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CONTINUOUS QUALITY IMPROVEMENT (CQI) FOR COGNITIVE SKILLS IN COMPUTER NETWORKING SUBJECT

Nur Idawati Md Enzai[1]
Siti Sara Rais[2]
Mohd Amir Hamzah Ab Ghani[3]
Norhayati Ahmad[4]
Syazilawati Mohamed[5]

[1]Faculty of Electrical Engineering, Universiti Teknologi MARA Cawangan Terengganu Kampus Dungun, Malaysia, (E-mail: nurid333@uitm.edu.my)
[2]Faculty of Electrical Engineering, Universiti Teknologi MARA Cawangan Terengganu Kampus Dungun, Malaysia, (E-mail: sitisara851@uitm.edu.my)
[3]Faculty of Electrical Engineering, Universiti Teknologi MARA Cawangan Terengganu Kampus Dungun, Malaysia, (E-mail: mohdamirhamzah@uitm.edu.my)
[4]Faculty of Electrical Engineering, Universiti Teknologi MARA Cawangan Terengganu Kampus Dungun, Malaysia, (E-mail: norha291@uitm.edu.my)
[5]Faculty of Electrical Engineering, Universiti Teknologi MARA Cawangan Terengganu Kampus Dungun, Malaysia, (E-mail: syazilawati@uitm.edu.my)

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Abstract: *Academicians worldwide have been implementing the Outcome-Based Education (OBE) approach to measure, monitor, and assess whether or not the Program Outcomes (POs) can be achieved in terms of developing the skills of the graduates. Faculty of Electrical Engineering (FKE) of Universiti Teknologi MARA Cawangan Terengganu (UiTMCT) uses a tool known as Course Outcome – Program Outcome (CO-PO) template to conduct PO measurement at the course level. The analysis results are then used for continuous quality improvement (CQI) tasks. This article focuses on an elective final year subject offered in FKE UiTMCT, Network Routing Fundamentals. For the year 2020 intake students, one PO out of three POs only achieved 53.5%, which is the cognitive skills-related PO. Though the attainment is over 50%, precautionary measures were taken for 2021 intake students to prevent the PO attainment from plummeting. For the year 2021 intake and year 2022 intake students, cognitive skills-related PO attainment increased to 76.9% and 68.5%, which also surpassed the Program Monitoring Level of 65%. This article explains the CQI activities conducted which is based on Plan-Do-Check-Act (PDCA) mechanism and analyses the related PO attainment results as well as outlining future actions.*

Keywords: *Program Outcome, Outcome-Based Education, Cognitive, CQI, PDCA*

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Introduction

FKE UiTMCT has been monitoring the PO achievement with Key Performance Indicator (KPI) of 50% at the program level. As preventive measures, at the course level, 65% is set as a Monitoring Level to avoid the performance from dropping suddenly. The Faculty of Electrical Engineering determined both key performance indicators through endorsement in minutes of meeting. This study focuses on an elective subject Network Routing Fundamentals. Based on the automated analysis conducted using the CO-PO template, the cognitive skills performance of cognitive skills is below the Program Monitoring Level for the 2020 intake, the first intake that implemented the Engineering Technology Accreditation Council (ETAC) approved syllabus.

The continuous assessments mapped to cognitive skills are Written Test 1 and Test 2. The students' performance in these assessments did not meet the faculty's KPI, indicating a shortfall in achieving the expected learning outcomes. This gap highlights the need for the course to implement targeted actions and strategic improvements. Therefore, this study is significant in exploring Continuous Quality Improvement (CQI) measures aimed at enhancing students' cognitive skills.

