses require the visualization of complex concepts that are often invisible to the naked eye, such as electron flow or electromagnetic fields. Traditional static lectures rely heavily on verbal descriptions and 2D whiteboard diagrams, which can impose a heavy cognitive load on students trying to mentally model these dynamic systems (AliSoy et al., 2021). Research by Theobald et al. (2020), which analyzed data from over 9,000 STEM students, confirmed that active learning environments significantly outperform traditional lecturing, particularly in reducing failure rates and narrowing achievement gaps. Additionally, Deslauriers et al. (2019) demonstrated that while students may perceive "chalk and talk" lectures as effective due to their fluency, actual learning gains are substantially higher in interactive settings. This suggests that conventional methods fail to facilitate the deep conceptual change required for mastering technical subjects.

Moreover, research by Freeman et al. (2014) provides empirical evidence that traditional lectures are less effective at engaging students compared to active learning strategies. In their comprehensive meta-analysis of 225 studies in undergraduate STEM education, Freeman demonstrated that students in classes with traditional lecturing were 1.5 times more likely to fail than those in classes with active learning. They found that active learning increases examination performance by approximately 6%. These findings highlight a critical gap in traditional pedagogy, while it may be efficient for covering vast amounts of content, but it is often inefficient for ensuring that content is retained and understood.

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

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

To overcome this issue, the student engagement framework has been utilized. This framework not only supports students in achieving academic excellence but also equips them with essential 21st-century skills, as outlined in Table 1 (Helmi et al., 2019), thereby making their learning experience more comprehensive. By implementing a holistic approach to learning, students are encouraged to participate actively, think critically, collaborate with peers, and efficiently utilize digital tools.

In today's digital era, students are increasingly familiar with interactive and dynamic learning environments. Utilizing educational applications (apps) not only grabs their attention but also offers a more immersive and active learning experience (Nadeem, 2019). These apps can turn abstract concepts into visually engaging and interactive content, making the learning process more impactful and memorable. Additionally, studies by Alim et al. (2019) and Gon & Rawekar (2017) have demonstrated that the use of educational apps significantly encourages student engagement.

ClassPoint is a plug-in app for PowerPoint that allows various interactive activities to be conducted for both online and face-to-face classes. Research by Arshad et al. (2023) focused on electrical and electronics engineering courses, where the integration of ClassPoint through the Book-end Division Approach energized student participation and led to improved academic outcomes. Similarly, study in Mahfud Hidayat et al. (2023) demonstrated that ClassPoint made lessons more interactive, motivating students and enhancing their attention, which also resulted in better performance. These findings suggest that ClassPoint is an effective tool for boosting engagement and academic success across various educational disciplines. Study in Setiyanto (2023) further supported these findings, reporting positive student perceptions of ClassPoint in midwifery documentation courses. These studies collectively suggest that

ClassPoint is an effective tool for enhancing student engagement and performance across various subjects.

Class Design Using the Book-end Division Approach

The Book-end Division Approach is a simple, yet effective instructional design used in informal collaborative learning (Smith et al., 2009), which breaks down classroom sessions into small segments; advanced organizing, intermittent discussion, and closure. The advanced organizing phase serves as an introductory session aimed at activating students' prior knowledge. Intermittent discussion encourages students to actively engage with the learning material, lecturer will assess students' understanding and facilitate discussion and collaboration. The closure segment is designed to recap and summarize the session (Helmi et al., 2019). Figure 2 illustrates the instructional design for a 50-minute session following the Book-end Division Approach.

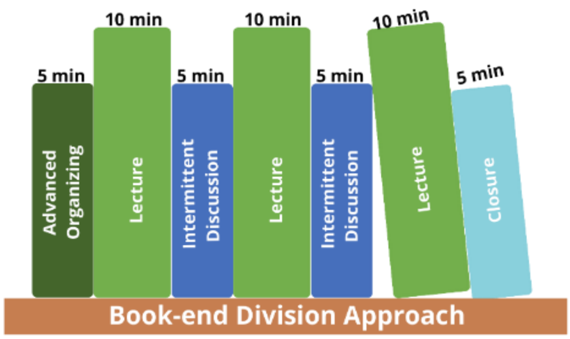


Figure 2. Book-End Division Approach

In conventional teaching, instruction is a one-way communication where only the lecturer delivers the lecture. By using this approach, the small segments provide students with opportunities to actively participate in the learning process, effectively shifting it from a lecture-centered to a student-centered learning. This engagement throughout all segments helps maintain students' learning retention, allowing them to digest the new knowledge in manageable portions.

Table 2. Active Learning Activities Using ClassPoint

Book-end Division Approach	Activity	ClassPoint Features
Advanced organizing	Focus listing, opening question	Word cloud, multiple choice, short answer
Intermittent discussions	Think-pair-share, in-class teams, question and answer pairs	Slide drawing, image upload, multiple choice
Closure	Two-minutes paper, one final question, reflection	Word cloud, multiple choice, short answer

The TEL microsystem is established in the classroom by combining the Book-end Division Approach with ClassPoint as shown in Table 2. During the Advanced organizing session, instructors use activities such as focus listing and opening questions to assess student's prior knowledge. ClassPoint facilitates these activities with features such as word clouds, multiple-choice quizzes, and short answers. In the intermittent discussion session, activity like think pair share and in-class teams helps students to cognitively engage with the lesson content. ClassPoint's slide drawing and picture uploads can be utilized to conduct intermittent discussions. Finally, the Closure session provides an opportunity for students to summarize and reflect on the class content through activities such as two-minute papers, and one final question. ClassPoint features that can be utilized for closure include word cloud, multiple-choice question, and short answer.

This approach provides a systematic framework for educators to integrate technology-enhanced activities and assessments into their lesson plans. Each session or segment is conducted through collaborative learning, beginning with thinking on the material learned individually, followed by peer discussions to exchange ideas, and concluding with a sharing of insights with the entire class. These collaborative learning also creates a comfortable learning environment that fosters critical thinking and teamwork skills.

Figure 3 depicts the research flowchart. The study begins with designing the research instrument to ensure the tools and methods align with the study's objectives. Following this, the intended lesson outcomes are defined, specifying the goals students should achieve. The implementation phase involves the constructive alignment of these outcomes with the teaching activities and assessments, facilitated by setting up the ClassPoint TEL environment to support interactive and engaging lessons.

The research then proceeds to final stage with student engagement post-test to measure the effectiveness of the instructional design. The data collected is analyzed to conclude the impact of ClassPoint TEL environment towards students' engagement. The post-test was distributed online for one week following the end of the semester. This allowing the study to account for variations in student responses by capturing a holistic view of their experience and ensures the data reflects sustained engagement over the 14 weeks period, rather than short-term excitement about the new tool or reactions to difficult topics.

To quantitatively assess the effectiveness of the intervention, a survey instrument was adopted from

Arshad et al. (2023), utilizing the methodological structure of the Utrecht Work Engagement Scale (UWES) (Bakker & Leiter, 2010). The instrument was validated through an online review with an expert to confirm relevance, a pilot test with a sample group, and revisions based on feedback to improve clarity and accuracy.

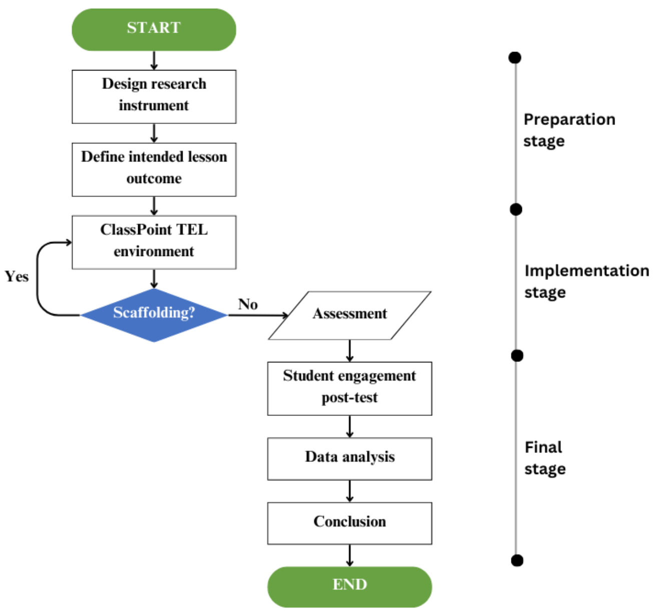


Figure 3. Methodology Flowchart for ClassPoint TEL Environment

The instrument evaluates student engagement across three dimensions as defined by Maroco et al. (2016). The first dimension is cognitive engagement, which reflects a student's willingness to exert effort to comprehend difficult concepts and skills. Next is affective engagement, which encompasses the student's emotional connection to the learning environment, instructors, and peers. The third dimension is behavioural engagement, which pertains to observable participation and conduct within the classroom. The final instrument comprised 39 items utilizing a 5-point Likert scale and multiple-choice formats to gather data on these engagement domains, alongside demographic characteristics (gender, race, learning mode) and student perceptions of the technology-enhanced class atmosphere.

The Implementation using ClassPoint

Every class is unique; during the first class of the semester, students are provided with a ClassPoint class code to join the class activity, as depicted in Figure 4. The class remains accessible in PowerPoint throughout the semester (14 weeks). This longitudinal approach ensures that the data reflects sustained engagement rather than temporary interest. Once enrolled, students can engage in all activities via their mobile phones, laptops, or tablets. For the lecturer, all displays and activities are managed and viewed directly through PowerPoint.

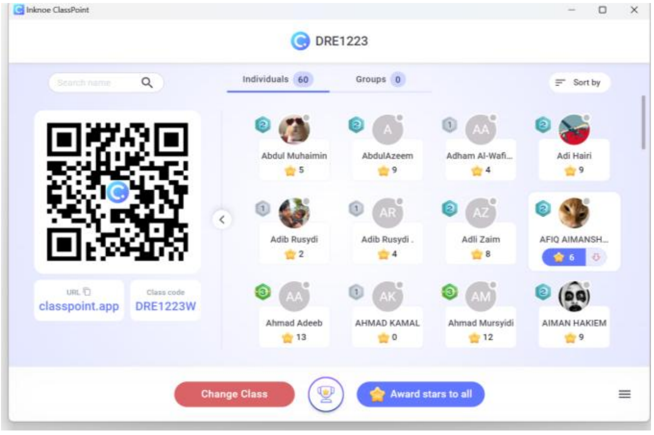


Figure 4. Students for the DRE1223 course joined the class through ClassPoint.

An example of the implementation of the Book-End Division Approach using ClassPoint for one of the topics in the Digital Electronics course is shown in Table 3. All students' answers for each activity are received directly by the lecturer, who can provide immediate feedback to help improve students' understanding during the class session. This strengthens student engagement in the learning process.

Table 3. Example of Book-End Division Approach Activities for the Magnitude Comparator Topic

BDA Activity	Activity
Advanced organizing	1. Focus Listing - Students individually list the characteristics of each Medium Scale Integrated (MSI) logic circuit they have previously learned, then compare with a neighbor. A pair is then selected using the ClassPoint name picker. 2. Card Game - Students are given binary number cards and asked to differentiate their number from their neighbor's. This question aims to engage students with the next topic, Magnitude Comparator (MC).
Lecture 1	Explanation of the basic concept of MC.
Intermittent discussions (ID1)	Pair composition activity through a worksheet. Students design a 2-bit MC and upload a picture of the worksheet through ClassPoint.
Lecture 2	Explanation on how to design an MC with more bits.

Intermittent discussions (ID2)	Pair composition activity through a worksheet. Students design a 4-bit MC by modifying answers from ID1. The 4-bit MC operation is broken down into steps to make "scaffolding" easier for students.
Closure	Formative assessment is given to evaluate students' understanding. Feedback is requested for the active learning activity through ClassPoint quick poll.

One of the activities conducted is shown in Figure 5. This activity allows students to upload images of their answers directly into PowerPoint through ClassPoint. The lecturer can view the answers and initiate discussions based on the submitted responses.

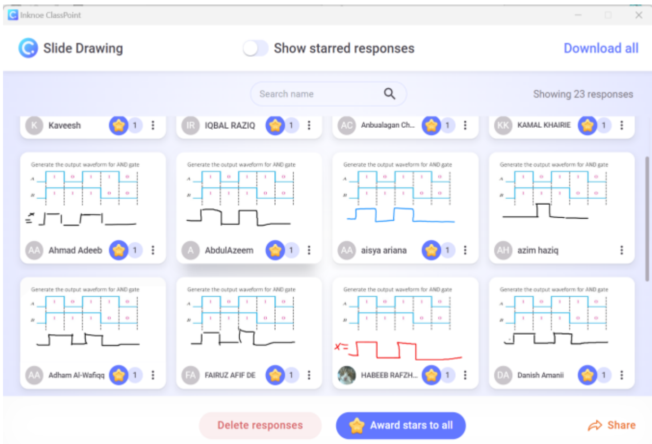


Figure 5. Intermittent discussion activity using the slide drawing function in ClassPoint

Results and Discussion

A study was carried out to assess student engagement and participation during class sessions. To collect data, a post-test instrument was designed, gathering information on demographics, student perceptions of educational technology use in the classroom, and levels of engagement.

The study involved 69 participants from the Digital Electronics courses, comprising 51 male students and 15 female students. Participants were both diploma and degree students enrolled in Digital Electronics and Digital Logic Design courses as tabulated in Table 4.

Table 4. Example of Book-End Division Approach Activities for the Magnitude Comparator Topic

Program	Course name	Numbers of participants
Diploma	Digital Electronics	38
Degree	Digital Electronics	13
	Digital Logic Design	15
Total		66

The demographic diversity included various ethnicities within the FTKEE, UMPSA as shown in Figure 6. The donut chart illustrates the racial composition of the survey participants, with a significant majority being Malay, who constitute 78% of the respondents. This is followed by Chinese and Indian participants, each making up 7% of the total. Participants identified as "Other" account for 6%, while Foreigners represent the smallest group at 2%.

ClassPoint's interactive features varied in terms of usage and student preference. Figure 7 shows student preferences for interactive quizzes within ClassPoint. Multiple Choice stands out as the most favoured option, with 48% of students preferring it due to its simplicity, user-friendly interface, and structured response options. Image Upload, chosen by 19% of students, allows sharing visual content like diagrams or images, facilitating collaborative discussions and visual explanations during class activities. Short Answer, selected by 13% of students, requires providing concise written responses, suitable for open-ended queries or exercises that encourage critical thinking. Slide Drawing is the least preferred tool, possibly due to its complexity in allowing students to effectively convey ideas through drawing on slides. These findings enable educators to adjust their teaching methods effectively by using preferred tools to enhance engagement and interaction within the classroom setting.

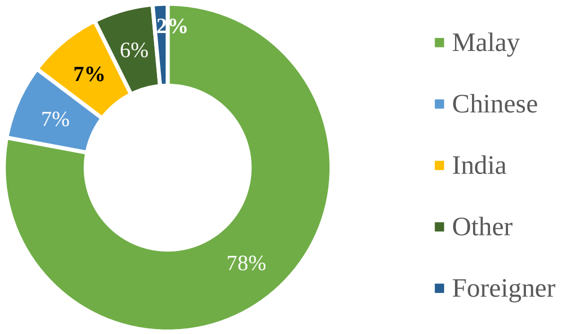


Figure 6. Race composition of the survey participants

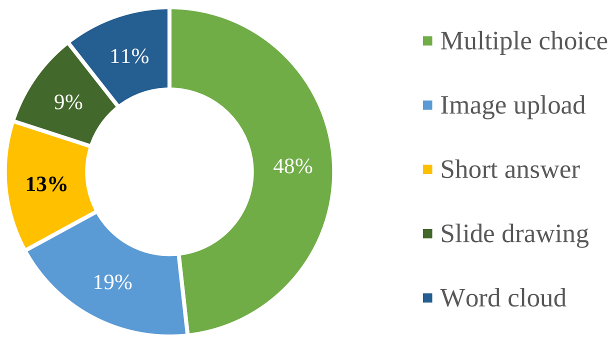


Figure 7. Interactive quiz in ClassPoint that had been actively applied

The Likert scale responses in Figure 8 indicate an impact in student participation in class. ClassPoint has significantly boosted student participation in group discussions and question-asking, with more than half of the students actively engaging. For instance, 33 students mentioned that ClassPoint often encourages them to participate more actively in class by asking questions, while 26 students mentioned it does occasionally. Furthermore, 40 students reported that they participate more active in class discussion, and 24 students mentioning they participate occasionally, showing a high level of engagement in ClassPoint TEL environment.

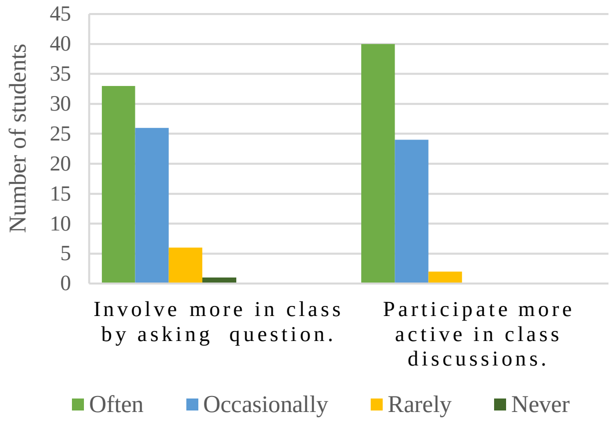


Figure 8. Impact of ClassPoint on student participation frequency

The results also indicate high levels of motivation and positive feelings towards the classroom environment, as illustrated in Figure 9. Specifically, 29 students strongly agreed and 34 students agreed that they felt energetic and capable, while 32 students strongly agreed and 29 students agreed that the classroom was an interesting place. Furthermore, 58 students strongly agreed and agreed that they had fun in class, and 27 students strongly agreed and 33 students agreed that they were motivated to learn more about the topic.

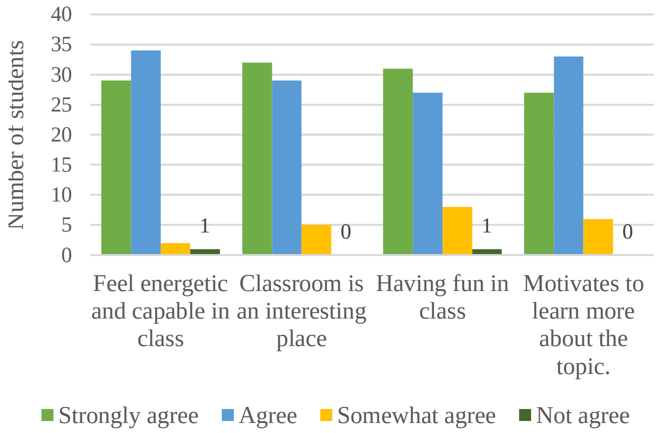


Figure 9. Impact of ClassPoint on student motivation in class

These results highlight that the Book-end Division Approach using ClassPoint not only enhanced student engagement but also made the learning experience enjoyable and motivating. The interactive nature of the classroom by ClassPoint activities contributed to students' positive perceptions and strengthened their commitment to continuous learning. The enriched microsystem with technology integration using ClassPoint played a significant role in fostering a meaningful learning experience.

Conclusion

In conclusion, integrating the Book-end Division Approach with ClassPoint within the TEL framework has effectively fostered student engagement in Digital Electronics courses at FTKEE, UMPSA. This method has fostered a more interactive and collaborative learning environment, encouraging active participation and the development of essential 21st-century skills. Future work will also extend this approach into online learning environments through the lightboard ecosystem and studio-based teaching model developed at UMPSA. This includes adapting Book-end Division Approach and ClassPoint for synchronous online delivery, leveraging real-time interaction tools, and exploring how AI-enhanced features can further support presence, participation, and continuity of engagement in virtual classrooms. These enhancements aim to optimize the scalability of active learning across physical, hybrid, and fully online courses in future iterations.

Acknowledgement

This work was financed by Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA) under teaching and learning research grant (PPU230104) and Tabung Persidangan Dalam Negara (TPDN). The authors would like to acknowledge the support of this work by UMPSA, and the support provided by the Engineering Education Research Group, FTKEE, UMPSA.

Conflict of Interest

The authors declare that there are no conflicts of interest associated with this research. No financial, personal, or professional relationships have influenced the design, execution, or reporting of this study.

References

Alim, N., Linda, W., Gunawan, F., & Md Saad, M. S. (2019). The Effectiveness of Google Classroom as an Instructional Media: A Case of State Islamic Institute of Kendari, Indonesia. Humanities & Social Sciences Reviews, 7(2), 240–246. https://doi.org/10.18510/hssr.2019.7227

AliSoy, H., AkdeniZ, R., & Özbey, N. (2021). The Visualization of Solutions to Electromagnetic Field Problems by Using Matlab. European Journal of Engineering and Applied Sciences, 4(2), 61–65. https://doi.org/10.55581/ejeas.1035321

Arshad, N. W., Bakar, Mohd. S., Hasan, N., Abdul Karim, R., & Abdul Wahab, Y. (2023). Implementing Book-end Division Approach using ClassPoint to Energize Electrical and Electronics Engineering Student Engagement. Asean Journal of Engineering Education, 7(2), 51–57. https://doi.org/10.11113/ajee2023.7n2.138

Bakker, A. B., & Leiter, M. P. (Eds.). (2010). Work Engagement (0 ed.). Psychology Press. https://doi.org/10.4324/9780203853047

Bond, M., & Bedenlier, S. (2019). Facilitating Student Engagement Through Educational Technology: Towards a Conceptual Framework. Journal of Interactive Media in Education, 2019(1), 11. https://doi.org/10.5334/jime.528

Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K., & Kestin, G. (2019). Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. Proceedings of the National Academy of Sciences, 116(39), 19251–19257. https://doi.org/10.1073/pnas.1821936116

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active Learning Increases Student Performance in Science, Engineering, and Mathematics. Proceedings of the National Academy of Sciences, 111(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Gon, S., & Rawekar, A. (2017). Effectivity of E-Learning through Whatsapp as a Teaching Learning Tool. MVP Journal of Medical Sciences, 4(1), 19. https://doi.org/10.18311/mvpjms/0/v0/i0/8454

Helmi, S. A., Mohd-Yusof, K., & Hisjam, M. (2019). Enhancing the implementation of science, technology, engineering and mathematics (STEM) education in the 21st century: A simple and systematic guide. 020001-020006. https://doi.org/10.1063/1.5098172

Mahfud Hidayat, I., Supriyani Siregar, E., Aminah Hasibuan, S., Purnama Sari, I., & Tunas Bangsa Pematangsiantar Yanti Anggraini, S. (2023). The Implementation of ClassPoint in Learning English: A Case Study at SMK Muhammadiyah 3 Karanganyar on Eleventh Grade in Academic Year 2021/2022. Journal of Indonesian Student Assesment and Evaluation (JISAE), 9(2), 126–131. https://doi.org/10.21009/jisae.v9i2.36808

Maroco, J., Maroco, A. L., Campos, J. A. D. B., & Fredricks, J. A. (2016). University student's engagement: Development of the University Student Engagement Inventory (USEI). Psicologia: Reflexão e Crítica, 29(1), 21. https://doi.org/10.1186/s41155-016-0042-8

Nadeem, N. H. (2019). Students' Perceptions About the Impact of Using Padlet on Class Engagement: An Exploratory Case Study. International Journal of Computer-Assisted Language Learning and Teaching, 9(4), 72–89. https://doi.org/10.4018/IJCALLT.2019100105

Prince, M. (2004). Does Active Learning Work? A Review of the Research. Journal of Engineering Education, 93(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Setiyanto, S. (2023). Pandangan Mahasiswa dalam Penggunaan Media Pembelajaran Interaktif pada Mata Kuliah Dokumentasi Kebidanan Menggunakan ClassPoint. Journal of Innovation And Future Technology (IFTECH), 5(1), 69–78. https://doi.org/10.47080/iftech.v5i1.2463

Smith, K. A., Douglas, T. C., & Cox, M. F. (2009). Supportive teaching and learning strategies in STEM education. New Directions for Teaching and Learning, 2009(117), 19–32. https://doi.org/10.1002/tl.341

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., Chambwe, N., Cintrón, D. L., Cooper, J. D., Dunster, G., Grummer, J. A., Hennessey, K., Hsiao, J., Iranon, N., Jones, L., Jordt, H., Keller, M., Lacey, M. E., Littlefield, C. E., … Freeman, S. (2020). Active Learning Narrows Achievement Gaps for Underrepresented Students in Undergraduate Science, Technology, Engineering, and Math. Proceedings of the National Academy of Sciences, 117(12), 6476–6483. https://doi.org/10.1073/pnas.1916903117

Digital Transformation of Primary and Secondary Education Institutions: A Case of the Czech Republic

Article history
Received
27 November 2025
Received in revised form
16 December 2025
Accepted
18 December 2025
Published online
27 December 2025

Martin Lukas
Department of Information Technologies, Faculty of Economics and Management, Czech University of Life Sciences Prague, Kamýcká 129, Prague, Czech Republic, Europe
lukas@pef.czu.cz

Abstract
Digital transformation (DT) of primary and secondary (P&S) education in the Czech Republic has accelerated over the past decade, yet research on its impact and digital maturity (DM) remains limited. This gap is significant given the global emphasis on technology-driven learning environments and the evolving role of students, teachers, and parents. This study investigates how DT influences the quality of the education process and stakeholder interactions in Czech P&S institutions. Three research questions guide the analysis: students' perception of DT, their need for increased IT integration, and whether DT affects communication between students, teachers, and parents. An exploratory survey was conducted among 65 students aged 6–19 across all Czech regions. Findings indicate that DT is generally perceived positively, though attitudes toward increased IT use remain neutral, and its influence on communication is inconclusive. The study contributes by providing empirical evidence on DT and DM in Czech P&S education, highlighting regional disparities and offering a basis for future comparative research.

