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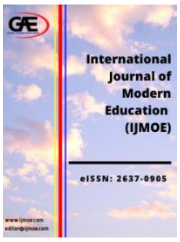

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IMPLEMENTING ALTERNATIVE ASSESSMENTS WITH DESIGN THINKING IN ENGINEERING EDUCATION: ENHANCING OUTCOMES FOR BROADLY-DEFINED ENGINEERING PROBLEMS

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Abstract:

This study examines the use of alternative assessments, integrated with design thinking, in the Integrated Technology Design Project (ITDP) course to improve engineering education outcomes. Traditional assessments often focus on memorization and theoretical knowledge, abandoning practical skills and real-world problem-solving abilities. Additionally, there is a pressing need for alternative assessment approaches that integrate real-world problem-solving skills, fostering a more holistic and applicable skill set among engineering graduates. To address this issue, the study employs a performance criteria matrix (PCM) aligned with course and program outcomes, focusing on seven (7) broadly-defined engineering problems (SP) and relevant knowledge profiles (SK). All 88 students in the ITDP course are evaluated through four types of PCM for Final Project, Presentation, Assignment and Interim Report. The results indicate high student attainment in key program outcomes, especially in problem analysis, modern tool usage, teamwork, and project management. The alternative assessments fulfilled the ETAC Standard 2020 which is aligned to the Graduate Attributes and Professional Competencies (GAPC2021) under the purview of the International Engineering Accords (IEA), effectively promoting practical skills and critical thinking. The study highlights the importance of refining assessment strategies to better align with industry needs and enhance student preparedness for the engineering profession. Future research should explore the new ETAC Standard 2024 requirements via gap analysis, integrating advanced digital tools and simulations, conducting longitudinal studies on the effectiveness of alternative assessments, and increasing industry stakeholder involvement in assessment

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design. These efforts aim to ensure that assessment strategies remain relevant and effective in preparing graduates for the evolving demands of the engineering field.

Keywords:

Alternative Assessment, Design Thinking, Engineering Education

Introduction

Engineering education is currently experiencing dynamic changes through a combination of various fields such as computer science, biology, and business management to create more well-rounded and adaptable graduates. This trend is designed to equip students with the diverse skill set needed to tackle complex, real-world problems. There is also a significant shift towards hands-on, experiential learning methods, including project-based learning (PBL), internships, and laboratory work. These approaches enable students to apply theoretical knowledge in practical scenarios, thereby enhancing their problem-solving abilities and industry readiness.

In addition, engineering curricula are placing greater emphasis on sustainability, environmental impact, and ethical practices. This shift is motivated by a global focus on sustainable development and responsible engineering. The United Nations Sustainable Development Goals (UNSDGs) emphasize 17 goals to address global challenges, including those related to poverty, inequality, climate change, environmental degradation, peace, and justice. The use of digital tools, simulations, and virtual laboratories is also on the rise, with technologies such as artificial intelligence (AI), machine learning, and the Internet of Things (IoT) being integrated into engineering courses to keep up with industry advancements.

Moreover, engineering programs are fostering global collaboration through exchange programs, international projects, and partnerships with global institutions. This trend is crucial for developing cultural competency and teamwork skills, which are essential for modern engineers. Additionally, engineering education is increasingly emphasizing lifelong learning in response to the rapid pace of technological change. Programs such as continuous professional development through online courses, certifications, and workshops are introduced to ensure that engineers remain up-to-date with the latest advancements in their field.

The traditional assessment methods in engineering education, which heavily emphasize rote memorization and theoretical knowledge, fall short of preparing students for the complexities of real-world engineering problems. These methods often neglect critical practical skills and higher-order thinking abilities such as creativity, critical analysis, and problem-solving, essential for professional practice (Lian, 2023). According to Ari (2020), standardized tests lack the flexibility to accommodate diverse learning styles and interdisciplinary competencies, leading to a disconnect between educational outcomes and industry requirements. As a result, there is a pressing need for alternative assessment approaches that integrate real-world problem-solving skills, fostering a more holistic and applicable skill set among engineering graduates as stated by Tanna et. al. (2022). Based on a study conducted by Vilela & Silva (2023), innovative assessments such as project-based evaluations and design thinking exercises, offer a promising solution to bridge this gap and better align educational practices with professional demands.