PO monitoring and analysis mechanism is in line with Outcome-based education (OBE) that has gained importance in the field of engineering education (Othman, Aziz, & Shah, 2023). To identify areas for continuous improvement, several engineering education programs have established learning objectives, course-level competencies, and program-level assessments (Shankararaman & Ducrot, 2016). There are three different types of learning outcomes: affective, behavioural, and cognitive (Wei, Saab, & Admiraal, 2021). Educators need to support the students in reaching higher levels of comprehension in their subject (Lamb, Annetta, Firestone, & Etopio, 2018). The process should be continuous and undergo improvement from time to time. Therefore, various related research studies have been done to achieve this goal.

Literature Review

(Wajid, Chattha, Khawaja, & Ahmadi, 2023) discusses a proposal to enhance the performance of student learning outcomes (SOs) and course learning outcomes (COs) for continuous quality improvement (CQI) identified by the Electrical Engineering (EE) Department, Faculty of Engineering, Islamic University of Madinah, Saudi Arabia. The performance was gathered via an automated CQI system in EvalTools, under the Faculty Class Assessment Report (FCAR) tab, where each instructor is mandated to reflect on underperforming SOs and COs. The feedback was thoroughly analyzed, and they identified key mathematical concepts that have a significant impact on student performance in core EE courses. The feedback was thoroughly analyzed and it was observed that poor performance in SOs and COs across a variety of fundamental EE courses was associated with students' weak foundation in Mathematics. The study recommends strategies to address math-related issues, including updating the Engineering Mathematics course and emphasizing differentiation rules and integration applications in tutorials.

A study in (Chowdhury, Chisty, Tushar, Ahmed, & Waliullah, 2023) explores Outcome-Based Education (OBE) in a 2021 International Finance course at the International University of Business Agriculture and Technology, Dhaka, Bangladesh. It uses an automated system for assessment and proposes Continuous Quality Improvement (CQI) strategies. Course learning

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outcomes were measured using a self-created spreadsheet and compared to a 70% key performance indicator target. The first three out of five CLOs met the standard KPI.
Research by (Chattha, Alkassem, & Al-Ahamdi, 2020) outlines the course outcomes (CO), specific performance metrics (PI), assessment rubrics, and CQI approaches employed in the 'Signals and Systems' course for undergraduate Electrical Engineering students at the Department of Electrical Engineering, Faculty of Engineering, Islamic University of Madinah, Kingdom of Saudi Arabia. There are ten (10) COs mapped with Accreditation Board for Engineering and Technology (ABET) SOs. The performance is analysed based on the students' assignments using customized web-based software 'EvalTools' from MAKTEAM Inc. The average percentage is subsequently employed to categorize students into the EAMU classifications, denoting 'Excellent', 'Adequate', 'Minimal', and 'Unsatisfactory', according to predetermined evaluation standards. The CQI approach includes understanding student backgrounds, adjusting lectures based on feedback, improving English skills, balancing workload, introducing key course outcomes early, using problem-based learning, clarifying course outcomes, teaching auxiliary condition extraction, explaining signal differences, and early coverage of complex topics. A comparison was made between the results from the Fall Semester of 2017-18 (before CQI) and the Spring Semester of 2017-18 (post CQI), revealing significant enhancements.

A study by the School of Engineering (SOE) at Taylor's University outlines the Conceiving – Designing - Implementing - Operating (CDIO) initiative and implementation of OBE as compulsory by Engineering Accreditation Council (EAC) accreditation. Project-based learning (PBL) was used in designing the academic curriculum by following the Engineering Accreditation Council (EAC) requirements, and it was delivered through a series of project-based design modules that act as core modules from semester 1 to semester 8. The integration of the CDIO educational framework and PBL has played a crucial role in module planning, design, and implementation, ultimately helping to meet the EAC requirements (Al-Obaidi, 2021).

The issues and challenges that arise from carrying out the school improvement plan are studied by (Ab Latif, Hamzah, & Nor, 2021). The study associates the importance of involvement from the principal and the school administration with the data collected to back the findings. The School Improvement Plan (SIP) used the PDCA Cycle Model related to the organization's continuous improvement plan. The studies show that principals face challenges in the implementation of SIP such as data management, no guidelines in SIP, and communication difficulties between data and aspects of the principal's behavior, which resulted in a poor quality and unauthentic SIP. The output led to the incapability of enhancing student and school achievement. The roles, support and commitment of the principals, school staff, District Education Office (PPD), and Jabatan Pendidikan Negeri (JPN) are much needed to ensure the improvement of schools in Malaysia.