Keywords: Digital transformation, information technology, digital maturity, primary and secondary education.

Introduction

Digitalization is changing every aspect of human life, including education (Laterza et al., 2023). The digital literacy of the population then influences our entry and opportunities when engaging in the community of peers, in the family, in studies or in the labour market (Miškelová et al., 2025; European Commission (2024) Czechia Digital Decade, 2025). Digital transformation has become a priority for higher education institutions (HEIs) in the second decade of the 21st century, and this is a natural and necessary process for organizations that claim to be leaders of change and highly competitive in their domain (Benavides et al., 2020). As the educational landscape changes rapidly, secondary schools increasingly adopt digital technologies to transform teaching and learning experiences (Yuliandari et al., 2023). Digital Transformation (DT) initiatives are often implemented through projects (Rolf et al., 1995). The objective of DT in education is to realize a comprehensive vision that facilitates ongoing innovation and advancement in teaching and learning, concurrently streamlining administrative and management services for students, educators, and the community to enhance operational efficiencies. The penetration of IT projects into business is considered DT. DT is a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies (Vial, 2019). Students have a different, often critical view of DT. Teachers have a different view of DT by being drawn into the teaching process. Parents often do not express their views on DT in primary and secondary education, even if they perceive it as rather detached and distant. DT is an ongoing process that allows entities to move up to an upper level of digital maturity (DM). Digital education transformation is a slow process due to various obstacles that hinder the transformation of academic units into learning organizations (Kalogeratos, 2022). DM refers to a state of being complete, perfect, or ready (Lahrmann, 2011) and results from progress in developing a system (Teichert, 2019).

While DT/DM scholarship is extensive in HEI (e.g., documenting strategies, governance, and implementation projects, etc.), student-centered evidence from P&S schools remains comparatively limited, especially in the Czech Republic (Benavides et al, 2020); Fernández et al., 2023; Laterza et al., 2023). European studies illustrate variability in P&S maturity and practices (e.g., DT/DM assessments of schools in Bulgaria and Croatia), underscoring the need for nationally grounded analyses to inform school-level priorities (Balaban et al., 2018; Gaftandzhieva et al., 2021, Mišianiková et al., 2021). Czech research has predominantly addressed DT in public administration and enterprise architecture, offering system-level

Lukas, M. (2025), Digital Transformation of Primary and Secondary Education Institutions: A Case of the Czech Republic, *ASEAN Journal of Engineering Education*, 9(2), 144-153. https://doi.org/10.11113/ajee2025.9n2.209

insights but not direct evidence on P&S education from the student perspective (Lukáš et al., 2022; Lukáš et al., 2023). Consequently, there is insufficient Czech-specific knowledge about how DT affects the perceived quality of the education process, the role of teacher digital competencies, and the contribution of parent/community engagement within P&S education.

Further, the article presents findings from a survey with respondents. Based on the survey, the differences in the complexity of the DT and the regions. were analyzed and identified. In the final section, findings are discussed and suggested further research (Mišianiková et al., 2021). The article consists of several sections, as follows.

The first section (Literature review) outlines the issues with the DT phenomenon and its relation to DM in the P&S education process and institutions, which are affected by the penetration of digital technologies into various aspects (e.g., students, teachers, and the wider community, including parents). It also illustrates how DT plays an essential role in the quality of the P&S education process and provides more specifics from he Czech Republic. The methodology part explains an electronic survey, designed to collect data from the Czech-speaking target group covered by sample data; the respondents involved came from different institutions of P&S education (The sample included only Czech-speaking students, regardless of nationality, to ensure consistent and comparable responses). The findings from a survey disseminated among a large professional audience spread across the Czech Republic (different regions and cities) are presented. The results summarize the differences in the target group's opinions on DM and DT (e.g., students, teachers, and the wider community, including parents). The study also identifies the differences between them and presents the results. The discussion presents the findings, discusses them, and suggests further topics for future research, as well as their limitations.

Previous studies and research have lacked students' perspectives on teachers' digital skills, parents' digital skills in communicating with the school, which offers them digital communication opportunities, and students' perspectives on the intensity and quality of digital technology use in teaching.

This case study addresses this gap by contributing to the knowledge of a nationwide, student-centered survey of DT/DM in a selected sample of Czech P&S education (ISCED 1–4; age 6–19). It also examines their willingness to respond to the demands and challenges of an education system that is compatible with the digital era while ensuring the function of schools as educational organizations (Yuliandari et al., 2023).

Literature review

Digital transformation

DT integrates digital technologies into core and support processes across sectors such as business, education, manufacturing, and public administration. It consolidates multiple digitalization initiatives into an end-to-end strategic change requiring organizational-level shifts in competencies. Adopting new technologies entails a comprehensive transformation of information flows, processes, technologies, and human factors (McCusker, 2018).

DT involves changes in an organization’s business model caused by adopting emerging digital technologies, which result in changes in organizational structures, products, or services (Hess et al., 2016). The DT of the university education system should have a broader focus and must include the modernization of corporate IT architecture management, which could contribute to structuring the efforts for innovation in education (Kaminskyi et al., 2018).

Digital transformation in P&S education

The rapid globalization trends of the 21st century have compelled organizations, including educational institutions, to undergo significant shifts toward digital transformation. According to the OECD Digital Economy Outlook, DT impacts economies and societies in intricate and interconnected ways, requiring sustainable strategic approaches (OECD, 2025). Organizations are increasingly embracing digital technologies such as cloud computing, big data, and artificial intelligence to maintain their relevance in an ever-evolving market (Sararuch et al., 2023).

Transformation of conventional education

The conventional method of education from schools (P&S education) to higher education (HEI) level is rapidly transforming into the digital mode of learning, and the cost of infrastructure installation is higher at once; later, the outcomes are valuable. The education system has been completely changed and shaped due to the transformation of traditional industries through digital technologies (Durakbasa, et al., 2028). Different aspects of using information and communication technologies promote effective teaching and learning for students with diverse needs (Bazalová, B., et al., 2025).

Global demands in P&S education

Education reforms are a significant element for the educational transformation; digital technologies depend on governments and policymakers. Adapting innovative technologies is difficult for individuals and educational institutes (Qureshi et al., 2021). Several sectors, especially the education industry, have necessitated DT in pursuit of becoming highly competitive in their domains and acquiring the position of revolutionary leadership. The digital transformation of global society and markets has brought new social, economic, and technological opportunities. It implies that many life changes had long crossed the borders of continents and states. These changes based on digitalization have been naturally one of the priorities of the European Union and the Czech Republic (Gaftandzhieva et al., 2022).

Digital maturity

Much more difficult circumstances than starting DT are visible to keep the achieved level of DM and smoothly progress to the next - upper - level. On the other hand, DM goes beyond a merely technological interpretation, simply reflecting the extent to which an organization performs tasks and handles information flows by IT but also reflects a managerial interpretation describing what a company has already achieved in terms of performing DT efforts, including changes in products, services, processes, skills, culture, and abilities regarding the mastery of change processes (Gellweiler, 2020). Prasanna and Choudhury indicate that satisfied students are the best advertisement for a university (Prasanna et al., 2024). According to Fernández et al. (2023), the DM of education institutions will grow by adding the implementation of a) digitalization initiatives that are technologically driven, b) IT governance best practices, and c) DT initiatives. DM (in P&S education) supports and reflects upon DT of educational institutions across various organizational, infrastructural, teaching and learning, competency, and cultural issues. It is a "valuable proxy for indicating the extent of technology adoption across the whole ecosystem of a school" (Harrison et al., 2014). Those who have achieved such DM have now witnessed significant improvements in the company's operations and increased customer satisfaction. Analogically, keeping the student satisfied with P&S and HEI education supported by digital technology from a long-term point of view means maintaining or increasing DM at the same level and/or higher. DM at the EU country level is regularly captured each year, as part of the DESI index (DESI, 2023). Covers all national economic sectors, including ISCED 2011-classified education.

Barriers to Digital Transformation in Czech Schools

Digital transformation in Czech primary and secondary education faces several systemic and operational challenges. Infrastructure limitations remain a critical barrier, as many schools experience insufficient ICT integration and unreliable internet connectivity, particularly in rural areas (European Commission, 2023; Czech School Inspectorate, 2022). Teacher digital competencies represent another significant obstacle; fewer than one-third of teachers report feeling adequately prepared to use ICT in instruction, and computer anxiety persists among educators, limiting effective adoption (European Commission, 2023; Švaříček et al., 2021). Curricular and strategic gaps further hinder progress. Although revisions to the Framework Educational Program introduced digital competencies, their implementation across subjects has been uneven and slow (Ministry of Education, Youth and Sports, 2021). At the institutional level, many schools lack comprehensive digitalization strategies and leadership support (European Commission, 2023). Equity concerns also emerge, as disparities in access to devices and connectivity deepen the digital divide among students, particularly between urban and rural schools (Czech School Inspectorate, 2022). Finally, the growing reliance on online platforms raises cybersecurity and data protection challenges, requiring robust governance and secure management of student information (European Commission, 2023).

Methodology

The current situation in DT and DM areas in the Czech Republic varies regionally in P&S education institutions. The aim is to contribute to a wider understanding of it across the regions of the Czech Republic and summarize it for future research studies. Based on the empirical evidence, which is partially mentioned here in this chapter and/or in the next chapter, the three research questions (RQ) are formulated, that examine and search for proof of evidence of how mature P&S education institutions of the Czech Republic are from the view of students, which also covers their perception of how digitally mature the teachers are as well as wider community (e.g., parents).

RQ#1: Is there an argument that students positively perceive the digital transformation of P&S education institutes? RQ#2: Is there, among the respondents, a need for more IT use in the ground and P&S education process? RQ#3: Does digital transformation enter more into the relationship between student and teacher or student and parents?

Regarding the limited empirical results on DT and DM in P&S education institutions in the Czech Republic, as mentioned in this article, and their practical relevance to the education sector, an exploratory survey was conducted across regions of the Czech Republic. The survey instrument for detailed analysis was constructed (Czech School Inspectorate, 2022). This survey consists of 17 questions spread into three sections. The first section collected identification information through three questions, in which respondents were asked to provide information about the region they belong to, the type of P&S education institution they studied, and the city of residence where the respondent originally lived. The second section, the main section of the survey, was dedicated to the questions about respondents' perception of DT and DM of P&S education institutions. There were, in total, nine questions belonging to this section. The last and third sections gathered information about how the respondents perceive teachers' digital skills, whether P&S education institutions are digitally transformed and/or matured, and how the wider community (e.g., parents) is involved in DT and DM of the P&S education process.

The survey design process begins with formulating the survey questions and refining them to be as specific as necessary. Each item was examined to ensure clarity for respondents, prevent monotony, and encourage engagement in answering. However, the survey is a non-exhaustive set of questions covering DT and DM of P&S education institutions. The survey examines respondents' perceptions of DT and DM in this area. Once the researchers had finished the survey design process, the optimization phase was initiated. The survey was piloted with four participants, each representing a different region of the Czech Republic (north, south, east, and west). Based on the pilot feedback, which was valuable for researchers, the survey layout was partially redesigned, and the survey questions were slightly rephrased. To obtain relevant and accurate information, the survey targeted students at ISCED 2011 levels 1 to 4. These students were aged between 6 and 19 years. The sample included respondents from all regions of the Czech Republic. The final version of the survey was disseminated electronically via Google Forms to the target group of respondents, which consisted of 140 individuals. The survey was distributed via email and accompanied by a brief explanatory letter (Zizikova et al., 2023). It meant sending out 140 survey invitations, which included a personalized cover letter with a link redirecting respondents to the survey; 65 responses received (46,4 % of responses). Participants were recruited through electronic channels, and the sample included students from different types of schools and regions. Despite these efforts, the sample does not reflect the entire Czech student population. The electronic distribution method may have introduced bias by favoring respondents with reliable internet access and higher digital literacy. However, internet availability among students is high. And, the participation was voluntary, which could result in self-selection bias and limit the generalizability of the findings.

The distribution of respondents by region of the Czech Republic is illustrated in Table 1, with the largest share of the Central Bohemia Region (47,71%, 31 respondents), followed by the Capital City Prague (13,8%, 9 respondents), and then by the South Bohemia Region, the Pilsen Region, the South Moravia Region, Moravian-Silesian Region.

To achieve this level of response, participation in the survey was encouraged through diplomatic outreach via personal and social network connections. The respondents (students) responded to the emergency in a friendly and understanding way; they saw the meaning in the questionnaire survey. Additionally, the survey in the Google Forms platform between August 2023 and February 2024 was published. The target group did not cover either the teachers or the parents. Only students' feedback and perceptions on how they view their involvement in DT and their skills in terms of DM were gathered. As much research on DT and DM (as well as enterprise architecture) is conducted in HEI, there is a focus on DT and DM in P&S education institutions in the Czech Republic.

Table 1. Regional distribution of respondents

Region in Czech Republic	Amount	%
Capital city Prague	9	13,8
Central Bohemia Region	31	47,7
South Bohemia Region	3	4,6
Pilsen Region	3	4,6
Karlovy Vary Region	1	1,5
Ústí Region	2	3,1
Liberec Region	2	3,1
Hradec Králové Region	2	3,1
Pardubice Region	1	1,5
Vysočina Region	2	3,1
South Moravia Region	3	4,6
Zlín Region	1	1,5
Olomouc Region	2	3,1
Moravian-Silesian Region	3	4,6
Total	**65**	**100**

The Czech Republic is located in the middle of Europe and has been a member of the European Union since 2004. There are approximately 10 million inhabitants living in a territory with an area of approximately 78,000 square kilometers. The capital city is Prague, where most people live (≈ 1 million). The Czech Republic has 14 regions/districts (see Table 1). The regional city administers each region. The Czech Republic borders the following countries: Poland (to the north), Slovakia (to the east), Austria (to the south), and Germany (to the west and north).

In contrast, Table 2 shows the type of educational institutions from which the individual respondents are. The ratio of respondents from Elementary school to respondents from vocational school to respondents from Gymnasium/Grammar school is 13:31:21.

The ISCED was designed in the early 1970s to serve as an instrument suitable for assembling, compiling, and presenting education statistics both within countries and internationally. The first version, known as ISCED 1976, was approved by the International Conference on Education in Geneva in 1975 and was subsequently endorsed by UNESCO. The second version, known as ISCED 1997, was approved by UNESCO as part of efforts to increase the international comparability of education statistics.

Table 2. Respondent's school type

School type	ISCED2011	Amount	%
Gymnasium/Grammar school (4 years)	ISCED 3&4	8	12,3
Gymnasium/Grammar school (8 years)	ISCED 2&3	5	7,7
Vocational school	ISCED 3	3	4,6
Vocational college	ISCED 3	24	36,9
Secondary vocational school	ISCED 3	4	6,2
Elementary School	ISCED 1&2	21	32,3
Total		**65**	**100**

Table 3 offers a demographic view of the size of the cities that individual respondents come from or live in. Usually, these are not cities and towns where educational institutions are located. Cities were categorized demographically according to the national methodology established by the Czech Statistical Office, https://csu.gov.cz (Czech Statistical Office, 2025). Therefore, Table 3 does not include data on the size of cities and municipalities in which educational institutions are located. Table 3 shows the population volume. 29,2% of respondents came from cities with 50,000 or more inhabitants, followed by 12,5% for a set of cities with 10,000 – 19,999 inhabitants, 2,000 – 4,999 inhabitants, and 1,000 – 1,999 inhabitants.

Table 3. Population of the respondent city/town

Population	***Amount***	***%***
up to 199 inhabitants	1	4,2
200 - 499 inhabitants	1	4,2
500 - 999 inhabitants	2	8,3
1 000 - 1 999 inhabitants	3	12,5
2 000 - 4 999 inhabitants	3	12,5
5 000 - 9 999 inhabitants	2	8,3
10 000 - 19 999 inhabitants	3	12,5
20 000 - 49 999 inhabitants	2	8,3
50 000 and more inhabitants	7	29,2
Total	**24**	**100**

As described above, the online survey consisted of three sections. The first is the identification section. Hence, Tables I, II, and III are extracted from the responses to the identification section.

The novelty of the data sample shown in Table 2 is: the sample provides indicative patterns across ISCED school types (elementary, gymnasium, vocational) that are valuable because no other case studies cover this theme in Czech Republic, and it offers a real-world snapshot of institutional composition, useful for linking digital maturity or readiness to school type.

Results

The statistical internal reliability of the 12 answers in the second and third sections of the survey, calculated with the Cronbach's alpha test, is 0,8027. The variance of each answer to the mentioned sections fluctuates between 0,5802 and 1,5737. The statistically verified data collected are considered reliable and valuable.

The survey's essential key findings are summarised in Tables 4, 5, and 6 (Schemas 1, 2, and 3). The results of the online survey are presented as follows. Table 4 is devoted to the second section of the online survey, which focused on respondents' perceptions of the delivery and management of P&S education institutions. The survey's third section is presented in Table 5 (which covers the wider community, specifically parents) and Table 6 (which covers teachers' digital skills). The indicators in Table 4 illustrate how the respondents judge the quality aspects of DT & DM. Interestingly, most respondents (43,1%, 28 respondents) perceive ICT classroom equipment positively. The same perception is Online learning materials (32,3%, 21 respondents) and the Online education process (33,8%, 22 respondents). In contrast, a minority of respondents view ICT classroom equipment negatively (4,6%, 3 respondents). A similar situation occurs in the section Online learning materials (6,2%, 4 respondents) and Online education process (6,2%, 4 respondents). However, 21,5%, 14 respondents, for very positive, and 23,1%, 15 respondents, for negative perceptions of the indicator of the Online education process might be considered alarming. These numbers are almost similar. The question is, why do 1/5 of respondents see the quality of DT & DM in their P&S education institutions negatively and very positively? What are the inhibitors and drivers for that? Although this difference between 21,5%, 14 respondents (very positively) and 23,1%, 15 respondents (negatively) is small, it would be interesting to ascertain why it is so through further research.

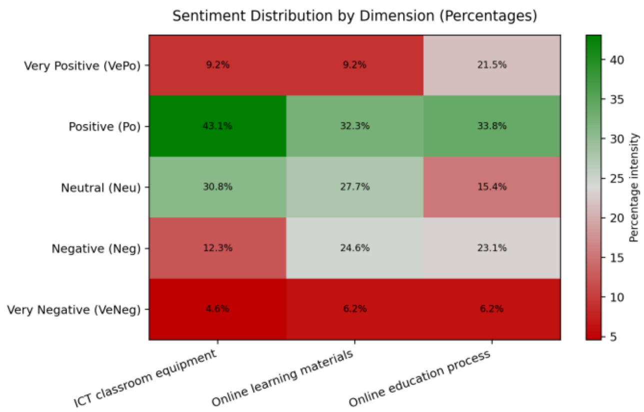
Sections A, B, and C of Table 4 present several pieces of empirical evidence and arguments (as detailed above) that the digital transformation of P&S education institutions is positively perceived by the respondents. The amounts for all sections are in total and in %, the highest for the Po indicator (positive: A = 43,1%, 28 respondents; B = 32,3%, 21 respondents; C = 33,8%, 22 respondents).

Table 4. DT & DM quality aspects

	A) ICT classroom equipment		B) Online learning materials		C) Online education process	
	Amount	%	Amount	%	Amount	%
VePo	6	9,2	6	9,2	14	21,5
Po	28	43,1	21	32,3	22	33,8
Neu	20	30,8	18	27,7	10	15,4
Neg	8	12,3	16	24,6	15	23,1
VeNeg	3	4,6	4	6,2	4	6,2
Total	**65**	**100**	**65**	**100**	**65**	**100**

Legend: VePo =Very Positively, Po = Positively, Neu = Neutral, Neg = Negatively, VeNeg = Very Negatively.

Schema 1. Heat map of DT & DM quality aspects



Key findings

This evidence confirms RQ#1, which is that respondents perceive the digital transformation of P&S education institutions positively. The VePo indicator (very positive: A = 9,2%, 6 respondents; B = 9,2%, 6 respondents; C = 21,5%, 14 respondents) also supports that idea. The amounts and % for VePo indicators are higher than those of VeNeg indicators (very negative: A = 4,6%, 3 respondents; B = 6,2%, 4 respondents; C = 6,2%, 4 respondents). Why the Neg indicator shows these numbers can be the follow-up and the specific scope of further research in the Czech Republic as well as in the context of Europe.

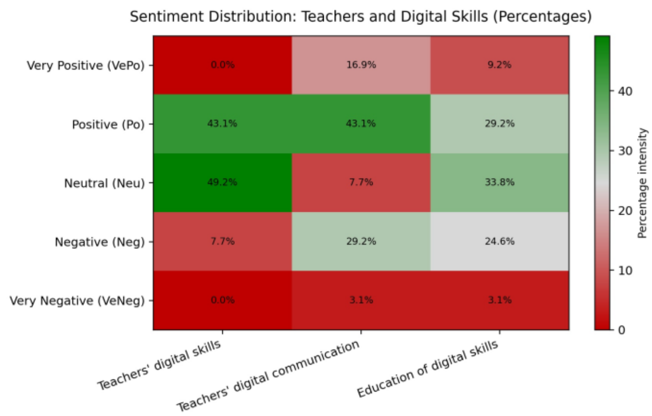
For the answer to RQ#2,-the numbers from Table 4, section A), especially the Neu & Po indicators. Based on that evidence, it is not easy to prove that the respondents have the need for more IT use because the amount of the Neu indicator (neutral: 49,2%; 32 respondents) prevails over the Po indicator (positive: 43,1%; 28 respondents). The needs of respondents for more IT use in P&S education institutions in the Czech Republic are mostly neutral.

Table 5 indicates respondents' perception of the DT & DM Teachers' Skill Aspect. The general view is neutral. Table 5 reveals certain differences in its section. For example, almost half of the respondents perceive teachers ' digital skills as neutral (49,2%, 32 respondents). The second place is devoted to positive perceptions (43,1%, 28 respondents), which is also with a little goodwill a half of the respondents. Interestingly, most respondents (43,1%, 28 respondents) judge teachers ' digital communication positively. Section of Education of digital skills. Neutral perception (33,8%, 22 respondents) for Education of digital skills is a little surprising. However, in comparison to teachers' digital skills and their digital communication, it is not a big surprise. No respondent indicated very positive or very negative feedback regarding teachers' digital skills.

Table 5. DT & DM teacher's skill aspect

	A) Teachers' digital skills		B) Teachers' digital communication		C) Education of digital skills	
	Amount	%	Amount	%	Amount	%
VePo	0	0	11	16,9	6	9,2
Po	28	43,1	28	43,1	19	29,2
Neu	32	49,2	5	7,7	22	33,8
Neg	5	7,7	19	29,2	16	24,6
VeNeg	0	0	2	3,1	2	3,1
Total	**65**	**100**	**65**	**100**	**65**	**100**

Schema 2. Heat map of DT&DM teachers' skill aspect

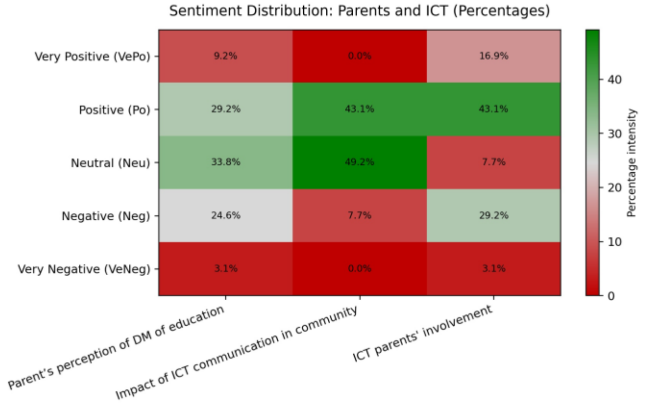


The respondents' perception of the digitalization of the wider community, particularly among parents, is illustrated in Table 6. Surprisingly, 29,2%, 19 respondents indicate a positive perception of DM in education. However, a higher number of parents evaluate it neutrally, as is unsurprising. The second section of Table 6 (impact of ICT communication in the community) demonstrates a neutral perception. There is no very positive rating. The positive rating is about 6% lower than the neutral rating, which should be considered as a surprise. The reasons why this is so can be the subject of further research. The rest of the respondents can be considered a minority because those who answered positively and neutrally make up 92,3%, 60 respondents, which is the overwhelming majority. The third section of Table 6 demonstrates how the parents are involved in the ICT area (from the respondents' point of view). The distribution of answers shows differences in comparison to the previous two sections mentioned. Almost 1/6 of respondents indicate that their parents are involved in ICT, and they use ICT. Only 3,1%, 2 respondents, judge their parents very negatively. Surprisingly, 43,1%, 28 respondents' parents are perceived positively in ICT usage. This can be seen as an award for parents. Generally, Table 6 shows the respondents' view of their wider community and provides overall results about the parents having their children between 6 – and 19 years. Based on the available evidence, it cannot be confirmed that digital transformation influences communication between students and teachers or between students and the wider community (e.g., parents).