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With the shift towards interdisciplinary engineering education, assessments must evaluate a broad range of competencies. Methods such as integrative projects and interdisciplinary team assessments provide a more holistic evaluation of students' abilities. Moreover, innovative assessments promote active learning and student engagement. Techniques such as peer assessments, reflective journals, and e-portfolios encourage students to actively participate in their learning process and reflect on their progress.

Additionally, innovative assessments provide detailed feedback essential for continuous quality improvement in teaching and learning processes. They help identify areas for improvement and ensure that educational programs align with evolving standards and industry expectations. Traditional exams may not cater to diverse learning styles and abilities, whereas innovative assessments offer multiple ways to demonstrate understanding and skills, making education more inclusive and equitable.

Engineering Technology Accreditation Council Standard 2024

Programme outcomes (POs) are the graduate attributes that reflect on the knowledge and skills that are expected to be acquired by the students upon graduation. In Malaysia, the Board of Engineers Malaysia (BEM) manages the accreditation process through the Engineering Technology Accreditation Council (ETAC) to evaluate engineering technology programmes. Students of an engineering technology programme are expected to attain the graduate attributes known as programme outcomes (PO) in the practice-oriented learning environment as outlined in Table 1 (Board of Engineers Malaysia, ETAC 2020).

Generally, the evaluation is based on the PO assigned to courses, thus Institutions of Higher Learning (IHL) that offer engineering technology programmes in Malaysia need to fulfill the minimum requirements set by the BEM to ensure that the programmes are being recognized, hence the graduates will be able to carry out relevant engineering practices as registered technologists during their career life. Since 2004, OBE has been the prime criterion for engineering accreditation in Malaysia as required by the Engineering Technology Accreditation Council (ETAC) to be qualified as a full member of the Sydney Accord (SA).

Table 1: Twelve (12) Programme Outcomes based on ETAC Standard 2020 and Mapped to the IEA Graduate Attributes and Professional Competencies (GAPC) 2021

Programme Outcomes (ETAC Standard 2020)	Graduate Attributes and Professional Competencies (2021)
PO1- Knowledge: Apply knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to defined and applied engineering procedures, processes, systems or methodologies; (SK1 to SK4)	PO1- Knowledge: Apply knowledge of mathematics, natural science, computing and engineering fundamentals and an engineering specialization as specified in SK1 to SK4 respectively to defined and applied engineering procedures, processes, systems or methodologies
PO2- Problem Analysis - Identify, formulate, research literature and analyse broadly-defined engineering problems reaching substantiated conclusions using analytical tools appropriate to their discipline or area of specialization;	PO2- Problem analysis: Identify, formulate, research literature and analyse broadly-defined engineering problems reaching substantiated conclusions using analytical tools appropriate to their discipline or area of specialisation with considerations for sustainable development; (SK1 to SK4)

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PO3- Design/ Development of Solutions - Design solutions for broadly-defined engineering technology problems and contribute to the design of systems, components, or processes to meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations; (SK5)	PO3- Design/ development of solutions: Design solutions for broadly-defined engineering technology problems and contribute to the design of systems, components or processes to meet identified needs with appropriate consideration for public health and safety, whole-life cost, net zero carbon as well as resource, cultural, societal, and environmental considerations as required; (SK5)
PO4- Investigation - Conduct investigations of broadly defined problems; locate, search and select relevant data from codes, data bases and literature, design and conduct experiments to provide valid conclusions; (SK8)	PO4- Investigation: Conduct investigations of broadly-defined engineering problems; locate, search and select relevant data from codes, databases and literature, design and conduct experiments to provide valid conclusions; (SK8)
PO5- Modern Tool Usage - Select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to broadly defined engineering problems, with an understanding of the limitations; (SK6)	PO5- Tool Usage: Select and apply, and recognize limitations of appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to broadly-defined engineering problems; (SK2 and SK6)
PO6- The Engineer and Society - Demonstrate understanding of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering technology practice and solutions to broadly defined engineering problems; (SK7)	PO6- The Engineering Technologist and the World: Analyze and evaluate sustainable development impacts to: society, the economy, sustainability, health and safety, legal frameworks, and the environment, in solving broadly-defined engineering problems; (SK1, SK5, and SK7)
PO7- Environment & Sustainability - Understand the impact of engineering technology solutions of broadly defined engineering problems in societal and environmental context and demonstrate knowledge of and need for sustainable development; (SK7)	
PO8- Ethics -Understand and commit to professional ethics and responsibilities and norms of engineering technology practice; (SK7)	PO7- Ethics: Understand and commit to professional ethics and norms of engineering technology practice and adhere to relevant national and international laws. Demonstrate an understanding of the need for diversity and inclusion; (SK9)
PO9- Individual and Teamwork: Function effectively as an individual, and as a member or leader in diverse technical teams;	PO8- Individual and Collaborative Team Work: Function effectively as an individual, and as a member or leader in diverse and inclusive teams and in multi-disciplinary, face-to-face, remote and distributed settings; (SK9)
PO10- Communicate effectively on broadly defined engineering activities with the engineering community and with society at	PO9- Communications: Communicate effectively and inclusively on broadlydefined engineering activities with the engineering community and with society at