Study by (Rusdin & Ali, 2019) elaborates on the importance of 4C skills: communication, collaboration, creativity, and critical thinking, and revisits the Connectivism Learning Theory that highlights the skills needed for students to prepare for the workplace. The 4Cs skills can complement engineering education that focuses more on technical skills and knowledge-based curriculum. Communication interlinks with collaborative skills that further improve the involvement of students in individual and group assignments. Creativity and critical thinking

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demand the cognitive capacity of each student and are closely related to students' technical knowledge. All the skills need time and resilience to cultivate a level that meets workplace standards.

A testing instrument was also created to assess high school students' cognitive learning outcomes for elasticity material grounded in differentiated learning, which was demonstrated to be valid, reliable, and compatible with the Partial Credit Model. The study aimed to develop a tool for measuring students' cognitive learning outcomes across visual, auditory, and kinaesthetic learning styles, and to identify the attributes of an assessment instrument for evaluating cognitive learning outcomes based on differentiated learning in the physics topic of elasticity. The study employed the ADDIE paradigm (Analyse, Design, Develop, Implement, Evaluate). A 16-item test with two anchor items was created, tested on 252 high school students, and verified by six experts. The Parscale application was used to analyze item difficulty, discrimination, and guessing level (Azizah, Istiyono, & Wilujeng, 2024).

Assessment of the affective domain is the focus in (Alias, Ruslan, & Zaki, 2025). A rubric was developed to assess the affective domain within an Environmental Laboratory course tailored for engineering students. It underscores the importance of continuous quality improvement (CQI) in enhancing educational materials. Similar to (Ab Latif et al., 2021), Plan, Do, Check, Act (PDCA) cycle is included as part of its CQI methodology for a systematic and ongoing process of refining the rubric. To ensure that assessments aligned with the latest educational standards, the rubric underwent regular updates between 2015 and 2023. Among the methodologies employed was the CQI process, which aimed to enhance the rubric for evaluating the affective domain, and the analysis of student performance data across multiple semesters. The findings indicate that the revised rubric led to improved student performance, particularly in raising minimum standards and narrowing performance gaps. Additionally, the results highlight how effectively the CQI process fostered equitable and consistent student outcomes (Alias et al., 2025)

(Manimaran & Haider, 2023) proposes a hands-on framework for CQI in engineering technology programs accredited by the Accreditation Board for Engineering and Technology (ABET). The authors focus on using a cycle of planning, doing, checking, and acting to bring about real improvements. Their approach includes collecting feedback from students, faculty, and industry, analyzing performance metrics, and using the results to revise teaching and course design. The framework has helped programs document improvements clearly, especially for accreditation purposes.

(Mohamed, Kar, Ahmed, & Idris, 2024) discusses how Continuous Quality Improvement (CQI) can be effectively applied to improve learning outcomes in an electronics course. The study is motivated by the need to meet program outcomes set by accreditation bodies, Engineering Technology Accreditation Council (ETAC). The authors adopt the Plan-Do-Check-Act (PDCA) model as the core CQI framework. The study focuses on making iterative improvements based on student performance data. The OBE-ANAS tool was used to assess course outcome attainment in line with program outcome requirements. Results from formative and summative assessments were used to refine teaching methods and lab activities. The findings show that integrating the PDCA cycle and OBE-ANAS enables targeted enhancements that strengthen student performance.