Table 6. DT & DM parents' skill aspect

	A) Parent's perception of DM of education		B) Impact of ICT communication in community		C) ICT parents' involvement	
	Amount	**%**	**Amount**	**%**	**Amount**	**%**
VePo	6	9,2	0	0	11	16,9
Po	19	29,2	28	43,1	28	43,1
Neu	22	33,8	32	49,2	5	7,7
Neg	16	24,6	5	7,7	19	29,2
VeNeg	2	3,1	0	0	2	3,1
Total	**65**	**100**	**65**	**100**	**65**	**100**

Schema 3. Heat map of DT & DM parents' skill aspect



All Po indicators for Table 5, section B, Table 6, section B, and C present the same amount and the same % (43,1%, 28 respondents). The key differentiator (with the deeper study of the mentioned sections of tables) is the other indicators, namely the Neu indicator for all of them.

Discussion

As evidenced by a sample of students who participated in the survey and are from P&S education institutions spread across the Czech Republic, the answers to the research questions are coherent. They detect that the DT of P&S education institutions of the Czech Republic is perceived positively (by students aged 6-19). The internal reliability of the survey instrument was assessed using Cronbach's alpha, which yielded a value of 0.8027. This exceeds the commonly accepted threshold of 0.7, indicating good internal consistency among the items. Therefore, the instrument can be considered reliable, supporting the credibility of the findings presented in the analysis.

Some respondents are lax in expressing their need for more IT equipment in the classrooms; the needs of respondents for increased IT use in P&S education institutions in the Czech Republic are mostly neutral. It is unsurprising that individuals of a similar age tend to express their opinions openly. Many perceive the P&S education process and its related resources, such as IT equipment, as insufficient or morally outdated. The predominant neutral attitude in response to more IT needs is understandable and seems to align with researchers' expectations. It is aligned with Yuliandari et al. (2023), where authors see "the smart learning environment is a combined educational system incorporating intelligent tools and techniques to create a delightful learning experience for learners and other individuals involved". As mentioned in the Results chapter, based on the evidence, it cannot be confirmed that DT enters and influences, to a greater or lesser extent, the communication between students and teachers, or the communication between students and the wider community in the Czech Republic. These case study results align with the global trends of DT in P&S education institutions, as is argued in a similar article for another European country - Bulgaria (Gaftandzhieva et al., 2022). Another comparable worldwide example is in Shermaine et al. (2024). According to Yuliandari et al. (2023), the results presented in this article generally align with the worldwide trends in P&S education institutions, specifically in terms of DT governance, DT leadership, DT implementation & methods, and the actors involved in DT.

Implications for interpretation.

Considering these factors, differences between Czech and other European results likely reflect structural program choices, teacher personal development ecosystems, national digital policy contexts, and family engagement dynamics, rather than measurement artefacts alone. Interpreting Czech findings through this lens enhances the explanatory soundness of the discussion and situates the results within the broader European evidence (Černý et al., 2023; European Commission/EACEA/Eurydice, 2023; European Commission, 2025; Fraillon, 2024; IEA, 2024)

Conclusion

A distinct and independent viewpoint is advanced in (Kopp et al., 2019). The students demonstrate readiness for digital transformation, whereas teachers exhibit gaps in competence (teachers remain insufficiently competent). This information is presented to provide context rather than to confirm or refute the claim. The finding may appear somewhat unexpected, particularly in the post-COVID era, yet the results indicate this trend. Consequently, digital transformation and digital maturity in P&S education institutions in the Czech Republic continue to increase annually. The contribution of the article is two-fold. First, the analysis demonstrates that students in P&S education are not indifferent to the issues of digital transformation and digital maturity. They show interest in topics extending beyond the teaching process and are willing to express their opinions. The results of the questionnaire survey confirm this observation. It corresponds to the research mentioned by Demartini et al. (2020) that 19% of respondents see DT and DM "like innovative teaching". Second, an overview was provided of how students aged 6–19 perceive the support of the P&S education process through IT equipment and related resources. The analysis also addressed their views on the quality of the education process facilitated by IT and on broader communication between P&S education institutions and parents. A holistic EA approach in the Czech Republic primarily focuses on supporting the development and management of P&S education institutions' data and digital transformation. Hence, P&S education institutions are part of the state education process; they must fulfill the requirements. Due to the requirement to approve digitization projects with budgets over 6 million CZK in the Czech Republic, the P&S education institutions are obligated by the Department of the Chief Architect of eGovernment of the Ministry of the Interior (Lukáš et al., 2023; Lukáš et al., 2022). Practically, the article highlights trends, including concerns about DT and DM in the Czech Republic.

The research results align with international trends. For example, in Slovakia (the eastern neighbor of the Czech Republic), the students' digital competencies, ranked at 48,6% (Zizikova et al., 2023), might be considered confirmation of a positive perception for sections A), B), and C), Table 4. Another study (Mišianiková et al., 2021) indicates that the following trends are similar to those used in our research. The mapping between them is as follows: "technologies allow to experiment with pedagogy and get instant feedback" (compare to Table 4, section A, C; Table 5, section B), "can help teachers automate or simplify a number of tasks" (compare to Table 4, section B), "provide instant access to the necessary information and develop important skills for working with sources" (compare to Table 4, section B; Table 5, section A), "interactive forms of activity allow developing communicative competence" and "the development of communicative skills by solving tasks and situations (compare to Table 5, section C; Table 6, section A, B).

Self-reported perceptions are inherently subjective and prone to social desirability bias, leading respondents to overstate positive experiences or underreport challenges. Age ranges among teachers, parents, and students introduce variability in digital literacy, leading to inconsistent interpretations across respondents. Additionally, these measures lack behavioral validation (high positive ratings may not accurately reflect actual competence or engagement) and rely on recall, which can lead to accuracy distortion. Finally, the prevalence of neutral responses suggests ambiguity that quantitative scales alone cannot resolve, underscoring the need for triangulation with objective data.

The limitations of the study and future research

Despite the limited length of the current article, the following limitations should be carefully considered: 1) the young respondents are not IT specialists but use IT actively in the education process; 2) the young respondents do not represent all age of students and are drawn from only one country, in Czech Republic, since digitalization of education is a global trend (Muthu et al., 2023); 3) the answers about DT and DM of P&S education institutions were influenced by the fact that all respondents are not able (due to their age) to consider broader contexts about the ends of education they receive, 4) due to the nature of RQ, the researchers neglected the teachers' and parents' points of view, similarly to Muthu et al. (2023), and 5) this research was limited to trends in P&S education institutions in a specific period of time (August 2023 - February 2024), (Shermaine at el., 2024), 6) the survey employed structured response formats without open-ended items; therefore, qualitative depth was limited. Future work will incorporate interviews or open-ended questions to enrich the interpretation of students' perceptions, 7. Findings may be affected by unit non-response, as response propensity could correlate with digital attitudes; response rates alone do not indicate bias. The sample underrepresents certain types of schools, ownership categories, regions, or urban–rural areas, which can affect generalizability. Post-stratification can mitigate representation error, but residual bias may still remain; clustering by school inflates variance.

Acknowledgement

The results and knowledge presented herein have been obtained with the support of an institutional grant. Internal grant agency of the Faculty of Economics and Management, Czech University of Life Sciences Prague, no. IGA - 2022B0006, Life Sciences 4.0. Plus.

Conflict of Interest

No conflicts of interest exist.

References

Balaban, I., Begičević Ređep, N. & Klačmer Čalopa, M. (2018) 'The Analysis of Digital Maturity of Schools in Croatia', International Journal of Emerging Technologies in Learning (iJET), 13(06), pp. 4–15. doi:10.3991/ijet.v13i06.7844. Available at: https://doi.org/10.3991/ijet.v13i06.7844.

Barretta, S.A.M. & Williams-Shakespeare, E.S. (2024) 'A Study of Digitalization of HE Institutions in the Caribbean', Open Journal In Education (OJED), 16(2), pp. 117–126. Available at: https://ojed.org/jcihe.

Bazalová, B. et al. (2025) 'Effective Teaching and Learning in Digital Education for Czech Students with Diverse Needs', Faculty of Education, Palacký University.

Benavides, L.M.C., Tamayo Arias, J.A., Arango Serna, M.D., Branch Bedoya, J.W. & Burgos, D. (2020) 'DT in HE Institutions: A Systematic Literature Review', Sensors, 20(11), p. 3291.

Černý, M. (2023) DigCompEdu: Digitální kompetence učitelů od teorie k praxi. Praha: Národní pedagogický institut ČR. Available at: https://digitalizace.rvp.cz/files/digcompedu.pdf.

Czech School Inspectorate (2022) Annual Report on the State of Education in the Czech Republic. Prague: CSI.

Czech Statistical Office (2025) ICT in Education – Statistics for 2024. Prague: CZSO.

Demartini, C.G., Benussi, L., Gatteschi, V. & Renga, F. (2020) 'Education and Digital Transformation: The "Riconnessioni" Project', IEEE Access, 8, pp. 186233–186256. doi:10.1109/ACCESS.2020.3018189.

Durakbasa, N., Bas, G. & Bauer, J. (2018) 'Implementing Education Vision in the Context of Industry 4.0', IOP Conference Series: Materials Science and Engineering, 448(1).

European Commission (2023) Digital Education Action Plan Progress Report. Brussels: European Commission.

European Commission (2024) Czechia Digital Decade Country Report. Brussels: European Commission.

European Commission (n.d.) Czech Republic in the Digital Economy and Society Index (DESI). Available at: https://digital-strategy.ec.europa.eu/en/policies/desi-czech-republic.

European Commission/EACEA/Eurydice (2023) Structural indicators for monitoring education and training systems in Europe – 2023: Digital competence at school. Luxembourg: Publications Office of the EU. Available at: https://www.eurydice.hr/cms_files/2023/11/1701167194_structural-indicators-2023---digital-competence.pdf.

Farias-Gaytan, S., Aguaded, I. & Ramirez-Montoya, M.S. (2023) 'DT and digital literacy in the context of complexity within higher education institutions: a systematic literature review', Humanities and Social Sciences Communications, 10, p. 386. doi:10.1057/s41599-023-01875-9.

Fernández, A., Gómez, B., Binjaku, K. et al. (2023) 'Digital transformation initiatives in higher education institutions: A multivocal literature review', Education and Information Technologies, 28, pp. 12351–12382. doi:10.1007/s10639-022-11544-0.

Fraillon, J. (ed.) (2025) An International Perspective on Digital Literacy: Results from ICILS 2023. Amsterdam: IEA / Cham: Springer. Available at: https://link.springer.com/book/10.1007/978-3-031-87722-3.

Gaftandzhieva, S., Doneva, R. & Docheva, M. (2022) 'Digital Maturity Level of Bulgarian Primary and Secondary Schools', ICERI2021 Proceedings of 14th International Conference of Education, Research & Innovation, pp. 8–9. doi:10.21125/iceri.2021.0554.

Gellweiler, C. (2020) 'Connecting EA & PPM: A Review and a Model for IT Project Alignment', International Journal of Information Technology Project Management, 11(1). doi:10.4018/IJITPM.2020010106.

Harrison, C., Tomás, C. & Crook, C. (2014) 'An e-maturity analysis explains intention-behavior disjunctions in technology adoption in UK schools', Computers in Human Behavior, 34, pp. 345–351. doi:10.1016/j.chb.2013.10.042.

Hess, T., Matt, C., Benlian, A. & Wiesböck, F. (2016) 'Options for formulating a digital transformation strategy', MIS Quarterly Executive, 15(2), pp. 123–139.

IEA (2024) ICILS 2023 International Report, Results, and Resources Now Available Online. Available at: https://www.iea.nl/news-events/news/icils-2023-international-report-results-and-resources-now-available-online.

Kalogeratos, G. & Pierrakeas, C. (2022) 'Knowledge and skills of the digital transformation of the Greek public school in the post COVID era', Proceedings of the 13th International Conference on Information, Intelligence, Systems & Applications (IISA), pp. 1–7. doi:10.1109/IISA56318.2022.9904416.

Kaminskyi, O.Y., Yereshko, J. & Kyrychenko, S.O. (2018) 'DT of University Education in Ukraine: Trajectories of Development in the conditions of new technological & economic order', Information Technologies and Learning Tools, 64, pp. 128–137.

Kopp, M., Gröblinger, O. & Adams, S. (2019) 'Five Common Assumptions That Prevent Digital Transformation At Higher Education Institutions', INTED2019 Proceedings, pp. 1448–1457. Available at: https://library.iated.org/publication_series/INTED.

Lahrmann, G. et al. (2011) 'Business Intelligence Maturity: Development and Evaluation of a Theoretical Model', Proceedings of the 44th Hawaii International Conference on System Sciences (HICSS).

Laterza, V., Asante, M.O., Tømte, C.E. & Pinheiro, R. (2023) 'Implementing Digital Transformations in HE Following COVID-19: A Norwegian Case Study', in Pinheiro, R. et al. (eds) Digital Transformation in Nordic Higher Education. Cham: Palgrave Macmillan.

Lukáš, M., Burešová, T. & Ulman, M. (2022) 'A novel approach to business process analysis and optimization based on EA: a case of local public administration in the Czech Republic', IDIMT-2022 Proceedings. Linz: TRAUNER Verlag Buchservice, pp. 59–66.

Lukáš, M., Burešová, T., Ulman, M., Havránek, M. & Jarolímek, J. (2023) 'DT at the national, regional, and local levels of public administration: A case of the Czech Republic', IDIMT-2023. 31st Interdisciplinary Information Management Talks. Linz: TRAUNER Verlag Buchservice, pp. 187–193.

McCusker, C. & Babington, D. (2018) 'The digital university: Staying relevant in the digital age', PricewaterhouseCoopers, pp. 1–20.

Ministry of Education, Youth and Sports (2021) Framework Educational Program Revision. Prague: MŠMT.

Mišianiková, A., Hubenakova, V., Kireš, M., Babincakova, M., Sveda, D. & Safarik, P. (2021) Assessment of Digitalization in P&S Schools by SELFIE Survey as a part of School Leaders Training, pp. 252–258. doi:10.1109/ICETA54173.2021.9726580.

Miškelová, M., Adamec, P. & Hrmo, R. (2025) The Level of Digital Competences of Secondary School Pupils in the Czech Republic, Lecture Notes in Networks and Systems, LNNS 1281, pp. xx–xx. Springer.

Muthu, C., Liang, C. & Hui, W. (2023) 'Digital Transformation in Higher Education', INTI Journal, Vol. 2023:05. doi:10.13140/RG.2.2.18720.25605.

OECD (2025) TALIS 2024 Country Note: Czechia. Paris: OECD Publishing.

Prasanna, P. & Choudhury, S. (2024) 'Transformation Strategies for Higher Education', Cognizant.

Qureshi, M.I., Khan, N., Raza, H., Imran, A. & Ismail, F. (2021) 'Digital Technologies in Education 4.0: Does it Enhance the Effectiveness of Learning? A Systematic Literature Review', International Journal of Interactive Mobile Technologies, 15, pp. 31–47.

Sararuch, S., Wannapiroon, P. & Nilsook, P. (2023) 'The Development of Agile Enterprise Architecture for Digital Transformation in Higher Education Institutions', Higher Education Studies, 13(3), pp. 69–79. doi:10.5539/hes.v13n3p69.

Švaříček, R. et al. (2021) Teachers' Digital Competence and ICT Integration in Czech Schools, Journal of Pedagogical Research, 6(2), pp. 45–62.

Teichert, R. (2019) 'Digital Transformation Maturity: A Systematic Review of Literature', Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 67, pp. 1673–1687. doi:10.11118/actaun201967061673.

Vial, G. (2019) ‘Understanding digital transformation: A review and a research agenda’, Journal of Strategic Information Systems, 28(2), pp. 118–144. doi:10.1016/j.jsis.2019.01.003.

Yuliandari, T.M., Putri, A. & Rosmansyah, Y. (2023) ‘Digital Transformation in Secondary Schools: A Systematic Literature Review’, IEEE Access, 11, pp. 90459–90476. doi:10.1109/ACCESS.2023.3306603.

Zizikova, S., Nikolaev, P. & Levchenko, A. (2023) Digital transformation in education, E3S Web of Conferences, 381, 02036. doi:10.1051/e3sconf/202338102036..

Process Eye-Tracking Data with Machine Learning Approach in Context of Fundamentals of Electrical Engineering

Article history
Received
28 November 2025
Received in revised form
12 December 2025
Accepted
12 December 2025
Published online
27 December 2025

Johannes Paehr**, *Thomas Norbert Jambor
Faculty of Electrical Engineering and Computer Science,
Leibniz University Hannover, Germany
** paehr@dei.uni-hannover.de*

Abstract

In this research study, first-semester students solved tasks in the context of the fundamentals of electrical engineering. They were wearing eye-trackers while solving the tasks. The collected data is used to train a machine learning model per task, that predicts based just on eye-tracking data, if a student is about to succeed in solving a specific task or if the student is about to fail. The trained models reach an accuracy of 85% respectively 91% depending on the task. In the future, this model will be integrated into a virtual environment where eye-trackers are present, to assist those students who might fail.

Keywords: Electrical Fundamentals, Eye-tracking, Machine Learning

Introduction

Electrical engineering students in their first semester tend to have difficulties with the fundamentals of Electrical Engineering. This is due to several reasons. Almost half of the students in the first semester have a different first language than German. So for some of these students, the language might be a barrier. Additionally, in some countries, the direction of electric current is taught differently because the charge carriers of the opposite polarity are used. Although this is not a problem from a technical point of view, it can lead to comprehension problems that represent a learning barrier. In particular, functioning mental models are not questioned and can still be an obstacle to learning when building up new knowledge. These not-questioned mental models are called preconceptions because they might be generally valid, but they also might be wrong.

Furthermore, there are different ways to obtain the university entrance qualification. Besides the possibility of obtaining the qualification in a foreign country, there are several options to obtain the qualification in Germany. All of them confirm their university entrance qualification, but the levels of knowledge in mathematics and physics are different.

This means that the students, especially in the first semesters, build a group of learners with several different preconceptions, some of them true, but not all of them. For this reason, analysis tools such as eye-trackers are particularly interesting because they provide insight into students' behavioral patterns.

In the following, we will describe how we collected eye-tracking data and how we used it to train two machine learning models that can predict whether a student will solve a task correctly or not. In the third step, the link to the learners is established. Here, a decision can be made on how to handle the results of the model. The first two steps are part of this article. The third step will be discussed in the Application section.

Related Work

The gaze behavior of the eyes reveals several insights into the current cognitive states of humans (Schindler & Lilienthal, 2019). Therefore, Raptis et al. highlight in their literature review the possibility of recognizing patterns in the gaze behavior, which can be recorded using eye-trackers (Raptis et al., 2016). The authors describe findings about the cognitive differences in visual perception tasks, which can be observed in eye-tracking data.

These observations were confirmed by Singh et al. when they showed that it is possible to train a machine learning model that can identify reading patterns that are typical for inspectors who should find common fault types in requirement engineering. The dataset contains eye-tracking recordings of 39 participants. As classifiers, Singh et al. used Bayesian, SVM, Ensemble, Tree, and Lazy Learners. (Singh et al., 2018)

Pritalia et al. propose an approach that detects the learning style (process information) of students based on eye-tracking data (Pritalia et al., 2020). They tested three different machine learning models (SVM, Naive Bayes, and Logistic Regression) and achieved an accuracy of 71% with the best approach. The dataset used in this study comprises 68 participants.

Many other papers have been published dealing with eye-tracking, but to the author's knowledge, none deal with preconceptions in the fundamentals of electrical engineering. However, all these publications

Paehr, J. & Jambor, T.N. (2025), Process Eye-Tracking Data with Machine Learning Approach in Context of Fundamentals of Electrical Engineering, *ASEAN Journal of Engineering Education*, 9(2), 154-161. https://doi.org/10.11113/ajee2025.9n2.210

show that machine learning models are suitable for extracting information from this type of data.

Study

Design of the Course

To help all of the students reach an almost equal level of knowledge in the fundamentals of electronics, we offer a course that is specially designed to detect and reduce misconceptions. A lot of the tasks the students have to solve are taken from Kautz (Kautz, 2010). The focus of the course is on developing helpful conceptions, respectively, to correct unhelpful conceptions about the physical quantities of current, voltage, and resistance.

To achieve this, the course includes both theoretical and practical parts. First, the theory is explained by a lecturer, and in the second part, the students become active and work on tasks related to the previously explained (Jambor, 2024). The course takes place in a lecture hall.

Idea

In the future, based on the eye movements while the students are working on a task, a virtual assistant should give hints if it detects a disorganized or unsystematic approach to solve the task. To achieve such a system, it needs to distinguish between a systematic and an unsystematic approach in solving the tasks. So the challenge is to find significant metrics based on eye-tracking data to distinguish between the different approaches of the students. Each metric has its advantages and disadvantages, and whether it is appropriate for the distinction must first be examined. Once suitable metrics are found, they can be used to train a machine learning network, which can then be used to classify the approaches of students just by using eye-tracking data. The steps required to achieve the model are condensed in Figure 1. The first step is the eye-tracking survey. To get access to the data, the software of the eye-tracker manufacturer is used. Within this software, it is possible to export the collected data. Afterward, various Python scripts can be used to filter the data or perform calculations on the data. Additionally, the training and testing of the models are realized using Python scripts.

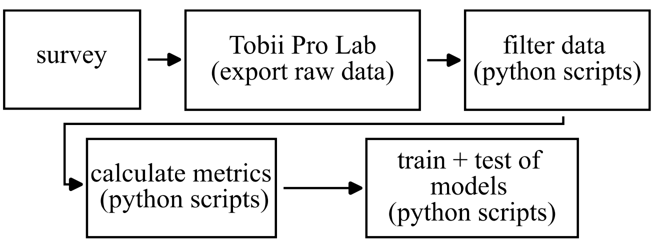


Figure 1. Steps from gathering data to the model.

Eye-Tracking Recordings

The eye-tracking recordings were made with mobile eye-trackers (Tobii Pro Glasses 2). They allow for gathering data in a realistic learning setting so that after a short time of familiarization, students behave like they would in a setting without the eye-trackers. Students have reported that they have forgotten to wear an eye-tracker. For those students who wear regular glasses, special prescription lenses were mounted to the eye-tracker because it is not possible to wear the eye-tracker and regular glasses at the same time. Due to the age of the young participants, most of them do not have aids in the form of glasses, or the prescription lenses are so low that most of the students chose not to wear the prescription lenses from the eye-tracker.

A total of 75 datasets were recorded in the course mentioned above. The datasets include 6 from female students and 69 from male students. The recordings were made in groups of six in the laboratory (the lecture hall is inappropriate for eye-tracking recordings). During the recording, the students worked individually. None of the students had to participate in the study, as it was voluntary. The students who participated in the study signed a declaration of consent, explaining who received the data and what may be done with this data. Students who took part in the study had no advantages or disadvantages compared to other students.

There are 48 usable recordings. 27 recordings are not usable because:

- The students looked under the glasses instead of through them, which makes it difficult for the eye-tracker to track the eyes at all. This happened especially to students who were not familiar with wearing glasses.
- The students started the task but did not finish it.
- The glasses slipped out of place. This can be observed on a heatmap that visualizes the fixation density when empty areas have a high density of fixations. Still, if the shift is small, the data might be usable, or if it is just a single shift, the data might be correctable. For this study, the shifted data is not taken into account.

Not all the tasks in the course are suitable for eye-tracking recording. Especially the practical parts where students have to place components on a breadboard and do some electrical voltage and current measurements are difficult to analyze because of the constantly changing surroundings. The latter results in almost no support for software-assisted analysis, so practical tasks are not recorded.

A task that is well-suited for recording with an eye-tracker is shown in Figure 2. The picture shows five electrical subnetworks. Three of them contain light bulbs, and the other two consist just of an open circuit or an ideal conductor. The first subtask for the students is to arrange the networks in ascending order (by their resistance).