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large, by being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	large, by being able to comprehend and write effective reports and design documentation, make effective presentations, taking into account cultural, language, and learning differences;
PO11- Project Management and Finance: Demonstrate knowledge and understanding of engineering management principles and apply these to one's own work, as a member and leader in a team and to manage projects in multidisciplinary environments;	PO10- Project Management and Finance: Apply knowledge and understanding of engineering management principles and economic decision-making to one's own work, as a member and leader in a team and to manage projects in multidisciplinary environments;
PO12- Lifelong Learning: Recognize the need for, and have the ability to engage in independent and life-long learning in specialist technologies.	PO11- Life Long Learning: Recognize the need for, and have the ability for i) independent and life-long learning and ii) critical thinking in the face of new specialist technologies. (SK8).

Source: *ETAC Standard (2020) and IEA GAPC (2021)*

The current ETAC Standard 2020 has prescribed 12 programme outcomes or graduate attributes with seven (7) broadly defined engineering problems (SP), five (5) broadly defined engineering activities (TA) and 8 knowledge profiles (SK) to be incorporated into the engineering technology programmes. The programme outcomes for this programme are mapped to the ETAC Standard 2020 and aligned to the recent International Engineering Accords requirements in the Graduate Attributes and Professional Competencies (GAPC) released in 2021. The GAPC2021 introduced only 11 programme outcomes with and additional SK9 and are incorporated in the new ETAC Standard 2024. This paper focuses on the attainment of the programme outcomes as per ETAC Standard 2020, but the assessment has been aligned with the new requirements in the GAPC2021.

Alternative assessment is chosen directly to assess whether the learning outcomes upon student graduation are achieved effectively (Yusop & Firdaus, 2021). The design thinking process is also incorporated to enhance students' critical thinking skills. The main objective of this paper is to study the alternative assessment method used for a culminating course, namely the Integrated Technology Design Project (ITDP).

Literature Review

Background on Alternative Assessments

Alternative assessments have emerged as a crucial component in modern engineering education, addressing the limitations of traditional assessment methods. Unlike conventional assessments that often focus on memorization and theoretical knowledge, alternative assessments emphasize practical skills, critical thinking, and real-world problem-solving abilities. According to Chirimbu (2023), alternative assessments, such as project-based learning (PBL), portfolios, and peer assessments, provide a more comprehensive evaluation of a student's capabilities by engaging them in tasks that mirror real-world engineering challenges. This approach not only enhances students' understanding and retention of material but also prepares them more effectively for professional practice by fostering essential skills such as teamwork, communication, and adaptability (Sapawi et. al., 2021). Additionally, it is observed that there is an improvement in the process of students' learning as an added advantage with the learning-oriented assessment approach mentioned in a study by Allamsetty et. al. (2024). Since learners have a role to play in classroom activities during the formation of the assessments, they are more encouraged to learn in a more enhanced way. This degree of learning together with the involvement in hands-on activities further enhances learning of engineering skills that are relevant in the field. Thus, the alternative means of assessment can be considered as the link between academics and professional engineering practice which makes them as an important approach to foster competent and adaptable future engineers.

The integration of design thinking into alternative assessments further enriches the educational experience by promoting creativity and innovation. Design thinking, a user-centered approach to problem-solving, encourages students to explore multiple solutions and iterate based on feedback, which is crucial for addressing complex engineering problems. Recent studies have shown that incorporating design thinking into engineering curricula leads to significant improvements in students' critical thinking and problem-solving skills (Shanta & Wells, 2020). For instance, a study by Gupta (2022) found that students who participated in design thinking-based projects demonstrated higher levels of engagement and a deeper understanding of course material compared to those assessed through traditional methods. This shift towards alternative assessments reflects a broader trend in engineering education to develop well-rounded graduates who are better equipped to meet the dynamic demands of the industry (Hadgraft & Kolmos, 2020).