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Table 1: Summary of Literature Review

No.	Study	Focus Area	Tools/Methods	Findings/Contributions
1	(Wajid et al., 2023)	CQI in EE learning outcomes -program level	EvalTools (FCAR), analysis of SOs/COs	Weak math foundation affects SO/CO performance; recommends enhancing math curriculum
2	(Chowdhury et al., 2023)	OBE in International Finance course	Self-developed spreadsheet, KPI comparison	3 out of 5 CLOs met 70% KPI; suggests CQI strategies
3	(Chattha et al., 2020)	CO-SO mapping in Signals & Systems course	EvalTools, EAMU classification, PBL, rubrics	CQI led to significant improvement post-intervention (Spring 2017-18)
4	(Ab Latif et al., 2021)	School Improvement Plan (SIP) challenges -school level	PDCA model, qualitative analysis	Identified data, communication, and leadership gaps as barriers to SIP success
5	(Azizah et al., 2024)	Cognitive assessment in physics (elasticity) -high school level	ADDIE model, Parscale, differentiated learning	Valid tool measuring cognition across learning styles; 16-item validated test
6	(Alias et al., 2025)	Affective domain assessment -Environmental Laboratory course	Rubric development, PDCA cycle	Revised rubric improved affective outcomes and performance consistency
7	(Manimaran & Haider, 2023)	Hands-on CQI for ABET-accredited programs -faculty level	PDCA cycle, stakeholder feedback	Framework supports clear CQI documentation for accreditation
8	(Mohamed et al., 2024)	CQI in Electronics course	PDCA cycle, OBE-ANAS, assessments	PDCA + OBE-ANAS enhanced lab and teaching methods effectively
9	(Al-Obaidi, 2021)	CDIO-PBL integration in curriculum -faculty level	CDIO framework, EAC-aligned design modules	CDIO and PBL effectively structured core learning across semesters
10	(Rusdin & Ali, 2019)	4C (communication, collaboration, creativity, and critical thinking) Skills in Engineering Education	Connectivism Learning Theory	4Cs strengthen cognitive & technical synergy; need resilience to mature
11	This Paper (FKE UiTMCT)	CQI for cognitive skills in Networking subject	CQI activities and analysis	Targeted improvement of cognitive skills in Diploma-level EE students

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Table 1 presents a summary of each literature study, comparing their focus areas, tools or methods used, and findings or contributions. In engineering education, studies by (Alias et al., 2025; Manimaran & Haider, 2023; Mohamed et al., 2024) have implemented Continuous Quality Improvement (CQI) frameworks by adopting PDCA to facilitate enhancements. The study that measures students' PO-SO performance utilized technology such as the web-based software 'EvalTools' in the research by (Chowdhury et al., 2023; Wajid et al., 2023), while the study by (Chattha et al., 2020) employed spreadsheets. Within the learning domain, cognitive skills are the focus of studies by (Mohamed et al., 2024; Wajid et al., 2023), while affective skills are emphasized in the work of (Alias et al., 2025). As a preventive measure within CQI, the structured implementation of CDIO and project-based learning (PBL) by (Al-Obaidi, 2021) aligns with the Plan and Do phases of the PDCA cycle, while the emphasis on 4C skills as a complement to engineering education, as highlighted by (Rusdin & Ali, 2019), likewise reflects a preventive approach within the CQI framework.

From the literature reviewed, several studies focused on specific courses (Alias et al., 2025; Azizah et al., 2024; Chattha et al., 2020; Chowdhury et al., 2023; Mohamed et al., 2024). Nevertheless, most existing studies focus on core courses within degree programs and pay limited attention to elective subjects or diploma-level programs, particularly those involving assessments in higher-order cognitive domains of Bloom's Taxonomy. Furthermore, CQI measures are typically implemented after final assessments, rather than being integrated continuously throughout the semester. Recognizing this gap, the present study focuses on an elective course: Network Routing Fundamentals, within a diploma-level engineering program and implements early and formative interventions such as mock quizzes, gamified tutorials, and progressive student performance monitoring to achieve faculty KPI thresholds of 50% at the program level and 65% at the course level. Therefore, this study not only fills a gap in the existing literature but also contributes to the development of a CQI model that is practical and scalable for implementation within the Outcome-Based Education (OBE) framework at local institutions.