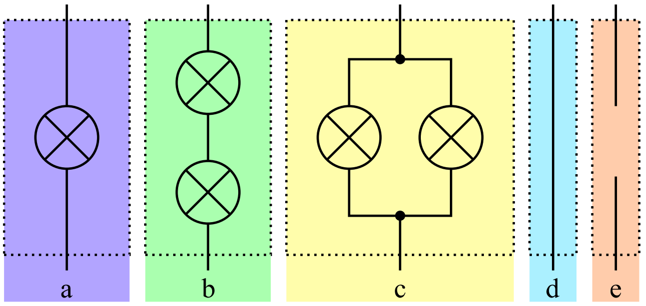


Figure 2. Students have to sort the electrical subnetworks by their resistance. The colors represent the areas of interest (AOIs).

To analyze the eye movements in such a task, areas of interest (AOIs) are defined (Holmqvist et al., 2015). Each AOI is colored in a different color. These colors are not printed on the paper the students are working on, they are just a visualization for the researcher. With defined AOIs, it is possible to generate several metrics that provide insights into students' behavior. The metrics used in this paper are:

- Dwell Strings (DS), which add an AOI-specific identifier to a chain of identifiers each time the student visits the AOI. The characters of the AOI itself are used as identifiers. If an identifier appears multiple times in a row without another identifier in between, the repetitions are removed from the DS. The reason for this is the comparability of different DSs. The DS should not map the processing speed of the tasks the students solve. Therefore, repetitions within the DS are removed.
- Dwell Time (DTi) represents the duration of the dwell. The DTi is used to compensate for the removal of the repetitions in the DS.
- Revisit Count (RC) represents the number of revisits in an AOI within a DS.

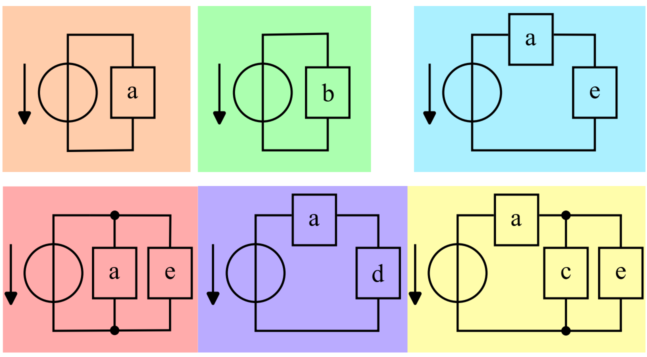


Figure 3. Students have to insert the subnetworks from Figure 2 and sort the circuits in ascending order by current. The colors represent the areas of interest (AOIs).

In the second task (see Figure 3), the students have to sort the circuits by the amount of current flowing. To do this, they have to fill in the boxes with the characters by the subnetworks in Figure 2. A typical difficulty in the fundamentals of electrical engineering is the effect of an electrical consumer in a network. While students typically understand that an electrical consumer acts as a barrier to current, the interaction of electrical consumers connected in series or parallel is a challenge. The tasks in this article address precisely this problem.

The core idea behind the tasks is that the physical consequences in series and parallel connections can be estimated based on the electrical current. Calculations are deliberately omitted at this stage, as the aim is for students to gain not only a mathematical understanding of electrical consumers, but also an idea of how they work within a circuit. The second task in particular practises this by requiring the electrical currents of the subcircuits to be compared with each other in different configurations.

Selection of Appropriate Metrics

Initially, it is not known which eye-tracking metrics might be suitable to distinguish between a student whose approach is systematic and a student whose approach is unsystematic. This is why several metrics are calculated, and those that are significant to differentiate between systematic and unsystematic approaches are used.

None of the metrics is normally distributed, which is why rank-based tests are used to measure the significance. Both the U-Test as well as the Kruskal-Wallis test indicate that the RC is within the significance level of $P \leq 0.05$. For the first task, the Kruskal-Wallis test calculates a p-value of 0.037 for AOI E. The RC of the other AOIs of the first task does not seem to be relevant, because the p-value is bigger than the significance level. For the second task, the p-value of the RC reaches the significance level with the top three AOIs in Figure 3 (0.021, 0.010, 0.010).

Machine Learning Model

Motivation

In previous work, other tasks from this course were analyzed and used to train different machine learning-based models (Paehr & Jambor, 2023). The best performance was achieved with a Long Short-Term Memory-based (LSTM) approach. The data used for training and testing the model was exclusively based on DS. In terms of the target application, in which students need to be identified by the application as not following a systematic approach to receive support, this is a problem. The entire DS is present when the task is completed by the student or when the student gives up, respectively, solves the task wrong without noticing the inconsistencies.

If the students are to receive hints, then they must receive them earlier, during processing. Based on the DS, this is not possible because the DS is only available after the task is completed. A second problem of this approach lies in the different lengths of the DSs (see

Figure 4). Each student generates a different DS with their gaze. As mentioned earlier, the students may have highly different preconceptions, so the lengths of the DSs differ. Unhelpful conceptions can lead to patterns in the DS that are not helpful. Consequently, it is likely that unhelpful conceptions will lead to incorrect sorting. However, the model does not allow us to draw conclusions about specific conceptions. Nevertheless, lecturers can benefit from knowing that problems frequently arise with specific tasks. The shortest DS is 15 characters long, while the longest DS is 287 characters long. These differences impede the ability of typical comparison algorithms, such as the Levenshtein distance (Levenshtein, 1966), to compare the DSs of the students with each other, because the length may have a bigger influence than the content of the string itself. The Levenshtein distance penalizes missing characters as much as not matching characters. This means that if the DSs to be compared are not nearly equal in length, it is not appropriate to use this algorithm to compare the DSs.

A similar problem exists with LSTM models because the input data of such a model needs to be equal in size. Consequently, the longest DS serves as the basis for determining the input size of the LSTM model. Therefore, the shorter DSs are filled up with zeros to match the size of the longest DS.

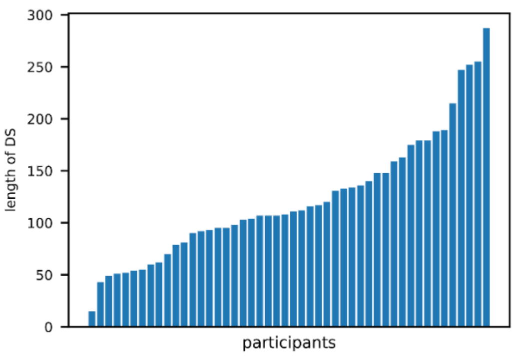


Figure 4. Different lengths of DSs in the first task.

This is why the DS has been divided into chunks (see Figure 5). The chunks consist of shorter parts of the entire DS. Consequently, it is expected that the prediction of a trained model is not as accurate as with the entire DS, but it opens up the possibility of getting the prediction earlier. The first prediction can be obtained after the student has reached the number of transitions between AOIs necessary to build the first chunk of the minimal length.

DS:	A	B	A	C	D	A	E	A	E	…
$chunk_1$:	A	B	A	C	D					
$chunk_2$:		B	A	C	D	A				
$chunk_3$:			A	C	D	A	E			
$chunk_4$:				C	D	A	E	A		
$chunk_5$:					D	A	E	A	E	
					⋮					

Figure 5. DS divided into overlapping chunks. In this example, the length of the chunks is 5.

So the research questions are as follows:

- RQ1: How many transitions are necessary to create a model that can predict the outcome of the student's work with sufficient accuracy?
- RQ2: How many parameters should such a model have to minimize overfitting and underfitting?
- RQ3: Can other significant metrics improve the performance of the model?

Design of the Model

In (Paehr & Jambor, 2023), eye-tracking data from a comparable task were analyzed with different machine learning models, like the decision tree (DT), the support vector machine (SVM) (Schölkopf & Smola, 2002), the hidden Markov model (HMM), and also a neural network with a bidirectional LSTM layer (BiLSTM-Net). The DT and the SVM were trained with position-based measures such as the fixation duration on an AOI. While these kinds of metrics are significant for this task, the results demonstrated that these models achieve an accuracy of 0.79 respectively 0.73 in predicting the success of students on a specific task. Additionally, sequence-based approaches (HHM and BiLSTM-Net trained with DS) were evaluated. The HMM achieved an accuracy of 0.73 while the BiLSTM-Net reached an accuracy of 0.8. The accuracy of the BiLSTM-Net is the reason why this model is adapted to the tasks here.

The base architecture of the models consists of LSTM and dense layers (see Figure 6). While the LSTM is an advanced version of a recurrent neuronal network (Hochreiter & Schmidhuber, 1997), it is designed to store input information and detect sequences over time efficiently. Therefore, the LSTM layer/s is/are responsible for learning the crucial dependencies that lead to success or failure, within the DSs. On the left side, two LSTM layers, each with 10 units, are stacked. The number of units is a control variable of the possible complexity of the model. The fewer units, the less complex the model can be.

Tests with the dataset have shown that the model fits better if two LSTM layers are stacked compared to a single layer with twice the number of units. This side of the model is responsible for learning patterns within the DSs and the corresponding DTis. This is why the input shape of this side is chosen to [None, chunk size, 2]. The first parameter is a placeholder for the number of datasets. Because the number of datasets depends on the chunk size, it varies through the different chunk sizes of the different trainings (within a single training, the chunk size stays constant). The second parameter is the chunk size, and the final parameter is set to two for the AOI position and the corresponding DTi. A dropout of 10% is added to the two LSTM layers to make the model more robust.

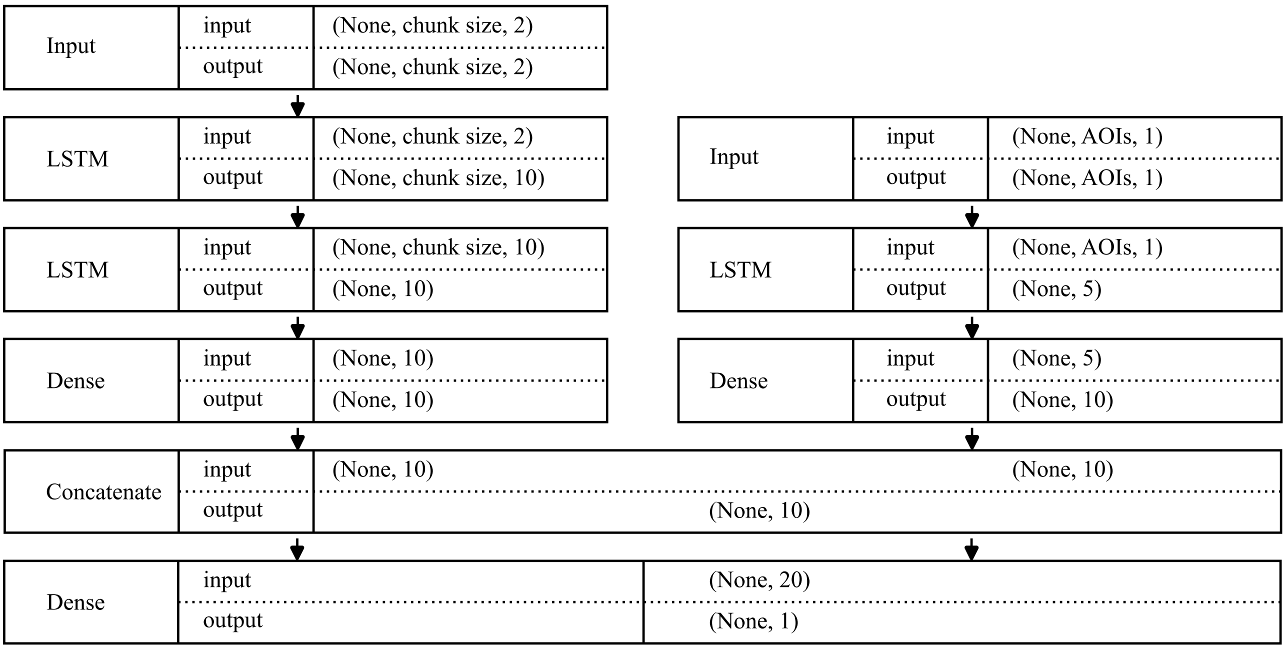


Figure 6. Architecture of the model: left: processing of the DS and the DTi; right: processing of the RC

The right side of the model consists of just one LSTM layer and a dense layer for transitioning the results of the LSTM layer to the output. This part of the model is supposed to learn information within the dataset about the RC. This is why the input shape is dependent on the number of AOIs. Consequently, the number of AOIs is five for the first task (see Figure 2) and six for the second task (see Figure 3). The number of units of this LSTM layer is comparatively small, with five units. The advantage of adding another significant metric to the model may be undermined if the number of units is chosen too large. As the results show (see Table 1 and Table 2), five units appear to be an appropriate choice.

To combine the results of both sides of the model, the concatenate layer is used. This layer does not own any weights that could be trained. It just concatenates the results of the layers above, which consist of two dense layers that are both activated by a ReLU function. The final layer of the model is a dense layer. This dense layer is necessary because the output of the LSTM layer is dependent on the number of units the layer consists of. Consequently, the dense layer is a translation layer between the outputs of the LSTM layer and the desired output of the model. For this model, just a single output is required to differentiate between the student's approaches. Consequently, a sigmoid function is used for activation. To train the model, the learning rate of the Adam optimizer is chosen to be 0.001.

Results

Due to the limited number of datasets, it is challenging to identify optimal parameter settings for the model. The number of trainable model parameters must be kept to a minimum to prevent overfitting the training data. On the one hand, this leads to poor accuracy of the test data, and on the other hand, it might cause a positive gradient of the loss function from the test data. Both the accuracy and the loss function result in a suboptimal performance of the model on never-before-seen data (test data).

This is why our best approach of the model has two LSTM layers (each with 10 units) followed by a dense layer (also 10 units, left side). In parallel (right side), a third LSTM layer with 5 units and a second dense layer with 10 units are added to the model to allow the integration of metrics such as RC into the model (see Figure 6).

Several other combinations of architectures were tested. Increasing the number of LSTM layers also leads to an increase in the number of trainable parameters, which in turn increases the risk of overfitting. The same effect can be observed when the units of the LSTM layers are increased.

It is commonly known, that Bi-LSTM networks adapt better than LSTM networks (Schuster & Paliwal, 1997). However, this is not always the case. The bidirectional part of the network increases the trainable parameters. In this special case, the accuracy of such a model increases for the training data, but the accuracy of the test data decreases if all other settings are constant, except for the LSTM layers, which are extended to Bi-LSTM layers.

Referring to the first research question (RQ1), the impact of varying chunk sizes is evaluated. For the first task, the shortest chunk size tested is five, and the longest chunk size tested is 180. For this test, all models between these sizes are separately trained. Due to the split into different sizes, the number of datasets is bigger when the chunk size is chosen shorter (see Equation (1).

$$k = N - c_s + 1 \quad (1)$$

N is the size of the DS, and k is the number of chunks for a chosen chunk size of c_S. Although the number of datasets is slightly higher due to this effect, the smaller the chunk size is, models trained with chunk sizes up to 30 do not adapt to the data well.

For the second task, it is appropriate to create a second model because different AOIs need to be included (see Figure 3). The basic structure of the second model is identical. The difference between the first and second model is the number of AOIs taken into account. The second task has six AOIs, while the first task just has five AOIs.

It is possible to use all AOIs from the first and the second task in one model, but this would also increase the length of the DS and create additional options for constructing the DS. Consequently, the AOIs from the first task are not used to train and test the model of the second task. The resulting lengths of the DSs from the first task are shown in Figure 7. Similar to the first task, the lengths of the DSs from the second task differ considerably.

The datasets are split into approximately 80% training data and 20% test data. The reason why it is just approximately 80% training data is that the entire chunks of one DS need to be either training data or test data. If a few chunks of one DS are designated as training data and the remaining chunks of the same DS are used as test data, it will occur that almost the same chunks are used to train and test the model. To prevent this, the training test split is done before generating the chunks. Because the DS are of different lengths, it can happen that the train test split is not perfectly 80/20.

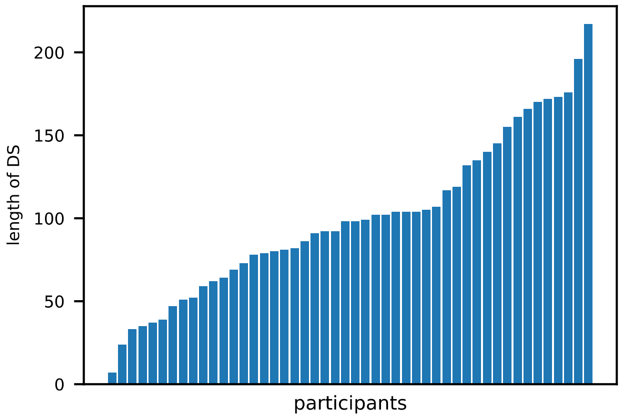


Figure 7. Different lengths of DSs in the second task.

Discussion

The number of datasets is of critical importance when working with ML approaches. Typical datasets in machine learning approaches are usually large. This is necessary because the model is supposed to generalize to fit not just data from the training, but also to never-before-seen data.

Table 1. Results of the model for the first task (see Figure 2)

chunk size	40		50		60	
	with RC	w/o RC	with RC	w/o RC	with RC	w/o RC
train	80%	-	90%	-	86%	-
test	76%	-	85%	-	81%	-

Table 2. Results of the model for the second task (see Figure 3)

chunk size	40		50		60	
	with RC	**w/o RC**	**with RC**	**w/o RC**	**with RC**	**w/o RC**
train	86%	83%	90%	86%	92%	-
test	85%	83%	86%	85%	91%	-

Gathering eye-tracking data is challenging. There are several reasons why most eye-tracking studies have fewer than 30 participants:

- Every eye-tracker needs to be calibrated before the recording can start. This process is not automated and consequently time-consuming.
- The eye-tracker does not work with all students. Sometimes, when the eyes of the participants are too moist, unintended reflections occur and make a recording impossible. Additionally, some types of contact lenses can be problematic.
- A problem with mobile eye-trackers is that they may slip. This is problematic when the glasses slip slightly more, as the calibration of the eye-tracker is designed to stay in position.

Nevertheless, our machine-learning approach reached an accuracy that is acceptable for the target application. The results indicate that the first model reaches an accuracy of 85% taking the metrics RC, DS, and DTi into account (see Table 1). The RC appears to be a critical factor in this model because it did not adapt well to the datasets when the RC was excluded from the analysis. Referring to RQ3, it should be noted that other significant metrics, in addition to those already mentioned, can enhance the model.

Referring to RQ1, the results demonstrate that a chunk size of 40 is sufficient to predict the result of the student with an accuracy of 76%. Considering that the majority of the students did 50 or more transitions when solving the task (see Figure 4), a chunk size in the range from 40 to 50 appears appropriate.

The second model, for the second task, performs even better (see Table 2). As observed in the previous model, the RC has a positive effect on the results in terms of test accuracy. Similar to the first task, the chunk size is sufficient to predict the success of the students before they have completed the task. A chunk size of 40 to 60 appears appropriate in this case as well.

The model size of both models is almost equal, and compared to typical machine learning approaches, fairly small. This is necessary because the model tends to overfit if the layers are chosen larger. To address this issue, more training data is necessary.

Limitations

While the models make it possible to predict whether a student will solve the tasks, further conclusions can also be drawn. For example, because the models are able to calculate this prediction, the influence of the input variables on these predictions can be determined. Since the input variables are the order in which the AOIs are gazed, the fixation lengths, and the RC, these variables are relevant for the prediction. A pattern for a systematic approach can be learned from the order in which the AOIs are gazed. The LSTM architecture used in this model is precisely suited for this purpose. Consequently, it can be assumed that the models tend to classify the systematic approach or the non-systematic approach, even though they have been trained using the results of the tasks. Since the fixation durations are also integrated into the model and there is a correlation with cognitive load (Skaramagkas et al., 2023), the model result can also be an indicator of cognitive load. These are indications of why the model arrived at the corresponding decision. However, it is not possible to say without further ado why the model arrived at the corresponding decision. It is also not possible to conclude that there is a specific preconception. There are numerous preconceptions in the fundamentals of electrical engineering, and machine learning approaches require more data sets with these preconceptions for training in order to be able to recognize the patterns of these preconceptions.

Since the tasks involve several concepts, such as parallel and series connections of electrical consumers, it is not possible to make a statement about the students' conceptual understanding of the relationships based on a binary classification of the models.

Application

There are several ways to deal with the models' predictions. On the one hand, automated support is conceivable, for example, within a VR application whose glasses have eye trackers. Depending on the model, irrelevant areas could be concealed at first. It is also conceivable that the necessary electrical rules for completing the task could be displayed optionally. If no VR environment is to be used, it is also conceivable that the model results would not directly influence the task sequence, but would only be available to the lecturer, who could repeat task-specific explanations.

The models proposed here are designed to generate the most accurate classification possible as early as possible. This means that the decision on when to take support measures can be made from a didactic rather than a technical perspective. The appropriate timing for a measure must be examined.

The question of how model results influence teaching depends on how the results of the models are used. If subliminal optional hints are used within a VR application, the impact of an incorrect model prediction is less pronounced than if the task were to be aborted. Another possibility is that the model results are only available to the lecturer. This allows the lecturer to objectively assess which tasks pose a challenge for the students. As a result, the lecturer can focus on repeating the relevant tasks.

Conclusion

The novelty of this approach lies in the fact that two models based on an LSTM architecture have been trained using eye-tracking data from the context of electrical engineering fundamentals. Currently, the model can differentiate between students who are probably successful in solving a specific task and students who may fail. The data basis of the models is based exclusively on eye-tracking data. Consequently, conclusions can be drawn from eye movements that have not been used in a classic scenario to date, meaning that potential has not been fully exploited. Models such as those presented in this article are a step toward making this potential accessible.

To utilize the models presented here, they need to be integrated into a virtual environment where eye-trackers are present. The data from the eye-tracker must then be filtered and fed directly into the models. This allows for the generation of optional hints for students who are about to fail within the learning situation.

To generate more specific hints, a finer differentiation might be helpful. However, to achieve this with sufficient accuracy, more data is needed.

The model is trained with data from students who solve the task on conventional paper. The assumption is that this data can be used to create support in a virtual environment if the virtual environment is similar enough. If this is not the case or the behavior of the students is different in the virtual environment, the model needs to be adapted or retrained.

The fact that models can be trained exclusively using data collected by eye trackers and can achieve accuracies of up to 91% shows that a wealth of information can be gleaned from gaze directions. In this approach, locations, fixation times, and RC have been used as significant metrics. It cannot be ruled out that other significant metrics exist that would allow for a more refined classification. In this respect, any approach that provides a broader perspective on learners may be helpful.

Acknowledgement

The authors would like to thank Leibniz University Hannover for the support provided in conducting this study.

Conflict of Interest

No conflicts of interest exist.

References

Hochreiter, S., & Schmidhuber, J. (1997). Long Short-Term Memory. Neural Computation, 9(8), 1735–1780. https://doi.org/10.1162/neco.1997.9.8.1735

Holmqvist, K., Nystrom, M., Andersson, R., Dewhurst, R., Jarodzka, H., & Weijer, J. V. D. (2015). Eye Tracking A comprehensive guide to methods and measures. A comprehensive guide to methods and measures (p. 560). Oxford University Press.

Jambor, T. N. (2024). From Theory to Practice: Improving Learning Through Action Orientation in Academic Education. 2687–2696. https://doi.org/10.21125/inted.2024.0741

Kautz, C. H. (2010). Tutorien zur Elektrotechnik (1st ed.). Pearson Studium.

Levenshtein, V. I. (1966). Binary codes capable of correcting deletions, insertions and reversals. Soviet Physics Doklady, 10(8), 707–710.