Design Thinking in Education

Design thinking has gained prominence in engineering education as an effective pedagogical approach that fosters creativity, critical thinking, and real-world problem-solving skills. This user-centered methodology encourages students to empathize with end-users, define problems, ideate solutions, prototype models, and test outcomes iteratively. Recent investigation indicates that incorporating design thinking into engineering curricula significantly enhances students' ability to tackle complex and ambiguous problems (Shanta & Wells, 2020). For example, a study by Milovanovic & Katz (2021) found that engineering students engaged in design thinking projects showed improved innovation skills and greater engagement with course material. Furthermore, design thinking promotes collaboration and interdisciplinary learning, which are crucial in modern engineering practices (Panke, 2019). According to Lynch et. al. (2022), by integrating design thinking into their courses, educators can prepare students to be more adaptable and resourceful, ultimately making them better equipped to meet the evolving challenges of the engineering profession.

Broadly-Defined Engineering Problems (BDEPs)

Broadly-defined engineering problems (BDEPs) are critical components of modern engineering curricula, as they encapsulate the complexity and interdisciplinary nature of real-world challenges. Unlike narrowly defined technical problems, BDEPs require engineers to integrate knowledge across various domains, consider diverse stakeholder perspectives, and navigate ambiguous scenarios to devise effective solutions. According to recent studies, incorporating BDEPs into engineering education significantly enhances students' critical thinking, problem-solving abilities, and adaptability (Patra, 2023). For instance, Prapulla et. al. (2023) found that students who engaged with BDEPs demonstrated greater proficiency in applying theoretical knowledge to practical situations and were better prepared for professional practice. Another study conducted by Boelt et. al. (2022) showed that BDEPs promote the

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development of soft skills such as teamwork, communication, and project management, which are essential for successful engineering careers. By integrating BDEPs into the curriculum, educators can create a more holistic learning experience that aligns with industry needs and prepares graduates to tackle the multifaceted challenges of contemporary engineering practice (Guerra & Rodriguez-Mesa, 2021).

Evaluation Tools for Assessing Integrated Design Projects

The assessment of Integrated Design Projects (IDPs) for Civil Engineering undergraduate students has attracted a lot of focus in the recent past with a major emphasis on the use of rubrics or Performance Criteria Matrix (PCM) as an evaluation tool for the process. Checklists also allow for easy assessment of student performance across the various dimensions adopted covering all the laid down competencies. A particular investigation was made by Basir et. al (2019) highlighting the need for alignment of Course Outcomes (CO) and Programme Outcomes (PO) to the assessment realm of capstone projects. Thus, the study showed that through the measurement of the COs and POs with the help of rubrics, one could improve the quality of engineering graduates substantially, as it was in tune with the requirements of Industry 4.0. This kind of structural approach enables the educators to assess almost all the competencies in the engineering students whether intellectual, soft skills or even the physical dexterity to shape the students for the engineering professions of the future.

Furthermore, rubrics offer fairness and objectivity in assessment and the caters for expectation congruency between the student and the instructor. The actual study conducted by Bashir et. al (2019) provided specific and elaborated rubric for assessment of capstone projects, which indicated a possibility to define whether and to what extent the learning outcomes have been met. Through a direct connection between the project evaluation criteria and the COs and POs, the rubrics did not only enable students to learn the appropriate concepts but also provided a practical way of learning about real-life engineering problems. This method is particularly useful especially in the thrust of Industry 4.0, especially where it comes to applying technology, innovation and sustainability.

Another study by Noh et. al (2021) was based on an activity, in which an analytic rubric for continuous assessment was employed when the students were asked to design a poster that would illustrate how Dynamics principles may be applied in real life in the course of a Dynamics subject project. The analytic rubric, which included the list of the evaluation criteria, was found useful as it provided students with the structure necessary for the organization of the projects and helped to formulate their goals and concerns properly. Such rubrics enriched the relationships between learning-teaching-assessment and provided students with the direction on how they could complete tasks of the project. When the findings of the study were analyzed it was found that most students were meeting or exceeding the levels set out in the performance criteria thus further supporting the use of the rubric in enhancing both student achievement and the quality of their projects. Another example of the use of sustainable design is a study that took place in the United States by Watson et. al (2020) and dealt with the ability to develop the skills related to the Implementation of Sustaining Design in civil engineering capstone courses which utilized Sustainable Design Rubric to gauge the students work.