This paper outlines the CQI activities and analysis to improve the performance of cognitive skills in the Network Routing Fundamental subject taken by FKE UiTMCT Diploma of Electrical Engineering (Electronics) students.

Methodology

This study focuses on the performance of three batches of students enrolled in the Network Routing Fundamentals subject. The first batch (16 students) took the subject in the October 2022 – February 2023 semester, the second batch (9 students) was enrolled during October 2023 – February 2024 semester, and the third batch (12 students) recently completed October 2024 – February 2025 semester. Network Routing Fundamentals is an elective subject offered for final-year students of the Diploma of Electrical Engineering (Electronics) program. Network Routing Fundamentals subject covers five chapters which refer to Cisco Certified Network Associate Syllabus that must be taught in 14 weeks, with three credit hours. Students attend two hours of lectures and two hours of laboratory each week. The course aims to achieve three ETAC POs and three COs. Table 2 outlines the program outcomes (POs) and course outcomes (COs) of Network Routing Fundamentals subject:

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Table 2: CO-PO Mapping

	CO	ETAC PO
1	Construct Wide Area Network (WAN) and implement dynamic routing protocol using network simulation tool.	PO5: Apply appropriate techniques, resources, and modern engineering and IT tools to well-defined engineering problems, with an awareness of the limitations **(Moden Tool Usage)**
2	Describe the function and operation of router for computer network.	PO3: Design solutions for well-defined technical problems and assist with the design of systems, components or processes to meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations **(Design/Development of Solutions)**
3	Demonstrate written communication skills to differentiate the current technology and legacy techniques on routing protocol for WAN communication.	PO10: Communicate effectively on well-defined engineering activities with the engineering community and with society at large, by being able to comprehend the work of others, document their own work, and give and receive clear instructions **(Communications**

The assessments include three parts, as shown in Table 3:

Table 3: Assessment Marks Allocation

Assessment Type	CO	PO	Continuous Assessment (%)	Total (%)
Written Test	CO2	PO3	25	50
			25	
Practical Test	CO1	PO5	10	10
Laboratory Exercise	CO1	PO5	15	15
Project	CO1	PO5	20	25
	CO3	PO10	5	

Table 3 shows that 50% of assessments are contributed by written tests or the cognitive domain. The data collected was based on the overall results of the students from three batches. For the October 2022 - February 2023 semester, one PO out of three POs only achieved 53.5%, which is the cognitive skills-related PO namely PO3. Though the attainment is over 50%, precautionary measures were taken for the October 2023-February 2024 semester to prevent PO attainment from further decreasing, subsequently achieving the KPI monitoring level of 65%. At course level, FKE UiTMCT uses a Course Outcome - Programme Outcome (CO-PO) template to calculate the CO and PO attainments. The CO-PO template provides a translation of raw student marks obtained from their enrolled course to the attainment of the respective POs in a quantitative way. The calculations of COs and POs attainments are based on the assessment marks scored by a batch of students such as tests, assignments, laboratory works, projects and final examinations.

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As stated in Table 2, the cognitive learning domain for the Network Routing Fundamental is assessed through two written tests with a total of 100 marks. An example of how the CO-PO template computes CO-PO attainment is as follows: For simplification purposes, only two students are considered.

Student A obtains 40 marks in Test 1 and 25 marks in Test 2.
The cognitive PO attainment for Student A is 40 + 25 = 65%.
Student B obtains 20 marks in Test 1 and 30 marks in Test 2.
The cognitive PO attainment for Student B is 20 + 30 = 50%.
The cognitive PO attainment for the Network Routing Fundamental subject is the average PO attainment: (65 + 50) / 2 = 57.5%

In summary, the PO attainments for all students are averaged to obtain the overall PO attainment for the subject. The blank CO-PO template is shown in Figure 1 above.