Paehr, J., & Jambor, T. N. (2023). Using Eye-Tracking Technology to Provide Assistive Support in a Mixed Reality Learning System. 6067–6072. https://doi.org/10.21125/iceri.2023.1516

Pritalia, G. L., Wibirama, S., Adji, T. B., & Kusrohmaniah, S. (2020). Classification of Learning Styles in Multimedia Learning Using Eye-Tracking and Machine Learning. 2020 FORTEI-International Conference on Electrical Engineering (FORTEI-ICEE), 145–150. https://doi.org/10.1109/FORTEI-ICEE50915.2020.9249875

Raptis, G. E., Fidas, C. A., & Avouris, N. M. (2016). Using Eye Tracking to Identify Cognitive Differences: A Brief Literature Review. Proceedings of the 20th Pan-Hellenic Conference on Informatics, 1–6. https://doi.org/10.1145/3003733.3003762

Schindler, M., & Lilienthal, A. J. (2019). Domain-specific interpretation of eye tracking data: Towards a refined use of the eye-mind hypothesis for the field of geometry. Educational Studies in Mathematics, 101(1), 123–139. https://doi.org/10.1007/s10649-019-9878-z

Schölkopf, B., & Smola, A. J. (2002). Learning with Kernels: Support Vector Machines, *Regularization, Optimization, and Beyond*. The MIT Press. https://doi.org/10.7551/mitpress/4175.001.0001

Schuster, M., & Paliwal, K. K. (1997). Bidirectional recurrent neural networks. *IEEE Transactions on Signal Processing*, *45*(11), 2673–2681. https://doi.org/10.1109/78.650093

Singh, M., Walia, G. S., & Goswami, A. (2018). Using Supervised Learning to Guide the Selection of Software Inspectors in Industry. *2018 IEEE International Symposium on Software Reliability Engineering Workshops (ISSREW)*, 12–17. https://doi.org/10.1109/ISSREW.2018.00-38

Skaramagkas, V., Giannakakis, G., Ktistakis, E., Manousos, D., Karatzanis, I., Tachos, N., Tripoliti, E., Marias, K., Fotiadis, D. I., & Tsiknakis, M. (2023). Review of Eye Tracking Metrics Involved in Emotional and Cognitive Processes. *IEEE Reviews in Biomedical Engineering*, *16*, 260–277. https://doi.org/10.1109/RBME.2021.3066072

AI-Marking Assistant: A Web-Based Application for Human-in-the-loop GAI Assisted Assessment Marking and Feedback

Article history
Received
1 December 2025
Received in revised form
12 December 2025
Accepted
18 December 2025
Published online
27 December 2025

Paul Craig[a], Thomas Selig[a], Yu Liu[a], Ling Wang[b], Erick Purwanto[a], Wan-ting Shen[c]*
[a]Department of Computing, School of Advanced Technology, Xian Jiaotong Liverpool University, China
[b]Educational Development Unit, Xian Jiaotong Liverpool University, China
[c]Department of Biological Sciences, Xian Jiaotong Liverpool University, China
**p.craig@xjtlu.edu.cn*

Abstract
This paper introduces AI-Marking Assistant (AI-MA), a prototype application that aims to improve the efficiency and consistency of grading and grading feedback by allowing educators to integrate Generative Artificial Intelligence (GAI) assistance into the grading process. While automated grading has the advantages over traditional human marking of being efficient, timely, consistent, scalable, and objective, there are also known limitations and potential issues associated with process. Grading and feedback can lack the nuance and context that would normally come from an expert marker. Results can also be biased by the training data and there are significant ethical and legal implications of allowing a machine to grade assignments without human oversight. AI-MA aims to overcome these limitations by offering a human-in-the-loop GAI assisted interface that allows educators to leverage the power of GAI while keeping an active oversight and interactive role in the marking process. AI-MA allows human graders to manually mark assignments, or edit the output of a GAI model with results fed back to the model in order to improve its performance. A pilot study with the application demonstrates its potential to significantly improve grader performance while maintaining the quality of marking and grade feedback for students. The evaluation with four markers and 250 student submissions showed a 40% reduction in marking time after initial examples were provided to the system.

Keywords: Educational technology, Generative AI, Human computer interaction, Automated assessment, Human-in-the-loop AI.

Introduction

The advantages of providing students with timely personal feedback on assignment submissions are well known to educators and academic researchers alike (Craig et al., 2014; Williams, 2024; Simonsmeier et al., 2020). Personalized feedback helps students understand their strengths and areas for improvement (Tetzlaff et al., 2021). Feedback tailoring to individual needs can guide students toward better performance (Tetzlaff et al., 2021). It can also improve motivation and confidence. When students receive specific, personalized feedback, they feel more motivated to engage with their learning and confidence grows as they see progress and understand how to enhance their work. Timely feedback can also foster a positive connection between students and educators, demonstrating care and investment in the student's progress to enhance overall student engagement.

Despite these benefits, providing personalized feedback presents challenges, particularly in large classes (Tetzlaff et al., 2021). The time required for marking assignments, providing comments, and addressing individual needs can be substantial, creating workload pressures for educators. Additionally, balancing encouragement with constructive criticism while maintaining positive rapport can be emotionally demanding (Øen, 2024).

The current literature identifies several standards for effective personalized feedback. Feedback should encourage students to engage with the assessment process, reflect on their performance, and consider how to improve (Tetzlaff et al., 2021). It should help students understand what good performance looks like through explicit statements of what is done well or poorly and why. Effective feedback recognizes learner differences and tailors feedback to individual needs, highlighting strengths and areas for growth. It should be fair, honest, and clear, balancing positive reinforcement with areas for improvement. Timeliness is also crucial, allowing students to act on feedback to close the gap between their current performance and

Craig, P., Selig, T., Liu, Y., Wang, L., Purwanto, E., & Shen, W (2025), AI-Marking Assistant: A Web-Based Application for Human-in-the-loop GAI Assisted Assessment Marking and Feedback, *ASEAN Journal of Engineering Education*, 9(2), 162 -170. https://doi.org/10.11113/ajee2025.9n2.213

desired standards. Meeting these requirements places a significant burden on educators that is particularly challenging for larger classes.

While various methods exist to automate assignment marking and feedback, they often have limitations. Multiple-choice question grading is easily automated but limited to objective questions that may not assess higher-level learning outcomes (Tuma, 2022). Peer marking and self-marking can shift marking burdens from teachers (Simonsmeier et al., 2020), but these methods require clear criteria that students can easily understand and may suffer from inconsistency and fairness concerns. Peer feedback can be valuable but similarly relies on clear criteria and may lack consistency.

Generative Artificial Intelligence (GAI) and other automated methods can also be applied to automated marking for short answer and essay questions (Burrows et al., 2015; Souppez et al., 2023). AI has clear advantages over traditional human marking as it is known to be efficient, timely, consistent, scalable, and objective (Farrelly & Baker, 2023; Chan & Colloton, 2024). However, there are disadvantages and limitations of AI grading that should be considered. These can be summarised as follows:

- **Lack of Nuance.** Automated grading lacks the nuanced understanding that an expert human marker brings. Context, tone, and subtle nuances in student responses can be challenging for AI to capture. While it can handle routine tasks, it may miss the depth and context that a human grader would naturally consider (Johnston et al., 2024).
- **Bias.** Biases can creep into automated grading systems. These biases stem from the training data used to develop the AI model. If the training data contains inherent biases, the system may perpetuate them during grading (Li et al., 2023).
- **Ethical concerns.** Ethical considerations arise when allowing a machine to grade assignments without sufficient human oversight. While the responsibility for the marking still lies with the educator, if they do not adequately monitor the marking process, bias and inaccuracies from the AI might be left in the marks given to the student (Farrelly & Baker, 2023).

It can be concluded that while AI has clear advantages, human oversight remains vital for holistic evaluation that ensures fair, accurate, and ethical grading practices. This aligns with the Human-in-the-Loop (HITL) AI paradigm, which emphasizes maintaining human agency and oversight in AI-assisted systems (Tarun et al., 2025). Furthermore, from an assessment validity and reliability perspective, AI-assisted tools must ensure that marks accurately reflect student achievement against learning outcomes while maintaining consistency across submissions (Messick, 1995).

A number of techniques aim to overcome the limitations of automated grading by allowing for greater human involvement in the automated marking process (Kaya & Cicekli, 2024; Malik et al., 2019). These demonstrate the potential for automated grading with increased human involvement in the process to make grading more efficient (Farrelly & Baker, 2023) and consistent (Farrelly & Baker, 2023; Chan & Colloton, 2024).

The GradeAid (Kaya & Cicekli, 2024) framework supports automated marking of short text answers by allowing markers to train a Natural Language Processing (NLP) model with a set of sample answers. This model achieves high levels of predictive accuracy and is effective at providing students with timely and effective feedback. It is however limited in that it requires a training dataset that covers a suitable range of answers and may suffer from scalability issues if this is not adequate. Similarly, commercial tools like Gradescope and Turnitin's AI Feedback Studio offer AI-assisted grading features but often lack the interactive, real-time fine-tuning capabilities of a true human-in-the-loop system.

Generative grading (Malik et al., 2019) provides feedback on open-ended assignments in structured domains (e.g., computer programming, graphics, and short response questions) using generative descriptions of student cognition, expressed as probabilistic programs to synthesize labeled example solutions to infer feedback for real student solutions. This grading achieves a 50% improvement over previous best results. This method also relies on being pre-configured with a set of example solutions and also may suffer from scalability issues if this is not adequate.

The aim of the work presented in this paper is to investigate a more human-in-the-loop approach to AI assisted marking where the marker can provide input during critical stages of the process, providing marking feedback examples and editing generated examples as-and-when required if the generated samples fall short of expectations. This should remove scalability and associated quality issues, as the training set will be augmented as-and-when required during the marking procedure, and potential ethical issues as all marks should be vetted by the human marker. This approach addresses a research gap in current educational technology which is a lack of interactive, adaptable AI-assisted grading tools that maintain meaningful human oversight while improving scalability. Theoretically, it contributes by operationalizing HITL principles within an assessment context while considering factors that influence technology adoption, such as perceived usefulness and ease of use (Venkatesh et al., 2003).

AI-Marking Assistant

The AI-Marking Assistant (AI-MA) is an online application that assists educators in marking larger numbers of text-based assignments. The motivation of the application's design is to allow markers to benefit from the efficiency and consistency of AI marking while avoiding the disadvantages such as bias and misunderstanding that can affect the marking quality. The application also allows for human oversight to avoid biases or inaccuracies being left in the marks when they are given to students. Indeed, the system allows the marker to fine-tune the AI marking process by allowing the marker to provide the system with examples of their marking for reference.

The assignment page of the interface presents the user with a list of all the assignments or has the option to add a new assignment, or click on the name of an assignment to start marking.

Assignment Setup Interface

To start adding a new assignment, the user opens the assignment setup page, names the assignment, sets a numeric value for the maximum grade, and provides instructions for the AI. An AI instructions field defines the role of the AI marking assistant and tells it to expect a set of instructions for the student and a marking scheme. This field has a default value as follows.

You are a virtual teacher who should provide a mark and feedback according to the following instructions and marking scheme.

The student instructions field tells the AI what instructions are given to the student for the assignment, and the marking scheme field provides the marking scheme.

After specifying the instructions for the AI, the user can drag and drop a CSV or MS Excel file to upload the data. They then specify the fields to identify each student and the fields for their assignment responses. This can be a single answer or a group of answers for which a single mark and paragraph of feedback are given.

Assignment Marking Interface

The assignment marking page of the AI-MA is shown in Figure 1. This is the area of the interface where users can mark assignment submissions and generate marks feedback. On the left-hand side of the page, the marker can see the name of the assignment, the marking criteria, and their progress in the marking. They can also configure the AI by setting the temperature.

The temperature set for AI defines how creative or predictable it is. When the temperature is low, the model tends to choose the most probable token (word) based on its training data. The output is more predictable and correct but lacks variation and creativity. With a high temperature, the model introduces more randomness. It considers tokens beyond the most probable ones. The generated text becomes more diverse, but there's a higher chance of grammar mistakes or nonsensical content. In general, marking tasks would require a low AI temperature, particularly in more scientific or engineering-oriented subjects where the instructions of the assignment are well defined. Higher AI temperatures would yield more creative feedback and could possibly be useful for formative tasks where feedback is used to trigger creative or original thought rather than more formal summative assessments.

The right-hand side panel shows the assignment submissions. The user can scroll up and down on this panel and expand or collapse individual student marks as and when required. After a student's mark is submitted, it is automatically collapsed to show just the student name, ID number, and mark. The marking

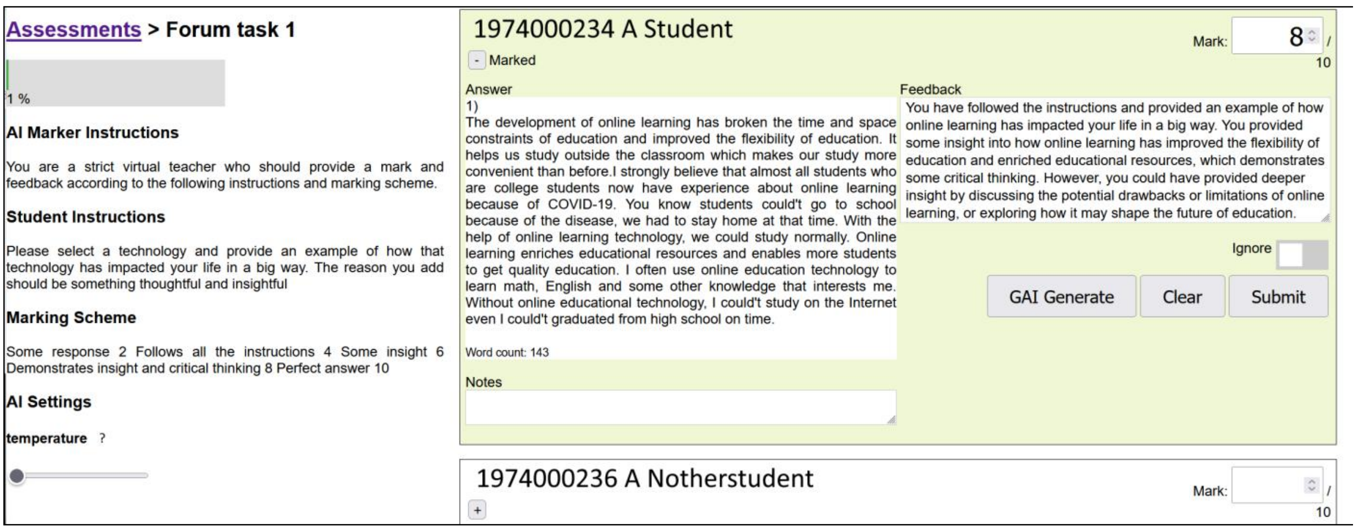


Figure 1. Assignment marking interface. The marker scrolls through student submissions of the right hand side of the screen. The Feedback and mark can be edited before being submitted to the GAI with uses it as an example for future marking.

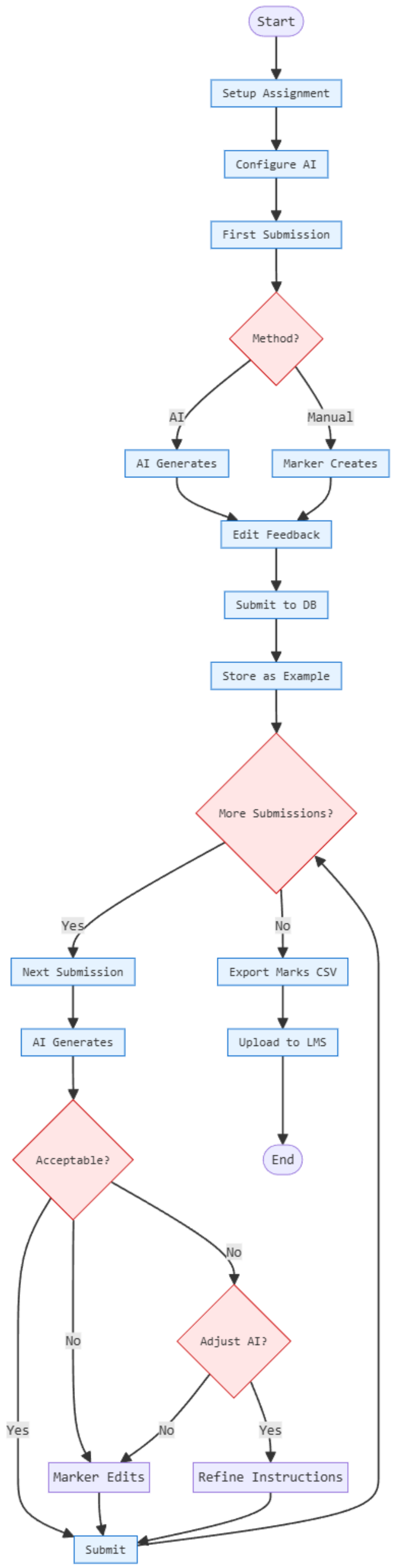


Figure 2. Workflow diagram of the AI-MA marking process

panels can be ordered either by the student's name, their ID, the mark, or the status of the marking (i.e., if a submission is marked, unmarked, or marked but not submitted).

The panels for individual student submission marks are laid out with their name and ID number at the top, the status of marking below this, the answer on the left-hand side, notes (added by the marker) below the answer, and the mark, feedback, and control buttons on the right-hand side. The notes box, feedback, and marks boxes are all editable. Clicking the ignore button indicates that the submission should be ignored. This would be the case if the student submitted their answer twice by mistake or if they have multiple chances to submit. The AI generate button uses AI to generate feedback and a mark. The clear button clears the mark and feedback. The submit button submits the mark and feedback to the database. The colour of the box will change if the marks are submitted or ignored, and a red warning will appear if feedback is typed but not submitted.

After feedback and marks are generated, they can be edited by the marker before being submitted to the database. These marks and feedback will be used, in turn, as examples to guide the AI for future marking. This allows the marker to selectively fine-tune the AI to improve its output. It also allows the marker to supervise the output of the AI and take responsibility for the marks submitted. This helps alleviate the ethical issues of automated marking, giving the human marker more input into the marking process.

Marking Workflow

The general workflow for marking student assignment submissions (see Figure 2) can be described as follows.

1. Upload the assignment submissions – The first step in marking is to specify the assignment AI instruction and upload the assignment submissions in CSV format as described in the Assignment Setup Interface above. This specifies the role of the AI, the instructions to students, and the assignment marking scheme. The data should contain one or more fields to identify each student and one or more text fields with a student's response(s) to the assignment questions or requirements.
2. Marking the first assignment submission – The next stage in marking is to proceed to the assignment marking page and begin marking with the first assignment. At this stage, it is important to understand that while the system has instructions on how to do the marking, there are still no examples of how the feedback should appear. The GAI Generate button can generate feedback, but this will not necessarily fit the marker's expectations with regard to the length of feedback, the tone of the feedback, or how much attention is paid to different marking criteria. The marker is therefore expected to edit the feedback (perhaps quite extensively) in order for it to fit

their expectations. The user will also likely need to add a mark for the first few submissions until the GAI can consistently mark according to their expectations. Once the marker is happy with the feedback and the mark, they can press submit to commit the mark to the database.

3. Marking the next assignment submissions – For the next assignments, the GAI Generate function will use submitted assignment feedback and marks as an example to generate new feedback and marks that better meet the marker's expectation. Normally these will require less editing and, as more assignments are submitted, less editing is generally required as the AI has more examples to use.
4. Refine GAI instructions (optional) – As part of the marking process, the marker can also adjust the GAI instructions. This can help adjust for the level of the AI if (if, for example, it is being too generous or strict) or account for requirements that have not been specifically stated in the AI instructions. The marker may want to tell the GAI to act as a strict marking assistant if it is too generous, or add additional criteria such as originality or insight if these are not explicitly addressed in the original marking scheme. This process can also encourage the marker to clarify points in the assignment specification or marking scheme for future assignments.
5. Export the marks – The final stage, after all the assignment submissions are marked, is to export the marks. Marks are exported in CSV format, which allows them to be uploaded into online learning platforms such as Moodle or Canvas.

System Architecture

AI-Marking Assistant's architecture is shown in Figure 3. The system is is built using PHP linked to an SQL database and the Azure Open AI API running ChatGPT 3.5. The UI makes extensive use of JavaScript for UI elements and Ajax to send and retrieve data from a server asynchronously without interfering with the display and behaviour of the existing page. The data is sent and received from ChatGPT in JSON format.

Data privacy and security measures include anonymization of student identifiers before processing through the Azure OpenAI API, encrypted data transmission, and local storage of sensitive information. The system also complies with institutional data protection policies and does not retain student submissions beyond the marking period.

Evaluation

In order to evaluate the AI-MA system, we used it for the marking of two different forum-based assignments with four different markers. These were two short forum tasks aimed at improving the student's understanding of emerging technologies, and a class test evaluating the students' knowledge of their project topic based on the contents of a report they had written. The total number of student submissions marked was 250 across two assignments, with four markers participating in the evaluation.

Before marking, each marker was given a five-minute training session to help them understand the operation of the interface. After marking, the markers participated in a structured interview where they were asked to reflect on the marking experience.

Ethical Considerations

The study was conducted in accordance with institutional ethical guidelines. Student submissions were anonymized before marking, and participants (markers) provided informed consent. The AI-MA system was deployed on a secure institutional server with access restricted to authorized markers. Student data was processed through Azure OpenAI API with appropriate data protection measures in place, including data anonymization and secure transmission protocols.

Example Assignments

Both assignments used in our evaluation were for an FHEQ level 3 (university preparation year) module introducing students to emerging technologies. The

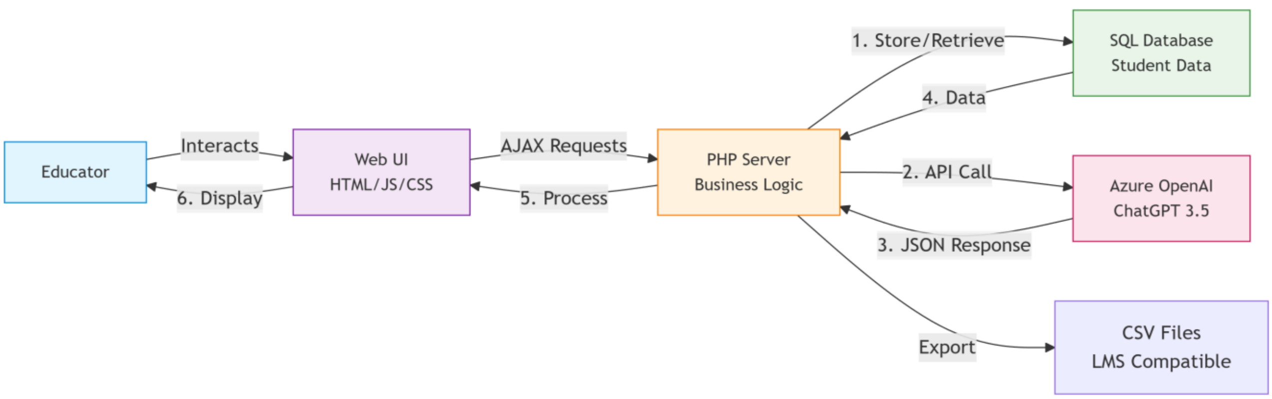


Figure 3. System architecture of AI-MA showing data flow between components

class had a total of 250 students, mostly non-native English speakers studying with English as the medium of instruction (EMI). Each assignment would contribute a small percentage (approx 5%) of the total module grade for a module with the normal credit weighting of a standard technical module.

The purpose of the first task was to introduce the topic of emerging technologies by asking them to describe a technology that had a significant impact on their life.

The instructions to students for this task are as follows.

Please select a technology and provide an example of how that technology has impacted your life in a big way. The reason you add should be something thoughtful and insightful.

The assignment marking scheme is as follows.

Some response 2, Follows all the instructions 4, Some insight 6, Demonstrates insight and critical thinking 8, Perfect answer 10.

The second marking task was also designed to help introduce the topic of emerging technologies. This time by asking them to describe an emerging technology that they expected to become the next big thing.

The instructions to students for this task are as follows.

You should identify an emerging technology you think will be big in 4 or 5 years when you graduate. Provide a single reason why you think that technology has the potential to be big. The reason you add should be something thoughtful and insightful.

The assignment marking scheme is as follows.

Some reasonable response 2, Follows all the instructions 4, Some insight 6, Demonstrates insight and critical thinking 8, Perfect answer 10.

One of the markers, the module leader, marked all submissions from each assignment. The other three markers marked a selection of twenty random submissions from each assignment. These were final year PhD students who worked as teaching assistants on the module and would also be responsible for supporting the students and answering questions for their final assignment, which would be a report outlining a proposal for a new product or service using an emerging technology. These TAs would benefit from the exercise to gauge the student's understanding of emerging technologies.

Performance

The marking performance of AI-MA is described in Table 1, with the average time taken to mark the first 10 and every subsequent 10 assignment submissions shown for AI-MA with GAI generation available and with GAI not available as a control. This shows that the performance of markers dramatically improves after the first 10 submissions marked and again significantly after the next 20 submissions marked. After this, the marker only needs a couple of seconds on average to mark each submission. This is a lot more than the normal gains in efficiency due to marker familiarity. Overall, this equates to a significant improvement in efficiency with about a 40% time saving for 60 submissions. This would likely improve to up to around 60% with larger numbers of submissions for assignments of this type.

Table 1. AI-MA Performance, Average Marking Time Per Submission (seconds) n=4 markers, measurements recorded under controlled conditions

Submissions	AI-MA	control
1-10	4.41s	4.52s
11-20	2.51s	3.87s
21-30	1.89s	3.97s
31-40	1.66s	3.66s
41-50	1.77s	3.73s
51-60	1.57s	3.64s

Statistical analysis shows a significant reduction in marking time between the first 10 submissions and subsequent batches ($p < 0.05$), with effect sizes (Cohen's d) ranging from 0.8 to 1.2 for different comparison points.

Table 2. AI-MA User Satisfaction (1 Very Negative, 3 Neutral, 5 Very Positive)

	Average Rating (1-5)	Standard Deviation
Usability	3.75	0.43
Functionality	4.75	0.43
Performance	5.0	0.0
Overall	4.5	0.17

Structured Interview

The structured interview to evaluate the application focused on the usability, functionality and performance. These questions were follows.

- Usability. Is the application easy to use? Is it east to achieve what you want to with the interface and does it operate how you would expect it to?
- Functionality. Is the functionality what you would expect from a grading assistant? Is there functionality you think is unnecessary or anything you feel needs to be added?
- Performance. What do you think of the quality of the feedback and marks suggested by the system? Does it match what you would expect from a human marker given the marking criteria supplied.

How did you have to edit the marks and feedback suggested in order to make them appropriate for the students?

- Overall. What is your overall impression of the system, would you use something like this for your marking in the future.

Each tester was scheduled a 30 minute session to answer the questions which were recorded and transcribed after the interviews were complete.

Results

The results of user satisfaction survey is shown in Table 2 with results based on analysis of 250 student submissions marked by four evaluators. Here it can be seen that users were generally very positive about the functionality and performance of the tool and less positive about the usability where they identified some minor issues. The results of our structured interviews were compiled and can be summarised as follows

Usability

The testers generally felt the usability of the application was satisfactory despite some minor issues. There was some confusion as to how to navigate to the Marking page from the Assignments page. The markers would also have preferred to be able to edit assignment AI instructions on the Assignment marking page. These could be considered as minor issues that could be easily resolved in the next iteration of development.

The import and export functions of the application had no major usability issues. This was relatively straight forward for the users and the most difficult step seemed to be exporting submissions and importing marks back into the Learning Management System used.

The usability of the marking page (where users would spend most of their time on the application) was also felt to be good and the users appreciated being able to scroll through the assignment submissions for efficient marking. Initially, the users had some difficulty knowing how to generate feedback and marks, but after they figured this out on the first submission the process became very intuitive.

Functionality

Overall the users were happy with the functionality of the system for marking short-form text based assignments. They also indicated how they would like to improve the functionality in a number of areas.

The markers would have liked to have the software include a user management system (UMS) to restrict access from other system users. As the version of the tool ran on an offline virtual server for a single module, this was not an issue. If the tool was to be made available for real life use on different modules, then a UMS would be required in order to control access and ensure student privacy.

The markers would also like to see the tool be available for different types of text based assignment including assignments with individual component marks, and assignments submitted as reports. Currently the system only supports a single mark for each submission and the length of assignment submissions is limited to around 1,200 words due to limitations of the ChatGPT API. While the first issue could be fixed by adjusting the interface to include multiple marking criteria, the second issue is a limit of the ChatGPT API and would be difficult to resolve.

Performance

The users were generally happy with the performance of the marking and thought it was to a sufficient level to justify using the tool for marking. The feedback of our markers was mostly consistent and can be summarised as follows.

- First feedback. The first time feedback generated for a particular assignment tended to be quite verbose but could be edited down to form more concise succinct feedback. After this feedback was edited and submitted it would be used as a model for future feedback.
- Subsequent feedback. After four or five examples of feedback where provided, the GAI became more reliable at providing suitable feedback. This tended to follow the same general form addressing different aspects of the marking scheme in the same order with similar language. This made the feedback easy to check to correct any issues.
- GAI Temperature. The markers kept the AI temperature low which tended to keep the GAI consistent. Raising the temperature made the text more varied but the marking less reliable.
- Tone. The tone of the feedback tended to be more positive than the testers would have preferred. In order to make it more balanced to properly account for short-comings the marking instructions needed to be edited to say 'you are a strict marking assistant'. After this there was a good balance of positive and negative as well as constructive criticism on how the answer could be improved.
- Marks. The marking was judged to be applied well and consistent with expectations. In most cases the mark matched the markers expectation. In less than 15% of cases the mark needed to be adjusted by 1 mark. In less than five percent of cases it needed to be adjusted by 2 or more marks. In these cases normally the GAI gave a mark that was too generous.
- Consistency and bias. After the initial 4 or 5 marking examples were given the marking was judged to be consistent a fair throughout the marking. Where bias was detected this could be

corrected easily be the marker. For example, after two good answers on the topic of Natural Language Processing (NLP), the GAI gave a slightly inflated mark for the next answer focusing on NLP. The marker was able to adjust the feedback and mark in a few seconds. This made the marking more reliable for subsequent answers using this topic.
- Answer length. Directions in the marking scheme related to the length of the answer would not be accounted for. For example, if a maximum word count was given or the marking scheme specified a concise answer this would be ignored.

Overall Outcome

Overall, all our test users agreed that they would be happy to use a system like the one proposed for their marking in the future. They believed that the advantages of improved efficiency and consistency would allow them to increase the amount of feedback and interaction with the students on a module to improve associated learning outcomes.

All test users agreed they would use such a system for future marking, acknowledging its potential to improve efficiency and consistency while maintaining necessary human oversight. However, they noted that further evaluation with more complex assignments and larger marker samples would strengthen these findings.

Conclusion

We have developed a web-based application for human-in-the-loop GAI assisted assessment marking and feedback and evaluated it with the assessment of two short written assignments. The interface works to help with marking and feedback for short text based answers and is evaluated to show potential to help educators to provide more consistent feedback in a more timely and efficient manner. The evaluation also demonstrates the potential to overcome limitations of fully automated marking by allowing markers to correct bias and other potential quality issues. As the marker is able to monitor and edit marks and feedback provided by the GAI and have their adjustments fed back into the GAI as marking examples, they can take responsibility for the marks and lead the GAI to be more consistant with their expectations. This corrects for GAI bias and removes the ethical problem of the GAI generating marks without supervision.

The human-in-the-loop approach implemented in AI-MA aligns with established frameworks for responsible AI in education (Medrano, 2025) as well as studies investigating human-AI partnering for other activities (Choudhury and Shamszare 2024; Lotfalian Saremi et al. 2025), balancing automation benefits with necessary human judgment. Theoretically, this work bridges HITL AI principles with assessment validity frameworks, demonstrating how AI can enhance grading consistency while preserving educator judgment. These are key factors in both assessment reliability and technology acceptance.

Our results also demonstrate some of the advantages and limitations of GAI generated feedback and marking in general. While marking with a low GAI temperature is shown to be consistent and generally reliable, it relies on precise instructions and can be overly positive. It also marks according to content without being able to judge aspects of the writing style such as conciseness. Future work will see us refine the interface and extend the functionality of the application so it can be used and evaluated with longer text based assignments. This would involve working to stretch the functionality of the ChatGPT API by chaining calls including different parts of each submission.

While the results are promising, several limitations should be acknowledged: the small sample of markers, focus on short text responses, and absence of comparison with expert human marking. Future work will extend the system's functionality for longer text-based assignments through API call chaining and explore integration with learning management systems. Additionally, research into student perceptions of AI-assisted feedback and its impact on learning outcomes will be valuable for understanding the broader implications of human-in-the-loop AI grading systems. Further theoretical exploration could examine AI-MA through the lens of comprehensive technology acceptance models (such as UTAUT) and assessment validation frameworks to strengthen its pedagogical foundations.

Acknowledgements

The research described in this paper is supported by Xi'an Jiaotong Liverpool University (XJTLU) Research Conference Fund and the XJTLU Academy of Future Education AIED research centre project AI and Learner Emotion grant number RC4AIED202401 as well as XJTLU Teaching Development Fund grant number TDF 202425S1-65 and XJTLU Academy of AI (AoA) Proof of Concept project reference number POC-25-05.

Conflict of Interest

The authors declare that there are no conflicts of interest for this paper.

References

Burrows, S., Gurevych, I., & Stein, B. (2015). The eras and trends of automatic short answer grading. International journal of artificial intelligence in education, 25(1), 60-117.

Chan, C. K. Y., & Colloton, T. (2024). Generative AI in higher education: The ChatGPT effect (p. 287). Taylor & Francis.

Choudhury, A., & Shamszare, H. (2024). The impact of performance expectancy, workload, risk, and satisfaction on trust in ChatGPT: Cross-sectional survey analysis. JMIR Human Factors, 11, e55399.

Craig, P., Roa-Seïler, N., Rosano, F. L., & Díaz, M. M. (2013, July). The role of embodied conversational agents in collaborative face to face computer supported learning games. In *Proc. 26th International Conference on System Research, Informatics & Cybernetics. Baden-Baden, Germany*.

Craig, P., Roa-Seiler, N., Diaz, M. M., & Rosano, F. L. (2014). A cognitionics approach to computer supported learning in the Mexican State of Oaxaca. *Informatica*, 38, 241.

Farrelly, Tom, and Nick Baker. "Generative artificial intelligence: Implications and considerations for higher education practice." *Education Sciences* 13.11 (2023): 1109.

Johnston, H., Wells, R. F., Shanks, E. M., Boey, T., & Parsons, B. N. (2024). Student perspectives on the use of generative artificial intelligence technologies in higher education. *International Journal for Educational Integrity*, *20*(1), 2.

Kaya, M., & Cicekli, I. (2024). A hybrid approach for automated short answer grading. *IEEE Access*, *12*, 96332-96341.

Li, M., Enkhtur, A., Yamamoto, B. A., Cheng, F., & Chen, L. (2025). Potential societal biases of ChatGPT in higher education: A scoping review. *Open Praxis*, *17*(1), 79-94.

Lotfalian Saremi, M., Ziv, I., Asan, O., & Bayrak, A. E. (2025). Trust, Workload, and Performance in Human–Artificial Intelligence Partnering: The Role of Artificial Intelligence Attributes in Solving Classification Problems. *Journal of Mechanical Design*, *147*(1), 011702.

Malik, A., Wu, M., Vasavadia, V., Song, J., Coots, M., Mitchell, J., et al. (2019). Generative grading: near human-level accuracy for automated feedback on richly structured problems. arXiv preprint arXiv:1905.09916.

Medrano, T. (2025). Co-Designing With AI: Human-Centered Approaches for. *Foundations and Frameworks for AI in Education*, 291.

Messick, S. (1995). Validity of psychological assessment: Validation of inferences from persons' responses and performances as scientific inquiry into score meaning. *American psychologist*, *50*(9), 741.

Øen, K., Krumsvik, R. J., & Skaar, Ø. O. (2024, January). Development of inclusive practice–the art of balancing emotional support and constructive feedback. In *Frontiers in Education* (Vol. 9, p. 1281334). Frontiers Media SA.

Simonsmeier, B. A., Peiffer, H., Flaig, M., & Schneider, M. (2020). Peer feedback improves students' academic self-concept in higher education. *Research in Higher Education*, *61*(6), 706-724.

Souppez, J. B. R., Goswami, D., & Yuen, J. (2023, December). Assessment and feedback in the generative ai era: transformative opportunities, novel assessment strategies and policies in higher education. In *International Federation of National Teaching Fellows Symposathon 2023*.

Tarun, B., Du, H., Kannan, D., & Gehringer, E. F. (2025). Human-in-the-loop systems for adaptive learning using generative AI. *arXiv preprint arXiv:2508.11062*.

Tetzlaff, L., Schmiedek, F., & Brod, G. (2021). Developing personalized education: A dynamic framework. *Educational Psychology Review*, 33(3), 863-882.

Tuma, F. (2022). Educational benefits of writing multiple-choice questions (MCQs) with evidence-based explanation. *Postgraduate Medical Journal*, *98*(1156), 77-78.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS quarterly*, 425-478.

Williams, A. (2024). Delivering Effective Student Feedback in Higher Education: An Evaluation of the Challenges and Best Practice. *International Journal of Research in Education and Science*, *10*(2), 473-501.

Emotional Intelligence in Engineering Problem-Solving: A Phenomenological Study Among Manufacturing Engineers

Article history
Received
12 October 2025
Received in revised form
22 November 2025
Accepted
26 November 2025
Published online
27 December 2025

Mohamad Norhakim Sahroni [a]*, Nur Izrah Mohd Puzi [b]
Nur Nabihah Zahiah [a], Mohamad Norarif Musyrif [a]
[a] Department of Science and Mathematics, Kolej Vokasional Tanjung Puteri, 80300 Johor Bahru, Johor, Malaysia
[b]Department of Science and Mathematics, SMK Permas Jaya, Bandar Baru Permas Jaya, 81750 Masai, Johor, Malaysia
**mnbshakim@gmail.com*

Abstract
Engineering graduates often enter the workforce with underdeveloped emotional intelligence (EI), leading to challenges in emotional regulation, decision-making, and social interactions that subsequently impact their employability and job performance. Despite its recognized importance for professional success, the integration of EI into engineering education remains inconsistent. This study aims to identify the essential Emotional Intelligence competencies required for successful engineering problem-solving. Using a phenomenological approach, semi-structured interviews were conducted with practicing engineers in a manufacturing setting. The findings reveal three key EI competencies frequently demonstrated by engineers, which are now formulated as empirical insights: (1) Initiative – Taking proactive steps to address issues and empirically validate assumptions; (2) Adaptability – Strategically adjusting to changes and collaborating across departments to manage uncertainty; and (3) Self-Recognition – Deep awareness of one's strengths, limitations, and the impact of one's behaviour on the team. These findings offer clear empirical insights into the critical role of Emotional Intelligence within the manufacturing engineering context, suggesting that engineering education programs should explicitly teach these skills.

Keywords: Emotional Intelligence, Engineering Problem-Solving, Initiative, Adaptability, Self-Recognition, Phenomenological Study.

Introduction

Emotional intelligence (EI) is increasingly recognized as a critical determinant of professional success in the engineering field. Its significance is evident in its strong correlation with enhanced job performance, effective stress management, rational decision-making, and the strengthening of interpersonal relationships within dynamic and challenging work environments (Talib et al., 2023; Ambotang & Hamid, 2021). Furthermore, a high level of EI among engineering professionals is a major contributor to effective collaboration, proficient communication, and adept conflict resolution within teams, while leaders with high EI can foster a positive work climate and enhance overall team performance (Ambotang & Hamid, 2021; Shofia etal., 2023). These soft skills are paramount in engineering disciplines, particularly those that require high technical precision and intensive team interaction for complex problem-solving.

The positive impact of EI begins even before engineers enter the workforce. At the academic level, a clear positive relationship exists between EI and academic achievement, where engineering students with high EI consistently demonstrate better performance in core subjects (Safa'udin, 2024; Wulandari & Pranata, 2023). EI also facilitates a smoother transition from academia to industry, building self-confidence and enhancing career decision-making abilities (Safa'udin, 2024; Wulandari & Pranata, 2023). Beyond academic and initial career success, EI plays a vital role in building psychological capital (PsyCap); such as self-confidence, optimism, hope, and resilience; which is crucial for maintaining mental well-being and overcoming challenges in the demanding engineering profession (Lye et al., 2022; Patil et al., 2023). From an employability perspective, EI serves as a key differentiator, as graduates with high EI are more proficient in the communication, teamwork, and problem-solving skills highly valued by employers (Patil et al., 2023; Lye et al., 2022). Therefore, the development of EI should be a major agenda for engineering institutions to ensure graduates are prepared to face the emotional and interpersonal demands of the workplace.

Despite its acknowledged importance, a significant problem persists: a majority of engineering graduates

Sahroni, M.N., Mohd Puzi, N.I., Zahiah, N.N, Musyrif, M.N. (2025), Emotional Intelligence in Engineering Problem-Solving: A Phenomenological Study Among Manufacturing Engineers, *ASEAN Journal of Engineering Education*, 9(2), 171-179. https://doi.org/10.11113/ajee2025.9n2.201

enter the workforce with underdeveloped EI. This deficiency manifests as difficulties in emotional regulation, low confidence in decision-making, and significant weaknesses in social interactions, which directly impair their ability to handle complex technical problems and manage critical issues within high-pressure manufacturing environments. This issue is particularly pertinent in the ASEAN region, where industry feedback frequently highlights that the Emotional Intelligence skill gap is among the biggest challenges faced by regional engineering graduates. This issue stems from an inconsistent and often marginalized integration of EI within existing engineering education curricula. Consequently, there is a critical misalignment between the recognized importance of EI and the actual teaching practices, ultimately producing graduates who are emotionally unprepared for the industry's demands.

While previous research has established the general importance of EI for engineers and the need for its integration into education, there remains a significant knowledge gap regarding the specific Emotional Intelligence competencies that are most critical for core engineering activities, particularly problem-solving within dynamic manufacturing settings. Therefore, this study aims to address this gap by investigating the lived experiences of practicing engineers. The primary objective of this research is to identify the empirical insights (empirical insights) concerning the essential emotional intelligence competencies required for successful engineering problem-solving in an industrial setting. By answering the research question - "What are the relevant emotional intelligence competencies required for success in Engineering problem-solving?" - this study seeks to provide empirical insights that can inform more targeted and effective EI interventions in engineering education.

Problem Statement

Although emotional intelligence (EI) is recognized as a critical aspect for professional success in engineering, the majority of graduates still enter the workforce with inadequate levels of EI. They often face difficulties in controlling emotions, lack confidence in making important decisions, and possess weak interpersonal skills. These problems subsequently affect their employability, job performance, and ability to adapt in dynamic and high-pressure professional environments. This issue stems from the inconsistent and incomplete integration of EI in the existing engineering education curriculum. Therefore, the main problem that needs to be addressed is the misalignment between the recognized importance of EI and its teaching practices that remain marginalized in the engineering education system, ultimately producing graduates who are emotionally unprepared to meet the actual demands of the industry.

Research Objective

This study is to identify the essential emotional intelligence skills required for success in Engineering problem-solving.

Research Questions

What are the relevant emotional intelligence competencies required for success in Engineering problem-solving?

Methodology

This study employed a qualitative, phenomenological research design to gain deep insights into the lived experiences of engineers. A purposive sampling strategy was utilized to select participants who could provide rich, relevant, and in-depth information pertinent to the research objective (Campbell et al., 2020). Specifically, a homogeneous sampling approach, a subtype of purposive sampling, was adopted to focus on individuals who shared similar key characteristics and could illuminate the specific phenomenon under study; emotional intelligence in engineering problem-solving (Creswell & Poth, 2018). This homogeneity was established by selecting participants who were all practicing engineers directly engaged in complex technical troubleshooting and daily problem-solving activities within the same manufacturing department.

The sampling frame was an electronic manufacturing company registered with the Federation of Malaysian Manufacturers (FMM) located in southern Johor. The study specifically targeted the manufacturing department, where engineers are critically engaged in daily problem-solving activities. To be eligible, participants had to be practicing engineers with direct involvement in technical troubleshooting and process improvement.

A total of six engineers were selected to participate in the study. This sample size is considered appropriate in phenomenological research, where the depth of understanding from a small number of participants is valued over breadth from a large sample (Smith et al., 2022). The participants comprised individuals of varying seniority levels and specializations within the manufacturing department, ensuring a diversity of perspectives while maintaining the homogeneity of their core professional context and experiences with problem-solving. The variation in seniority levels (e.g., Junior to Senior Engineer) was intentionally included to capture a broad range of experiences with problem-solving, yet all shared the critical and homogeneous trait of having direct, daily involvement in applying EI competencies to technical challenges in the same manufacturing context.

The nature of their work, which involves constant interaction with technical challenges, team members, and cross-functional departments, provided a fertile ground for observing and discussing the manifestation of emotional intelligence competencies in a real-world industrial setting.

Phenomenology Method and Interview Procedure

This study employs a phenomenological approach, specifically the interpretive (hermeneutic) tradition, rooted in Heidegger's philosophy. This approach was chosen as it allows the researcher to move beyond mere description, instead interpreting the contextual and nuanced meaning of engineers' lived experiences regarding EI competencies in an industrial setting. Compared to descriptive phenomenology (Husserl), the interpretive phenomenology used in this study emphasizes the co-construction of meaning and the researcher's role in interpreting those experiences within a broader context (Watson, 2024; Tavakol & Sandars, 2025; Sinfield et al., 2023). The primary goal of this method is to gain a deeper, contextual understanding of the *essence* of the engineers' lived experiences, which is crucial for generating new knowledge relevant to industry practitioners (Fréchette et al., 2020; Sinfield et al., 2023).

Phenomenological research is particularly valuable for exploring how individuals make sense of their experiences, often employing in-depth or semi-structured interviews. For this purpose, data were collected through semi-structured interviews conducted with the six selected engineers, with each interview lasting approximately 60 to 90 minutes. The interviews were guided by a protocol consisting of five core open-ended questions designed to elicit rich narratives about their experiences applying EI during challenging problem-solving situations. The methodology is inherently inductive, enabling the emergence of new knowledge that may not be anticipated by the researcher but is significant to practitioners (De Boer & Zeiler, 2024; Sinfield et al., 2023). The use of semi-structured interviews provided the necessary flexibility to encourage participants to share insights that might otherwise remain hidden, aligning with the inductive nature of qualitative research.

Given that this study uses the interpretive phenomenological approach, adherence to methodological rigour is essential to ensure the authenticity and depth of the findings. This interpretive approach, unlike the descriptive one, requires the researcher to be vigilant against personal bias through the process of reflexivity and bracketing, which is vital in capturing authentic lived experiences (Watson, 2024; Tavakol & Sandars, 2025; Sinfield et al., 2023; Jackson et al., 2018). Therefore, the choice of a method aligned with the research objectives—where the interpretive approach delves into contextual meaning—guided the entire research process to enhance the quality and trustworthiness of the results (Fréchette et al., 2020; Sinfield et al., 2023).

Figure 1 shows the flow chart for the phenomenological methodology and analysis.

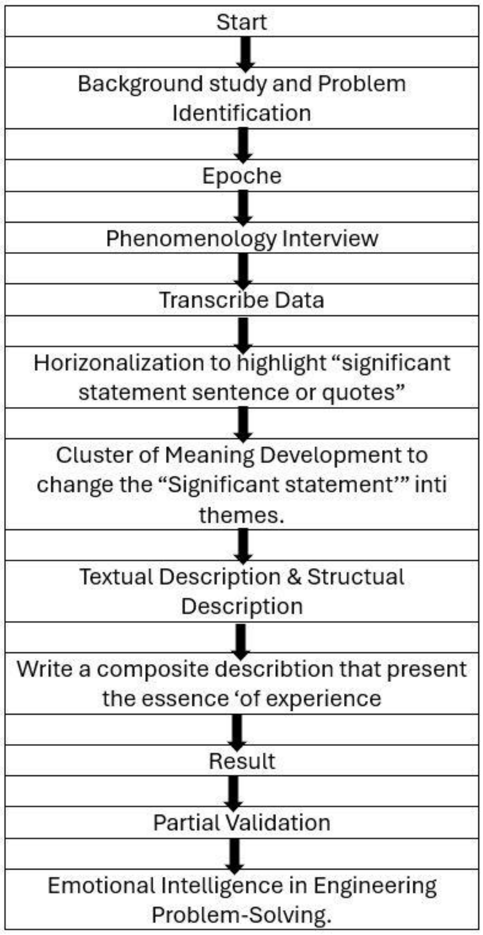


Figure 1. The Flow Chart for Phenomenological Methodology and Analysis

Data Analysis

The data analysis for this phenomenological study followed the systematic approach outlined by Moustakas (1994) to ensure a rigorous process of deriving meaning from the participants' lived experiences. The analysis involved several iterative stages aimed at distilling the essence of the engineers' experiences with emotional intelligence during problem-solving.

The initial step involved horizontalization, whereby each interview transcript was treated with equal value, and significant statements (horizons) that provided insight into the participants' experiences were identified. These statements were extracted verbatim, forming the raw data for subsequent analysis.

Following horizontalization, the significant statements were then clustered into meaning units or codes that represented specific aspects of the phenomenon. This process involved a meticulous reading and re-reading of the transcripts to identify recurring patterns and themes related to emotional intelligence competencies.

The coded meaning units were then synthesized to develop textural descriptions (what the participants experienced) and structural descriptions (how they experienced it) for each participant. This stage involved constructing individual textual-structural descriptions to capture the unique experience of each engineer.

Finally, through a process of imaginative variation and integration, a composite textual-structural description was developed. This synthesis, often referred to as the essence of the phenomenon, integrated all individual descriptions to identify the universal themes of emotional intelligence competencies that were essential for engineering problem-solving across all participants' experiences.

To ensure the trustworthiness of the analysis, several validation strategies were employed. Peer debriefing was conducted where the emerging themes were discussed with research supervisors to challenge interpretations and minimize researcher bias. Member checking was performed by sharing the preliminary findings with two participants to verify the accuracy and resonance of the interpreted data with their actual experiences.

Findings

As an engineer, the ability to solve complex problems in the industry does not rely solely on technical skills, but also requires mature emotional intelligence. As figure 2, Among the important skills to master are Initiative – taking proactive steps to address issues before they escalate; Adaptability – the ability to adjust quickly to changes in technology and market needs; and Self-Recognition – an awareness of one's own strengths and limitations to enable continuous learning and effective collaboration within a team.