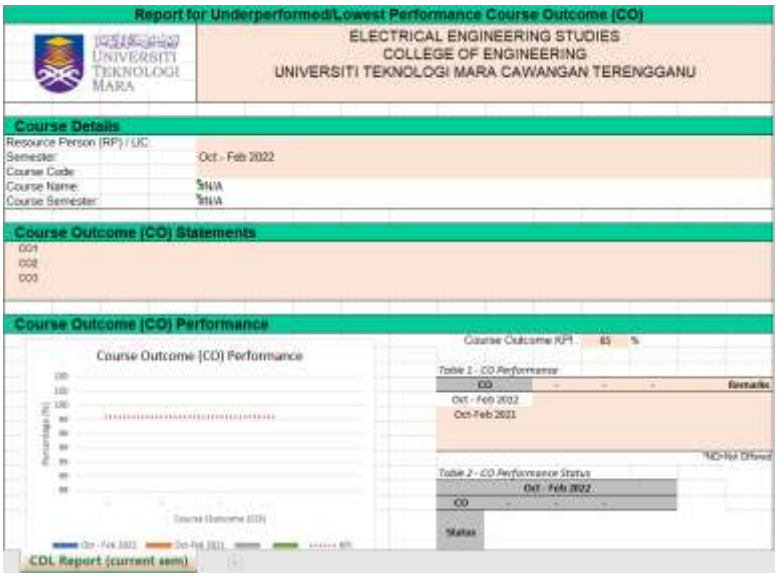

Figure 1: Blank CO-PO Template

Results And Discussions

This section describes the actions for CQI to improve PO3 attainment performance for the February 2023 – October 2024 semester. PO3 is part of the cognitive domain that includes six taxonomy levels: C1 is remembering, C2 is understanding, C3 is applying, C4 is analyzing, C5 is evaluating, and C6 is creating (Forehand, 2010). The cognitive taxonomy level for Network Routing Fundamentals subject is up to C5, the fifth level: evaluating, which involves making judgments through checking and critiquing based on criteria and standards. The written test questions are constructed based on the following specifications as shown in Table 4.

Table 4: Written Test Cognitive Level Allocations

Question Level	Easy	Medium	High
Cognitive Level	C1 - C2	C3 – C4	C5 – C6
% Marks (100 marks)	30 - 50	50 – 70	0 - 5

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The range of mark allocations is determined by the faculty based on the semester and the nature of the subject offered.

Even though there is no dedicated tutorial slot for this subject, a tutorial is conducted after each sub-topic completion. The students are given specified time to answer tutorial questions and allowed to refer to the notes and search on the Internet. Then, the students are randomly picked to answer the questions during the lecture and the instructor explains and discusses the answers. To prepare them for the real written tests, mock quizzes are also conducted where the students will answer the questions without referring to the notes or materials. Furthermore, a special revision class is also held during the test week. To make the tutorial session more interesting, online games such as Kahoot are also utilized. Kahoot! is a game-based student response system that was first established in 2012. Kahoot! aims to provide a game show experience while learning in class (Zhang & Yu, 2021). A screenshot of Kahoot! game graphical user interface is shown in Figure 2 below:

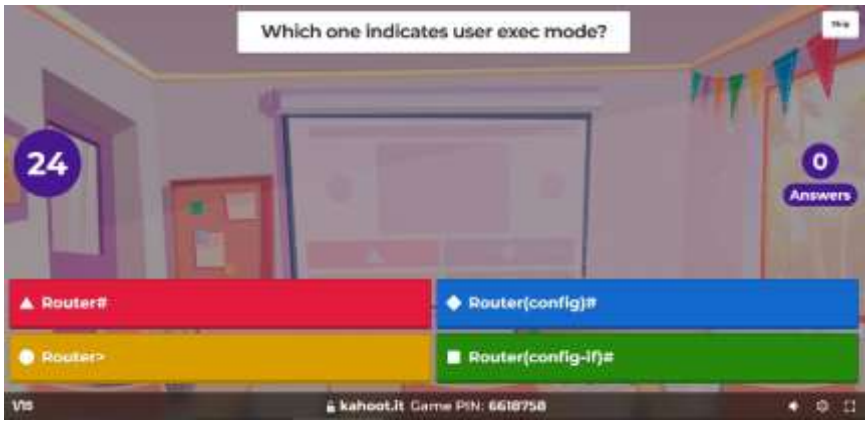

Figure 2: Screenshot of Kahoot! Interface

The students' performances are also monitored after the first test. The students who obtained low marks are given more attention to ensure they understand the subject's content and consequently score in the second test. At the end of the October 2023 – February 2024 semester, the students' results are analyzed for the three COs and three POs. The findings are shown in Table 5. All the CO-PO attainments have improved compared to the October 2022-February 2023 semester by more than 65% (monitoring level). CO2-PO3 attainment has increased from 53.5%, below the monitoring level to 76.9%.

Similar actions and measures were also conducted for the October 2024 - February 2025 semester. As a result, every CO-PO managed to achieve more than 65% attainment (monitoring level). CO1-PO3 and CO3-PO10 attainments increased compared to the previous batch. However, CO2-PO3 attainment decreases from 76.9% to 68.5%. All the 2021 intake students passed both written tests. However, for the 2022 intake, one student failed the first written test, but all students passed the second written test. This leads to the decline of CO2-PO3 attainment. For corrective actions, instead of only observing the results of the first written test and taking actions to improve performance on the next written test, the instructor is suggested to evaluate the students' understanding through mock quizzes or tutorials and identify their strengths and weaknesses even before conducting the first written test.

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Table 5: CO-PO Performance for Three Different Semesters

Semester	CO1-PO5	CO2-PO3	CO3-PO10
October 2024 – February 2025	94.6	68.5	87.5
October 2023 – February 2024	90.9	76.9	84.7
October 2022 – February 2023	84.5	53.5	72.9

The CQI mechanism is based on the Plan-Do-Check-Act (PDCA). The steps are as follows:
1. Plan – outline objectives and procedures to achieve specific results.
2. Do – proceed with the objectives.
3. Check – check the outcomes whether they are aligned with the objectives or not.
4. Action – identify issues from the 'do' and 'check phases', improve procedures (Isniah, Purba, & Debora, 2020).

Details of PDCA steps taken also need to be filled in the CO-PO template as shown in Figure 3 below:

Figure 3: PDCA in CO-PO Template

As CO1-PO3 performance improves and achieves the KPI monitoring level, the implemented three phases of PDCA will be executed similarly for the upcoming semester when the subject will be offered. However, the unique characteristics of the students as well as available facilities and syllabus content, will still be considered.

Conclusion

In conclusion, the implementation of the Outcome-Based Education (OBE) approach at the Faculty of Electrical Engineering (FKE), Universiti Teknologi MARA Terengganu Branch (UiTMCT), demonstrates a commitment to developing graduates' skills through systematic measurement and continuous quality improvement (CQI). The use of the CO-PO template has been instrumental in tracking the attainment of Program Outcomes (POs) at the course level,

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ensuring targeted improvements. The case study of the elective subject, Network Routing Fundamentals, highlights the effectiveness of these measures, evidenced by a significant improvement in cognitive skills-related PO attainment from 53.5% to 76.9% between the 2020 and 2021 intakes. Even though cognitive skills-related PO attainment for the 2022 intake decreased to 68.5%, the attainment is still above the KPI (65%). This success underscores the importance of proactive CQI activities based on PDCA mechanism in maintaining and enhancing educational standards. PDCA-based CQI method can also be implemented by other faculties and institutions. Future actions will continue to build on these findings, ensuring sustained excellence in student outcomes and overall program quality.

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