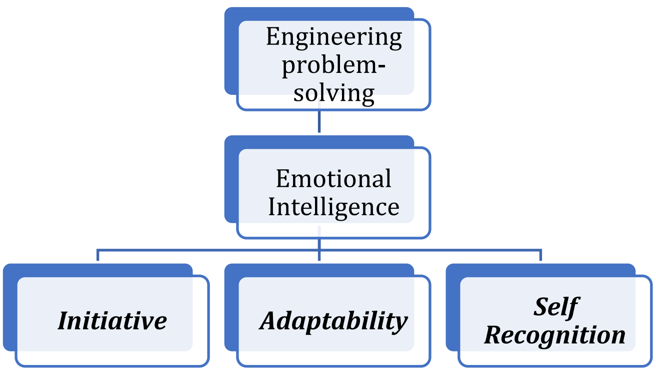


Figure 2: Findings of Emotional Intelligence

Initiative

Based on the analysis of the engineers' statements of initiative as table 1, the trait of initiative emerges as a fundamental value and critical daily practice in solving engineering problems within the industrial context. This initiative is not merely an additional action but a primary driver that enables engineers to gain deeper understanding, verify assumptions, and ultimately resolve issues more efficiently and effectively. The proactive approach demonstrated by these engineers directly translates into more robust and reliable problem-solving methodologies in industrial settings.

The detailed analysis reveals three key patterns of initiative that directly impact industrial problem-solving. First, engineers who proactively obtain primary data through physical measurements and direct observation (Engineers 1 & 2) bypass potential gaps in secondary reports, enabling empirical verification and reducing reliance on speculation. Second, the initiative shown in preliminary knowledge acquisition and planning (Engineers 3 & 4) through studying specifications, drawings, and initial calculations ensures that solutions are theoretically sound and practically feasible from the outset, preventing costly trial-and-error approaches. Third, the proactive expansion of investigation scope through comparative analysis across different models (Engineer 5) helps identify whether issues are isolated or systemic, ensuring comprehensive solutions rather than temporary fixes. Collectively, these initiative-driven approaches demonstrate how engineers in industry move beyond passive problem-solving to actively construct understanding, validate hypotheses, and develop solutions that address root causes rather than just symptoms.

Table 1. The analysis of the engineers' statements of initiative

No.	Engineer	Statement	Explanation
1	Engineer 1	**"I took the actual PCB part to analyse and take my own measurements..."**	This engineer did not wait for instructions. They proactively **took the physical component themselves** to analyze and take measurements. The actions of "taking" and "checking" show a high level of initiative.
2	Engineer 2	**"I took the actual PCB part to analyse and take my own measurements..."**	Similar to Engineer 1, this engineer shows initiative through proactive physical actions to investigate the problem hands-on.
3	Engineer 3	**"I was read the spec and take a calculator to make the initial calculation ..."**	This engineer did not just read the specifications passively. They took the next step by **immediately making their own initial**

			calculations before the actual analysis. This is a proactive action based on personal understanding.
4	Engineer 4	**"After I read the drawing, I'll confirm the same machine before, next I'll design the jig used...."**	This engineer systematically plans follow-up actions. The transition from reading the drawing to confirming the machine and then **planning to design their own tool (jig)** shows clear planning and initiative.
5	Engineer 5	**"Next, I take initiative to mail; I have another sample from different models to be measured...."**	This is the clearest example. This engineer literally uses the phrase **"I take initiative"**. They were not satisfied with the existing samples and proactively sought samples from other models for a more thorough comparison.

Adaptability

Based on the analysis of engineers' statements of Adaptability in interviews nas table 2, it can be concluded that adaptability is a crucial soft skill widely practiced in the engineering profession. In this context, adaptability is not merely about flexibility, but encompasses a proactive, strategic, and data-driven approach to handling uncertainty and solving complex problems. Overall, the excerpts show that adaptability is demonstrated through collective actions to obtain information. As mentioned by Engineers 1 and 2, they did not hesitate to organize meetings and interact with various departments such as Quality Control (QC), Production, and Warehouse. This action proves that an adaptable engineer understands the limits of their own knowledge and is willing to cross departmental silos to gather diverse data and build a stronger understanding of a problem. This aligns with the demands of modern engineering work, which requires close collaboration.

Furthermore, adaptability is also evident in a solution-oriented attitude and thorough investigation. Engineer 4, for example, emphasized the need to "research the design properly" to ensure the process has no defects. This shows that adaptability is not a rushed, reactive action, but a disciplined process of adjustment driven by curiosity to achieve optimal results. Similarly, Engineer 5 who went to the warehouse to check every stock to resolve a PCB issue demonstrates the ability to adapt investigation methods based on situational needs. Finally, adaptability is also closely related to pragmatic and data-driven planning. As stated by Engineer 6, to organize assembly stations, he first needed to know the standard time of each station. This shows that effective adaptation is not based solely on instinct but is preceded by a deep understanding of existing data and constraints, thereby enabling difficult decisions to be made with confidence.

Table 2. The analysis of the engineers' statements of Adaptability

No.	Engineer	Statement	Explanation
1	Engineer 1	**"...issuing an email to call a meeting to some departments ... for discussion regarding problems and data collection..."**	**Proactive Collaboration:** Not working in isolation. Immediately adapting their approach by involving various stakeholders to gain different information and perspectives.
2	Engineer 2	**"...I have to meet other departments to ask for different parts and the same part of the series..."**	**Seeking Comprehensive data :** Understands that the available data is insufficient. Adapting their strategy by seeking more diverse and specific data to strengthen the analysis.
3	Engineer 3	**"I need to set up the settings on the machine before the start date..."** *(Cont ext: To prevent problems)*	**Preparation and Technical Adjustment:** Adap ting machine parameters based on specific production requirements, demonstrating flexibility in handling equipment.
4	Engineer 4	**"...I need to research the design properly so that this process has no defects..."**	**Research and Improvement:** Not accepting the existing design. Willing to adapt and research the design to solve a potential defect problem before it occurs (proactive action).

5	Engineer 5	**"...I need to know every stock in the storage warehouse, so that I can take a sample for testing..."**	**Action-Oriented Investigation:** Facing an unclear problem (affected PCB) by adapting their method: going to the field, checking stock, and taking samples for testing based on their own assessment.
6	Engineer 6	**"...I had to first know the standard time of each station."**	**Data-Driven Planning:** Before making a physical adaptation (reorganizing stations), they adapted their plan by first obtaining critical data to ensure the decision would be effective.

Self-Recognition

Based on the analysis of the statements expressed by the engineers as table 3, it can be concluded that **Self-Recognition** is a critical element in the technical problem-solving process. This ability is reflected through several dimensions of internal awareness possessed by these engineers.

First, there is an awareness of **personal experience and knowledge**, as shown by Engineer 2. By actively reflecting on relevant past experiences, he demonstrates an understanding that the knowledge he has acquired is a valuable asset and the starting point for analyzing a new problem.

Second, there is an awareness of **one's own skill level and competence**. Engineer 5, for example, realizes that a task feels "simple" for him because the required data is complete. This statement not only shows confidence in his abilities but also a clear understanding of the external conditions that allow his skills to be applied effectively.

Third, the aspect of **metacognition** or awareness of one's own thought process is also clearly visible. Engineer 3 openly admits that he needs time to understand and visualize the problem after receiving data. This admission shows an introspective ability to recognize the speed and manner of his own information processing, which is a form of cognitive maturity.

Fourth, Self-Recognition is also reflected in the ability to **identify the limits of one's own knowledge**. Engineer 6 realizes that collaboration with other departments is an effective strategy to compensate for his shortcomings in certain areas. This awareness encourages a humble and open attitude to seek knowledge sources outside oneself, which ultimately enriches the solution.

In contrast, Engineer 4's statement focuses more on external obstacles ("lack of data") than self-evaluation. This contrast further underscores that authentic Self-Recognition occurs when an engineer is able to separate challenges originating from within themselves (such as knowledge, experience, and cognitive process) from challenges originating from their external environment.

Overall, Self-Recognition is not merely self-confidence, but a deep and honest understanding of one's own strengths, weaknesses, learning style, and limitations. This ability is the foundation for a more focused, adaptive, and effective problem-solving approach in the field of engineering.

Table 3: The analysis of the engineers' statements of Self Recognition.

No.	Engineer	Statement	Explanation
1	Engineer 2	"... Apart from that, I also try to recall previous issues of whether I have ever experienced the same problem or same condition or a new problem especially specification and reject quantity. It can help to analyse this problem."	This engineer is actively **reflecting on their own past experiences** as a first step in problem-solving. This shows an awareness of the value of their personal knowledge.
2	Engineer 3	"After I received the information or data. It took me a while to understand and imagine the problem........"	This statement shows an awareness of their **own cognitive process and limitations in understanding**. They acknowledge needing time to process information, which is a form of metacognition (thinking about their own thinking).
3	Engineer 4	"... after the meeting on the issue by the production department. I feel that this problem is	This is more of an **assessment of the external situation (lack of data)** than self-reflection. They are

		difficult to solve due to lack of data, it has to do additional testing and get a lot of data......"	identifying an external obstacle, rather than evaluating their own abilities, knowledge, or approach.
4	Engineer 5	".....Setting up this datasheet is simple for me because all the required data is already provided. I just need to perform an initial confirmation and test ten units of PCB to ensure that the specifications are correct…."	They demonstrate **a wareness of their own skill level** ("simple for me") and understand the conditions that make the task easy (complete data). This shows they can assess their own capabilities within a given context.
5	Engineer 6	"... discussions with other departments can help me to make calculations and set the rules more effectively...."	This engineer recognizes the **limitations of their own knowledge** and identifies a strategy (collaboration) to compensate for it. This shows self-awareness about the need for external input.

Discussion

Initiative

In an industrial context, initiative is a fundamental value and critical daily practice in solving engineering problems. This trait of initiative is not merely an additional action, but a primary driver that enables engineers to understand issues more deeply, validate assumptions, and ultimately solve problems more efficiently and effectively. Studies show that proactive behaviour and personal initiative of workers, including engineers, are crucial in generating, championing, and implementing innovations even when facing complex challenges and resource constraints (Weigt-Rohrbeck & Linneberg, 2019; Segarra-Ciprés et al., 2019; Björklund et al., 2022). Initiatives such as obtaining primary data through direct observation, early planning based on technical knowledge, and comparative analysis between models allow engineers to validate information empirically, avoid speculation, and ensure comprehensive solutions (Weigt-Rohrbeck & Linneberg, 2019; Ueki & Martínez, 2019; Omar et al., 2019). Furthermore, initiative is also closely linked to problem-solving skills, where proactive engineers are more likely to share knowledge, enhance innovation performance, and contribute to process improvements within the organization (Ueki & Martínez, 2019; Abbas et al., 2018). Overall, this initiative-based approach enables engineers to move beyond reactive solutions, build a robust understanding, validate hypotheses, and develop solutions that address the root causes of industrial problems (Weigt-Rohrbeck & Linneberg, 2019; Ueki & Martínez, 2019; Omar et al., 2019; Segarra-Ciprés et al., 2019; Björklund et al., 2022; Abbas et al., 2018).

Adaptability

Adaptability is an extremely important soft skill in the engineering profession, especially in facing evolving job roles, industry demands, and technological challenges. Adaptability in engineering is not just flexibility, but involves a proactive, strategic, and data-driven approach to handling uncertainty and solving complex problems. Studies show that adaptable engineers tend to collaborate across departments, gather information from various sources, and adjust investigation methods according to situational needs, aligning with the cooperation requirements in the modern engineering world (Brunhaver et al., 2024; Omar et al., 2023; Poláková et al., 2023). Adaptability is also associated with a disciplined problem-solving attitude and the ability to make decisions based on a deep understanding of existing data and constraints (Ishmael et al., 2025; Poláková et al., 2023; Sanz-Angulo et al., 2025). Additionally, studies find that adaptability contributes significantly to the employability of engineering graduates, career success, and the ability to work in dynamic and multidisciplinary environments (Brunhaver et al., 2024; Omar et al., 2023; Poláková et al., 2023). Therefore, the development of adaptability needs to be emphasized in engineering education through specific training, collaborative learning, and exposure to real-world situations to ensure future engineers are capable of adapting to the constantly changing industrial challenges (Brunhaver et al., 2024; Caeiro-Rodríguez et al., 2021; Sanz-Angulo et al., 2025).

Self-Recognition

Self-Recognition or self-awareness is an important element in the technical problem-solving process, as it involves an individual's ability to honestly assess their own experiences, skills, and knowledge limits. In the context of technical skills assessment, a systematic review shows that objective performance assessment; such as that conducted through machine learning; can help individuals identify their skill levels and areas needing improvement, thereby enhancing self-awareness of their strengths and weaknesses (Lam et al., 2022). Furthermore, the aspect of metacognition, which is the ability to understand and monitor one's own thought processes, is recognized as an important factor in the assessment and improvement of technical skills (Lam et al., 2022). Studies also emphasize that identifying knowledge limits and the need for collaboration are effective strategies for overcoming individual shortcomings, aligning with the concept of Self-Recognition which demands honesty in self-assessment (Lam et al., 2022). Therefore, Self-Recognition is not merely self-confidence, but involves deep reflection on experiences, skills, learning styles, and limitations, which forms the basis for a more focused, adaptive, and effective problem-solving approach in the field of engineering (Lam et al., 2022**).**

Conclusion

This study successfully identified three core emotional intelligence competencies essential in industrial engineering problem-solving: Initiative, Adaptability, and Self-Recognition. Initiative serves as the primary driver for proactive action, enabling engineers to validate assumptions empirically and implement innovations. Adaptability allows engineers to strategically adjust approaches, collaborate across departmental silos, and handle uncertainty in dynamic industrial environments. Meanwhile, Self-Recognition functions as the foundation for metacognition, enabling honest assessment of one's strengths, weaknesses, and cognitive processes, subsequently guiding self-improvement and effective collaboration.

The combination of these three attributes enables engineers to transcend reactive problem-solving, build deep understanding of issues, and subsequently develop holistic solutions capable of addressing root causes of problems within constantly evolving industrial environments.

The study's findings provide practical implications for engineering education. To bridge the gap between EI's importance and current pedagogical practices, targeted EI training needs to be integrated into curricula through: designing problem-based learning modules that foster Initiative; collaborative projects simulating real-world dynamics to develop Adaptability; and reflective exercises such as structured journals that promote Self-Recognition among students.

While providing deep insights, this study has limitations in terms of small sample size and specific industrial context that may limit the generalizability of findings. Future research is recommended to involve larger and more diverse samples across engineering disciplines, use mixed-methods approaches to quantify the impact of identified competencies, and conduct longitudinal studies to track the development of EI competencies from university to career stage.

In conclusion, this study provides a fundamental framework of essential EI competencies for engineering problem-solving, while offering clear guidance to educators and institutions for producing graduates who are not only technically proficient but also emotionally and socially intelligent.

Acknowledgement

The authors would like to thank Federation of Malaysian Manufacturers (FMM) and Universiti Teknologi Malaysia for making this research possible.

Conflict of Interest

The authors declare no conflict of interest.

References

Abbas, M., Sajid, S., & Mumtaz, S. (2018). Personal and contextual antecedents of knowledge sharing and innovative performance among engineers. Engineering Management Journal, 30(3), 154–164. https://doi.org/10.1080/10429247.2018.1451681

Ambotang, A., & Hamid, R. (2021). Pengaruh kepimpinan instruksional, kecerdasan emosi dan personaliti guru besar terhadap prestasi kerja guru sekolah rendah di Sabah. Sains Insani, 6(1), 35–44. https://doi.org/10.33102/sainsinsani.vol6no1.236

Björklund, T., Gilmartin, S., & Sheppard, S. (2022). The dynamics of innovation efforts in the early career. Creativity and Innovation Management, 31(4), 632–647. https://doi.org/10.1111/caim.12534

Brunhaver, S., Sajadi, S., & Makarov, T. (2024). More than just nice to have: Engineering managers' perceptions about the role of adaptability in hiring and promotion decisions. 2022 ASEE Annual Conference & Exposition Proceedings. https://doi.org/10.18260/1-2--42099

Bush, E., Singh, R., & Kooienga, S. (2019). Lived experiences of a community: Merging interpretive phenomenology and community-based participatory research. International Journal of Qualitative Methods, 18, 1–11. https://doi.org/10.1177/1609406919875891

Caeiro-Rodríguez, M., Manso-Vázquez, M., Mikic-Fonte, F. A., Llamas-Nistal, M., Fernández-Iglesias, M. J., Tsalapatas, H., Heidmann, O., de Carvalho, C. V., Jesmin, T., Terasmaa, J., & Sørensen, L. T. (2021). Teaching soft skills in engineering education: An European perspective. IEEE Access, 9, 29222–29242. https://doi.org/10.1109/ACCESS.2021.3059516

Creswell, J. W., & Guetterman, T. C. (2019). Educational research: Planning, conducting, and evaluating quantitative and qualitative research (6th ed.). Pearson.

Fréchette, J., Bitzas, V., Aubry, M., Kilpatrick, K., & Lavoie-Tremblay, M. (2020). Capturing lived experience: Methodological considerations for interpretive phenomenological inquiry. International Journal of Qualitative Methods, 19, 1–16. https://doi.org/10.1177/1609406920907254

Ishmael, O., Kiely, E., & Healy, J. (2025). Soft skills as predictors of success in software engineering through analysis of confidence, adaptability and time management. Proceedings of the 6th European Conference on Software Engineering Education, 1–8. https://doi.org/10.1145/3723010.3723025

Lam, K., Chen, J., Wang, Z., Iqbal, F. M., Darzi, A., Lo, B., Purkayastha, S., & Kinross, J. M. (2022). Machine learning for technical skill assessment in surgery: A systematic review. NPJ Digital Medicine, 5(1), 1–14. https://doi.org/10.1038/s41746-022-00566-0

Lye, A. L., Liew, P. S., Fadzil, H. M., & Foong, C. C. (2022). Effect of emotional intelligence and demographic characteristics on psychological capital among chemical engineering students. Journal of Chemical Education, 99(8), 2839–2847. https://doi.org/10.1021/acs.jchemed.2c00105

Matua, G. A., & Van Der Wal, D. M. (2015). Differentiating between descriptive and interpretive phenomenological research approaches. Nurse Researcher, 22(6), 22–27. https://doi.org/10.7748/nr.22.6.22.e1344

Omar, M., Romli, A., Azeem, N., & Zakaria, A. (2023). Relationship between career adaptability and employability skills: Towards engineering graduates career development. International Journal of Academic Research in Business and Social Sciences, 13(12), 2584–2602. https://doi.org/10.6007/IJARBSS/v13-i12/20351

Omar, N., Mohamad, M. M., Mukhtar, M. I., & Paimin, A. N. (2019). Influence of cognitive, affective, and conative elements in promoting engineering problem solving skills. Journal of Technical Education and Training, 11(2), 30–37. https://doi.org/10.30880/jtet.2019.11.02.003

Patil, S., Patil, A., & Patil, A. (2023). Effectiveness of emotional intelligence among postgraduate management and engineering students. Journal of Engineering Education Transformations, 37(1), 1–8. https://doi.org/10.16920/jeet/2023/v37i1/23143

Poláková, M., Suleimanová, J. H., Madzík, P., Copuš, L., Molnárová, I., & Polednová, J. (2023). Soft skills and their importance in the labour market under the conditions of Industry 5.0. Heliyon, 9(8), e18670. https://doi.org/10.1016/j.heliyon.2023.e18670

Safa'udin, M. (2024). Pengaruh kecerdasan emosional (KE) terhadap prestasi belajar matematika dengan gaya belajar (GB) sebagai variabel moderasi. Dharma Pendidikan, 20(1), 1–15. https://doi.org/10.69866/dp.v20i1.521

Sanz-Angulo, P., Galindo-Melero, J., De-Diego-Poncela, S., & Martín, Ó. (2025). Promoting soft skills in higher engineering education: Assessment of the impact of a teaching methodology based on flipped learning, cooperative work and gamification. Education and Information Technologies. Advance online publication. https://doi.org/10.1007/s10639-025-13322-0

Segarra-Ciprés, M., Escrig-Tena, A., & García-Juan, B. (2019). Employees' proactive behavior and innovation performance: Examining the moderating role of informal and formal controls. European Journal of Innovation Management, 25(1), 191–213. https://doi.org/10.1108/EJIM-02-2019-0041

Shofia, A., Subando, J., & Effendi, A. (2023). Peran guru pendidikan agama Islam dalam peningkatan kecerdasan emosional dan spiritual pada siswa di sekolah menengah atas Majlis Tafsir Al-Quran Surakarta tahun ajaran 2022/2023. *Rayah Al-Islam, 7*(3), 1045–1062. https://doi.org/10.37274/rais.v7i3.797

Sinfield, G., Goldspink, S., & Wilson, C. (2023). Waiting in the wings: The enactment of a descriptive phenomenology study. International Journal of Qualitative Methods, 22, 1–11. https://doi.org/10.1177/16094069231207012

Talib, J., Mokhtar, F., Raji, N., & Nordin, F. (2023). Jenis gaya asuhan ibu bapa, kecerdasan emosi dan hubungannya dengan tingkah laku remaja delinkuen. Universiti Malaysia Terengganu Journal of Undergraduate Research, 5(2), 1–16. https://doi.org/10.46754/umtjur.v5i2.383

Tavakol, M., & Sandars, J. (2025). Twelve tips for using phenomenology as a qualitative research approach in health professions education. Medical Teacher, 1–6. https://doi.org/10.1080/0142159X.2025.2478871

Ueki, Y., & Martínez, J. M. (2019). The impact of engineers' skills and problem-solving abilities on process innovation. *Economic Research-Ekonomska Istraživanja, 33*(1), 2018–2037. https://doi.org/10.1080/1331677X.2019.1596826

Watson, A. (2024). A postmodernist qualitative research approach: Choosing between descriptive and interpretive phenomenology. Journal of Advanced Nursing. Advance online publication. https://doi.org/10.1111/jan.16730

Weigt-Rohrbeck, J., & Linneberg, M. S. (2019). Democratizing innovation processes: Personal initiative in bottom-up eco-innovation. European Journal of Innovation Management, 24(2), 481–500. https://doi.org/10.1108/EJIM-12-2018-0278

Wulandari, W., & Pranata, O. (2023). Analisis kecerdasan emosional siswa dalam pembelajaran sains. DIKSAINS: Jurnal Ilmiah Pendidikan Sains, 3(2), 124–133. https://doi.org/10.33369/diksains.3.2.124-133

Zaheer, M., & Asad, S. (2024). Emotional intelligence and academic achievement among college students of pre-medical and pre-engineering. Human Nature Journal of Social Sciences, 5(1), 1–12. https://doi.org/10.71016/hnjss/bwkgyf19

ABET and Global Quality in Engineering Education

Article history
Received
20 October 2025
Received in revised form
24 November 2025
Accepted
25 November 2025
Published online
27 December 2025

Urbano Luna-Maldonado, Héctor Flores-Brecedaa, Alejandro Isabel-Luna Maldonado*

Autonomous University of Nuevo León, Faculty of Agronomy, Francisco Villa S / N, C.P. 66050 Col. Ex-Hacienda El Canadá, General Escobedo, Nuevo León, México

**alejandro.lunaml@uanl.edu.mx*

Abstract

A strong commitment to educational quality and continuous improvement is essential in the development of any engineering program seeking international recognition. Through a comprehensive process of self-assessment, documentation, and external evaluation, such programs demonstrate compliance with global standards of engineering education. International accreditation validates the academic, curricular, and formative strength of a program, ensuring that graduates are well-equipped to address complex challenges in a globalized professional environment. The integration of best teaching practices, industry collaboration, and an outcome-based educational model are critical to achieving and sustaining excellence. This achievement reflects the institution's dedication to delivering a comprehensive, relevant, and globally aligned education that meets both current market needs and international expectations in higher education. This study addresses this challenge by documenting and analyzing the specific institutional experience of one engineering program during its latest ABET accreditation cycle. The work details the chronology of the procedures and efforts required, including the development and documentation of compliance with the eight ABET criteria, the preparation of the self-study report, and the external evaluation. The findings provide a practical methodological blueprint for other institutions and emphasize the critical necessity of integrating an Outcomes-Based Education model and sustained continuous improvement practices to achieve and maintain global quality.

Keywords: ABET, Global engineering education, International accreditation.

Introduction

Engineering educational programs have increasingly focused on continuous improvement (CI) and academic excellence since their inception (Lantada, 2020). Over the years, many programs have developed strong academic foundations and earned national and international recognition for training competent professionals in their respective fields (Christensen et al., 2015; Sheppard et al, 2008). Effective engineering education requires a pedagogical framework that extends beyond the transmission of technical knowledge to actively support student engagement, deep conceptual understanding, and the development of essential professional competencies (Felder & Silverman, 1988; Verma, 2007; Wankat & Oreovicz, 2015). Commitment to quality education is often formally recognized through accreditation by national and international boards (Gaston, 2023; Lagrosen, 2017). For example, some programs are accredited by national organizations specific to their sector, while many seek international accreditation through ABET, a U.S.-based, non-governmental organization and the global standard-setter that provides programmatic accreditation for post-secondary degree programs in applied and natural science, computing, engineering, and engineering technology (Le, 2025; ABET, 2024; Lattuca & Stark, 2009). The ABET accreditation process involves rigorous evaluations typically conducted every six years, which ensure that programs meet global standards of educational quality and relevance (Downey et al., 2006; Chen et al., 2023; Mills & Treagust, 2003; Zarate-García et al., 2020). Programs that successfully undergo multiple accreditation cycles demonstrate sustained commitment to CI and alignment with international standards (CHEA, 2010; Harvey & Newton, 2017; Prince & Felder, 2006). It is important to note that while academic accreditation in the United States is generally voluntary, professional licensure and employment in engineering often require a degree from an ABET-accredited program (Henderson, 2022; Barret et al., 2020; Medina & Valdez, 2011). Furthermore, ABET accreditation is becoming increasingly important for fostering global competence and supporting the professional mobility of graduates (Graham, 2018), given ABET's extensive presence in over 42 countries.

While substantial literature addresses the criteria and impact of ABET accreditation within the U.S., there

Luna-Maldonado, U., Flores-Brecedaa, H., Luna Maldonado, I.L. (2025), ABET and Global Quality in Engineering Education, *ASEAN Journal of Engineering Education*, 9(2), 180-187. https://doi.org/10.11113/ajee2025.9n2.202

is a significant scholarly void regarding accessible, documented methodological models that detail the specific, chronological institutional actions required for successful accreditation and the subsequent cultural shift to a sustained CI system, particularly within Latin American engineering education programs. This study addresses this gap by presenting the ABET accreditation process applied to a specific engineering educational program, highlighting the institutional efforts and procedures required to meet international standards. The work's significance lies in providing a practical, documented model, a Scholarly Experience Sharing Paper, that validates academic quality against global standards. Specifically, it details the actions and extensive documentation undertaken during the latest evaluation cycle, covering compliance with all keys ABET criteria (students, outcomes, CI, curriculum, faculty, etc.). This detailed approach reinforces the effective integration of an outcome-based educational (OBE) model and sustained CI practices, offering valuable, actionable insights for the engineering education community.

Program Standards and Accreditation Methodology

Program Requirements

The specific program requirements within the general field of engineering are as follows: Criterion 1, Students; Criterion 2, Program educational objectives; Criterion 3, Student Outcomes; Criterion 4, Continuous Improvement; Criterion 5, Curriculum; Criterion 6, Faculty; Criterion 7, Facilities; and Criterion 8, Institutional Support.

Student Outcomes (SOs)

Every successful engineering program must demonstrate that its graduates are prepared for professional practice by achieving seven core competencies. Graduates must be able to identify, formulate, and solve complex problems by applying principles of engineering, science, and mathematics, and utilize engineering design to develop solutions that meet specific needs while thoughtfully considering crucial factors like public safety, social impact, and economic feasibility. Furthermore, they must possess the professional skills to communicate effectively with diverse audiences and function successfully on multidisciplinary teams by providing collaborative leadership. Crucially, successful engineers must also recognize ethical and professional responsibilities, make informed decisions regarding the global and societal impact of their work, and possess the ability to conduct experiments, analyze data, and acquire new knowledge as required for lifelong professional growth.

The general requirements are based on the recognition that a semester credit hour normally represents approximately one class hour per week for a semester or three laboratory hours per week for a semester. The engineering program curriculum must include a minimum of 30 semester credit hours (or equivalent) of college-level mathematics and basic sciences, with appropriate experimental experience, and a minimum of 45 semester credit hours (or equivalent) of engineering topics. Although ABET does not prescribe detailed lists of courses for every discipline, the program must demonstrate that students attain depth in mathematics (through differential and integral calculus, and where appropriate differential equations, linear algebra, numerical analysis, probability and statistics), and that the sciences include appropriate calculus based physics and/or chemistry sequences with experimental work. The general education component must complement the technical curriculum and be consistent with the program educational objectives and the institutional mission; it may include humanities, social sciences, and foreign languages beyond native language, as well as relevant non-traditional topics such as professional ethics, social responsibility or cultural values. Courses focused solely on routine physical training, military drill or similar activities without academic depth do not count. Optional courses in accounting, industrial management, finance, personnel administration, or engineering economics may satisfy general education requirements only if they support the program objectives and are designated as electives.

Engineering design

A rigorous engineering design experience must be a holistic process that develops student creativity using open-ended problems and modern design theory and methodology. This experience must guide students through the professional stages of design, including formulation of problem statements and specifications, consideration of alternative solutions, establishing feasibility, understanding production processes, and employing concurrent engineering design to achieve a detailed system description. Furthermore, it is essential for students to design within a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, ethics, and social impact.

Engineering Design and Laboratory Experience

Engineering design cannot be confined to a single course; it must be an integrated experience that evolves with the student's academic development. This culminates in a significant design experience; typically a project, course, or thesis; near the completion of the program. This capstone must focus the student’s attention on professional practice, be meaningful within their major, and build substantially on prior coursework. Furthermore, courses focused solely on drafting or similar fundamental skills are insufficient to satisfy this comprehensive engineering design requirement.

An engineering program must include comprehensive laboratory experience as an essential means of integrating theoretical knowledge with practical application. This experience should culminate in students developing and conducting their own experiments, a core function of practicing engineers, with a strong emphasis on safety procedures throughout the program's upper levels.

In addition to the technical labs, basic science coursework must incorporate a laboratory component. All students must also demonstrate the ability to apply probability and statistics effectively to engineering problem-solving.

Proficiency in written English is essential for professional engineering practice in the United States. While dedicated composition courses establish a necessary foundation, the effective development and demonstration of these skills must be integrated across the curriculum. Students must demonstrate their communication abilities through assignments and projects within both technical engineering and general education courses.

ABET defines an engineering program as an organized educational experience composed of a cohesive, sequenced set of courses designed to provide reasonable depth in upper-level coursework. This structure must feature a clearly defined engineering core where depth is primarily achieved. Ultimately, the program must effectively cultivate the student's ability to apply relevant knowledge to the practice of engineering.

Accreditation Process

The ABET accreditation process (Figure 1) begins with the submission of the Request for Evaluation (RFE), which initiates the formal review of the engineering program. This application, typically due by January 31, must include required supporting documentation, such as the program's official transcript detailing all courses, credit hours, and academic structure. Upon receipt of the RFE, ABET assembles a review team, which is led by a Team Chair (TC) and includes at least one Program Evaluator (PEV) with specialized expertise in the discipline being reviewed.

The evaluation visit will typically be conducted over a three-day period, from Sunday to Tuesday, usually scheduled between late October and early November. During this period, the team will review several documents, including the institution's detailed Self-Study Report. They will also hold meetings with administrators, faculty, students, and support staff to verify compliance with accreditation criteria and gather direct evidence of educational quality (Figure 2).

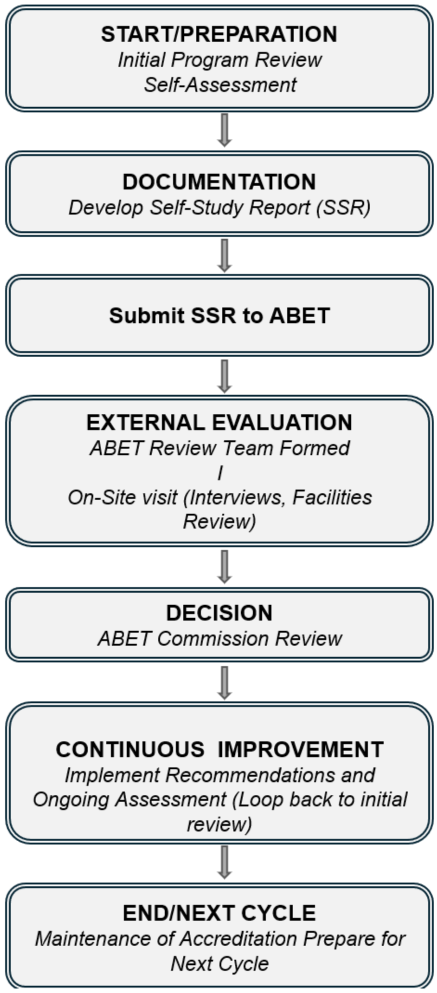


Figure 1. ABET accreditation process.

Figure 2. ABET evaluator and Autonomous University of Nuevo Leon faculty members during the laboratory visit as part of the accreditation review process. ***Source: Author's own work***

The Team Chair (TC) and Program Evaluator (PEV) will assess the academic and professional qualifications of the faculty, as well as the adequacy of laboratories, equipment, facilities, library resources, and other supporting infrastructure. They will also review student work, including exams, lab reports, design projects, and students, built prototypes, to evaluate learning outcomes. Interviews with students will provide additional insight into the educational experience and the effectiveness of the curriculum. Furthermore, the review team conducts a comprehensive qualitative and quantitative analysis of the curriculum for compliance with ABET criteria.

This analysis covers the balance of coursework across core technical domains, mathematics, basic sciences, engineering sciences, and engineering design, and ensures adequate coverage of general education, particularly the humanities and social sciences. Based on their findings, the TC will prepare a Preliminary Statement summarizing the evaluation results. Finally, they will hold a debriefing session with the university authorities (Figure 3). The relevant ABET Commission, such as the Engineering Accreditation Commission (EAC) will review and edit the preliminary report, then send it to the institution for due process.

This procedure will allow the institution to correct any factual inaccuracies or respond to observations. The institution's response will be assessed by the evaluation team to determine whether revisions are warranted. Finally, the preliminary report, institutional response, and related materials will be submitted to the commission for final review and accreditation action. The official accreditation decision is typically announced in mid-July of the year following the evaluation visit, after the EAC convenes to review all reports and related documentation. This meeting finalizes the accreditation status based on the evaluation team's findings, the institution's responses, and other pertinent materials.

Figure 3. Overview of the ABET accreditation debriefing, including evaluator feedback, identified strengths, and suggested actions for program enhancement in University of Magdalena. ***Source: Author's own work.***

If no shortcomings are identified during the evaluation, accreditation will be granted to the program. The Final Statement will be sent to the university's rector, and the accreditation status will be published on the ABET website (Figure 4).

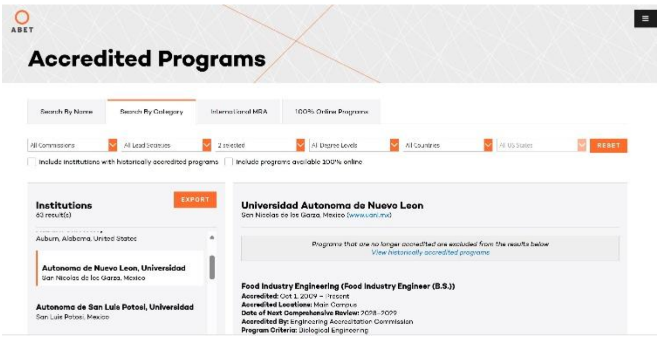


Figure 4. ABET webpage displays the international accreditation status of the educational programs. ***Source: From Accredited Programs, by ABET, 2025.***

The ABET accreditation process, rather than being a mere compliance exercise, functions as a powerful conceptual model for driving educational transformation within engineering programs. It is theoretically grounded in Quality Assurance in Higher Education principles and driven by CI Theory. This framework posits that adherence to ABET Criteria and Standards (Input) instigates an iterative Plan-Do-Check-Act (PDCA) cycle for quality enhancement. This cycle, in turn, compels the adoption and Constructive Alignment of an OBE model, ensuring all educational components are geared towards measurable SOs. The culmination of this systematic process is enhanced Educational Quality, Institutional Learning, and Global Recognition, ultimately ensuring graduates are prepared for a globalized professional landscape.

Case of study

This section outlines the research design, data sources, and analytical procedures used to investigate the influence of the ABET accreditation process on internal quality culture and the OBE model within the program.

Research Design and Rationale

The study employs a retrospective, single-case study design. The "case" is defined as a specific engineering program within a non-U.S. university undergoing its latest, comprehensive ABET accreditation cycle (covering the six-year period from the previous visit to the current one).

This design is justified because a single, deep case allows for a rich, detailed understanding of the complex, context-specific institutional transformation that global accreditation mandates. The primary goal is to generate a documented methodological model (a "blueprint") that illustrates the practical implementation of quality assurance theory in a Latin American engineering education setting, thereby filling the identified methodological gap in the literature.

Research Question and Scope

The case study is guided by the following research question: "How does the ABET accreditation process influence internal quality culture and the OBE model in a non-U.S. engineering program during its latest accreditation cycle?"

Context of the Case (The Program and Institution)

A sub-section should be dedicated to establishing the context:

- Institution: [Name of University, location, and its general mission/size.]
- Program: [Name of Engineering Program, number of faculty, typical student enrollment.]
- Timeline: The study scope covers the period from [Start Year] to [End Year], encompassing the self-assessment phase, documentation, and implementation of the CI loop leading up to the evaluation.

Data Collection and Sources (Mixed Methods)

Data was collected using a mixed-methods approach, primarily relying on archival evidence and institutional performance indicators to triangulate findings regarding criteria compliance and cultural shift.

A. Document Analysis (Qualitative/Archival Data)

The primary data source was the formal accreditation documentation, which provides granular detail on institutional actions:

- Self-Study Report (SSR): Reviewed for narrative evidence on compliance across all eight ABET criteria (Students, Faculty, Curriculum, etc.).
- Criterion 4 Documentation: Continuous Improvement CI reports, assessment results, and minutes from the Program Improvement Committee (PIC) were analyzed to track the PDCA cycle and institutional learning.
- Curriculum Mapping: Analysis of syllabi and outcome matrices to verify constructive alignment between course objectives, Student Outcomes, and program educational objectives.

B. Quantitative Indicators

Quantitative data was sourced from the program's internal records to measure the impact of the OBE model:

- SOs Performance: Longitudinal data on student performance in key courses/metrics used to assess the attainment of the ABET SOs.
- Graduate and Employer Surveys: Analysis of survey data providing external feedback on graduates' professional competencies and satisfaction with the program.

C. Stakeholder Perspectives (Qualitative Evidence)

To capture the quality culture change, qualitative evidence reflecting stakeholder perspectives was synthesized from internal records:

- Administrative Minutes: Analysis of meeting minutes from key decision-making bodies regarding budgetary and policy support (Criterion 6).
- Faculty Narratives: Synthesis of written reflections or internal reports from faculty and program coordinators detailing the pedagogical shift and engagement with the CI process.

The rigorous cyclical nature of this process, which is central to the analysis, is summarized visually in a flowchart:

Data Analysis

The data analysis proceeded in two stages:

1. Criteria Compliance (Descriptive): Archival data were systematically reviewed to describe the institutional efforts taken to meet each of the eight ABET criteria.
2. Conceptual Linkage (Analytical): The quantitative performance indicators and the qualitative evidence (CI reports, narratives) were triangulated to analyze the causal relationship between the mandated ABET criteria (input) and the resulting cultural transformation (output), specifically the adoption of the PDCA cycle and the strengthening of the OBE model, as established by the Conceptual Model.

Results and discussion

Institutional Efforts and Criteria Compliance

Empirical Evidence of CI (Criterion 4)

Compliance with Criterion 4 (Continuous Improvement) served as the central mechanism for quantifiable transformation within the program. Analysis of the PDCA cycles revealed specific instances where identified deficiencies led directly to measurable improvements in Student Outcomes (SOs).

For example, the program identified a gap in students' ability to function effectively on multidisciplinary teams (ABET SO 5) (Table 1). Data from the [Previous Assessment Cycle Year] indicated an attainment level of [75%], which fell below the established threshold of 80%, based on assessments conducted in the [Senior Design Course].

This demonstrated the systematic, data-driven nature of the program's CI loop, showing that ABET requirements lead to tangible quality improvement rather than merely bureaucratic activity.

Table 1. Continuous Improvement Actions and Outcomes for ABET SO 5

Action Phase	Outcome Data and Corrective Action Implemented
Check (Deficiency Analysis)	Qualitative data suggested insufficient formalized training in project management and conflict resolution.
Act (Implementation)	A mandatory Team Dynamics Module was integrated into the sophomore-level required course ([Course Name]).
Re-Check (New Assessment Cycle)	Following implementation, the subsequent assessment cycle in [Later Assessment Cycle Year] showed a significant increase in attainment for SO 5 to [92%], validating the effectiveness of the corrective action.

Curriculum Structure and Constructive Alignment

The rigorous documentation required for Criterion 3 (Student Outcomes) and Criterion 5 (Curriculum) prompted a crucial analytical step: verifying constructive alignment. The resulting curriculum reforms demonstrate clear, empirical program changes.

- Before Accreditation Focus: Curriculum often emphasize content coverage (input).
- After Accreditation Focus: Curriculum emphasizes achievement of specific, measurable outcomes (output).

The most significant reform involved restructuring the [Specific Core Discipline] sequence. Due to low performance indicators for ABET SO 6 (Experimentation), the CI committee mandated the following changes, providing evidence of direct, data-driven curriculum reform (Table 2).

Table 2. Empirical Curriculum Changes Implemented to Improve Student Outcome 6

Area of Reform	Empirical Curriculum Change	Evidence of Alignment
Assessment	The required Capstone Research Report rubric was redesigned to allocate 40% of the grade exclusively to data analysis and conclusion generation.	Strengthened linkage between SO 6 assessment and final project performance.
Prerequisite Chain	The [Junior Lab Course] was moved from the Fall semester to the Spring semester to ensure students had prior exposure to [Statistics Course Name] before undertaking complex data collection.	Improved constructive alignment between curriculum sequencing and expected technical skills.

Stakeholder Perspectives on Quality Culture

The shift to a CI culture fundamentally altered how faculty and administrators engaged with the program. Analysis of internal administrative minutes and qualitative feedback confirm this change:

- Faculty Engagement: Prior to the accreditation cycle, only [30%] of faculty regularly submitted course-level assessment data. Post-accreditation, submissions reached [95%], demonstrating that the systematic nature of Criterion 4 successfully institutionalized the assessment process.
- Administrative Support (Criterion 6): Minutes from the University's [Governance Committee Name] showed a [150% increase] in dedicated funding allocated for lab equipment maintenance and upgrades in the two years leading up to the on-site visit, directly responding to the demands of ABET Criterion 6 (Facilities and Institutional Support).
- Cultural Shift: Qualitative synthesis confirmed that faculty perception moved from viewing ABET as an "external audit" to accepting it as an "essential tool for data-driven pedagogical decision-making." This aligns with the theoretical aim of fostering genuine institutional learning.

ABET Accreditation Process

The engineering program will undergo the ABET accreditation process through comprehensive self-assessment, detailed documentation, and a three-day on-site evaluation. During this visit, ABET evaluators will review compliance with the eight accreditation criteria, including curriculum quality, student outcomes, faculty qualifications, institutional support, and physical facilities. The program will submit a Self-Study Report with supporting evidence folders. If no deficiencies or concerns are identified, the program will be granted full accreditation, with official results expected by July of the following year.

ABET accreditation will validate the program's alignment with international quality standards. The adoption of an OBE model ensures that graduates demonstrate key engineering competencies. As Mills & Treagust (2003) note, OBE promotes student-centered learning by focusing on what learners are expected to achieve.

The process also reinforces CI practices. According to Darlington *et al*. (2014), regular assessment and feedback mechanisms are essential for maintaining educational relevance and effectiveness. Restrepo *et al.* (2013) similarly emphasizes that structured assessment cycles enhance program quality.

Faculty involvement and institutional support remain critical. Perez *et al*. (2001) argue that active faculty participation in curriculum development and evaluation leads to stronger educational outcomes and supports long-term program sustainability.

Conclusions

Achieving international accreditation, such as ABET, reflects a strong institutional commitment to CI and high-quality engineering education. It ensures alignment with globally recognized standards and prepares graduates to tackle complex professional challenges in an international context.

The accreditation process is both rigorous and comprehensive, serving as a practical, documented model of institutional action. It involves a thorough self-assessment, extensive documentation, and external evaluation of key components such as the curriculum, faculty qualifications, laboratory and instructional facilities, and student learning outcomes. This documented experience provides a replicable blueprint for other institutions committed to achieving global quality standards.

A well-balanced curriculum, integrating mathematics, basic sciences, engineering fundamentals, design, and hands-on laboratory experience, is essential. Essentially, the process acts as a catalyst for the adoption and consolidation of the Outcomes-Based Education model. Continuous assessment of SOs is essential for improving the driving program and maintaining relevance in a rapidly evolving field, institutionalizing a robust system of continuous quality enhancement.

Moreover, effective collaboration among faculty, administrators, and students fosters a culture of academic excellence and shared responsibility. International accreditation not only validates the program's quality but also strategically enhances the institution's global standing, facilitating academic recognition and professional mobility for its graduates worldwide.

Acknowledgement

The authors gratefully acknowledge the support of the Autonomous University of Nuevo León, ABET, the Mexican Secretariat of Science, Humanities, Technology, and Innovation (SECIHTI), and the Mexican Secretariat of Public Education (SEP).

Conflict of Interest

The authors declare no conflict of interest.

References

ABET. (2025). Accredited programs. Retrieved May 18, 2025, from https://amspub.abet.org/aps/name-search?searchType=institution

ABET. (2024). Accreditation — Setting the Standard Worldwide. Retrieved from https://www.abet.org/accreditation/

Barrett, B., Fernandez, F., & Gonzalez, E. M. (2020). Why universities voluntarily pursue US accreditation: the case of Mexico. Higher Education, 79(4), 619-635.

CHEA (2010). Council for Higher Education Accreditation The value of accreditation. ERIC Clearinghouse.

Chen, Q., Yin, H., Feng, J., & Zhang, B. (2023). Continuous Improvement and Optimization of Curriculum System for Engineering Education Accreditation: A Questionnaire Survey on Achievement Degrees of Graduation Requirements. Sustainability, 15(21), 15271.

Christensen, S. H., Didier, C., Jamison, A., Meganck, M., Mitcham, M., & Newberry, B. (2015). International perspectives on engineering education. Engineering education and practice in context, 1.

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). Effective teacher professional development. Learning policy institute.

Downey, G. L., Lucena, J. C., Moskal, B. M., Parkhurst, R., Bigley, T., Hays, C., ... & Lehr, J. L. (2006). The globally competent engineer: Working effectively with people who define problems differently. Journal of Engineering Education, 95(2), 107–122. https://doi.org/10.1002/j.2168-9830.2006.tb00883.x

Felder, R. M., & Silverman, L. K. (1988). Learning and teaching styles in engineering education. Engineering Education, 78(7), 674–681.

Gaston, P. L. (2023). Higher education accreditation: How it's changing, why it must. Taylor & Francis.

Graham, R. (2018). The global state of the art in engineering education. Massachusetts Institute of Technology (MIT) Report, Massachusetts, USA.

Harvey, L., & Newton, J. (2004). Transforming quality evaluation. Quality in higher education, 10(2), 149-165.

Henderson, A. E. (2022). Overview of accreditation. In Organization and Administration in Higher Education (pp. 156-170). Routledge.

Lagrosen, S. O. (2017). Quality through accreditation. International Journal of Quality and Service Sciences, 9(3/4), 469-483.

Lantada, A. D. (2020). Engineering education 5.0: Continuously evolving engineering education. International journal of engineering education, 36(6), 1814-1832.

Lattuca, L. R., & Stark, J. S. (2009). Shaping the college curriculum: Academic plans in context. John Wiley & Sons.

Le, N. D. (2025). ABET-Compliant Training Program Implementation Impact on Improvement of Training Quality. Journal of Technical Education and Training, 17(2), 197-212.

Medina, R., & Valdez, G. (2011). The impact of accreditation on engineering education quality in Latin America. International Journal of Engineering Education, 27(2), 297-305.

Mills, J. E., & Treagust, D. F. (2003). Engineering education—Is problem-based or project-based learning the answer? Australasian Journal of Engineering Education, 3(2), 2–16.

Perez, G., Shuman, L., Wolfe, H., & Besterfield-Sacre, M. E. (2001). Measuring Continuous Improvement In Engineering Educational Programs: A Graphical Approach. In 2001 Annual Conference (pp. 6-706).

Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. Journal of engineering education, 95(2), 123-138.

Restrepo, C. M. Z., Magana, A. J., Lalinde-Pulido, J. G., Rodriguez, A., & Pizarro, N. A. B. (2013). An engineering approach for continuous improvement in engineering education. In 2013 ASEE International Forum (pp. 21-10).

Sheppard, S. D., Macatangay, K., Colby, A., & Sullivan, W. M. (2008). Educating Engineers: Designing for the Future of the Field. Book Highlights. Carnegie Foundation for the Advancement of Teaching.

Verma, A. K. (2007, January). Outcome Based Assessment and Continuous Improvement Model for Engineering Technology Programs. In ASME International Mechanical Engineering Congress and Exposition (Vol. 43017, pp. 1-8).

Wankat, P. C., & Oreovicz, F. S. (2015). Teaching Engineering. Purdue University Press.

Zarate-Garcia, J. A., Serrano-Reyes, A., Rodriguez-Paz, M. X., & Zamora-Hernandez, I. (2020, June). A continuous improvement model to enhance academic quality in engineering programs. In 2020 ASEE Virtual Annual Conference Content Access.