In combination, these investigations signal the importance of rubrics in assessing Integrated Design Projects (IDPs) in civil engineering instruction. These assessment tools provide a clear-cut approach to aiding student learning, ensure that the output of higher learning institutions

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matches the expectations of employers, and offer instructors insight into the performance of their students. Thus, using rubrics, it is possible to fulfill standards of outcome-based education and explain the expectations towards civil engineering graduates to prepare them for facing multifaceted working conditions. Furthermore, rubrics are useful in educational accountability and what is more, improvement; they act as a link between academic standards and professional experience.

Methodology

This study is centered on one of the culminating courses in Infrastructure Management Undergraduate Program. The Integrated Technology Design Project (ITDP) course is designed for final-year undergraduate students and focuses on conceiving, designing, implementing, and operating integrated civil infrastructure projects, emphasizing the development of personal, interpersonal, and engineering skills. Structured around the Design Thinking Process, the ITDP involves stages such as Empathy, Define, Ideate, Prototype, and Test. There are five (5) course outcomes (CO) for IDTP course that mapped to five (5) IHL programme outcomes (PO) as depicted in Table 2.

Table 2: Mapping of IDTP Course and Programme Outcomes

CO	Statement	IHL PO
CO1	Ability to analyze particular conditions of a project and its requirements.	PO2: Solve broadly-defined engineering problems systematically to reach substantiated conclusions, using tools and techniques appropriate to their discipline or area of specialization.
CO2	Ability to design different civil infrastructure technology system using different types of softwares and simulation tools.	PO5: Select and apply appropriate techniques, resources and modern engineering tools, with an understanding of their limitations.
CO3	Ability to enhance the project design with application of appropriate green technologies and sustainable practices.	PO8: Demonstrate an awareness of and consideration for societal, health, safety, legal and cultural issues and their consequent responsibilities.
CO4	Ability to demonstrate collaborative work through project ideas, design, and final products.	PO6: Function effectively as individuals, and as members or leaders in diverse technical teams.
CO5	Ability to develop a project management plan that consists of master works programme and related project management elements.	PO10: Demonstrate an awareness of management, business practices and entrepreneurship.

To capture the application of the Design Thinking Process throughout the course, several well-planned alternative assessments are crafted. Students work in teams to address real-world problems by empathizing with end-users, defining project challenges, generating creative solutions, prototyping, and testing their ideas. For ITDP course, alternative assessments in the form of project-based tasks are developed. Table 3 depicts the Design Thinking Process and the tasks breakdown.

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Table 3: Mapping of IDTP Course and Programme Outcomes

DT Process	Task Number	Tasks
Empathy	1	Determine the key activities and develop selected documents that are involved during pre-planning stage of given infrastructure project.
Empathy	2	Interpret data and synthesize the information given related to the project, which includes other additional data searched from other sources and standards.
Define	3	Define problem statements and determine the set objectives for the proposed problem.
Ideate	4	Propose at least two different solutions and sketches based on Task 3
Prototype	5a	Select the best solution and build a functional prototype from Task 4 based on relevant aspects (i.e feasibility, sustainability, scalability, safety, accessibility, legal and regulatory compliance, and stakeholder engagement).
Prototype	5b	Write a reflection paper related to the tasks that you have done and contributed to your group (Individual Task)
Testing	6	Present your comprehensive solution of the infrastructure project through group presentation. Engage and obtain feedback from panel to refine/improve the proposed solution.

Performance Criteria Matrix (PCM)

The Performance Criteria Matrix (PCM) is a tool used to assess and evaluate students' performance in various tasks by aligning specific criteria with desired learning outcomes and program objectives. It provides a structured framework for evaluating competencies, such as technical skills, problem-solving abilities, and adherence to professional standards, ensuring that assessments are consistent and comprehensive. This matrix also helps in identifying areas for improvement and facilitating continuous quality enhancement in the educational process.

For the ITDP Course, there are four (4) types of PCM developed to assess and evaluate students' performance. The PCMs are aligned with the CO mapped with the PO stated earlier. Table 4 indicates the Constructive Alignment between the task deliverables, CO-PO, and its PCM.

Table 4: Constructive Alignment between Project-based Task Deliverables, CO-PO and PCM

Task Number	CO-PO	Project-based Task Deliverables	Performance Criteria Matrix (PCM)
1 2 3 4 5a	CO1-PO2 CO2-PO5 CO3-PO6 CO5-PO11	1. Masterwork programmes 2. Risk Management Plan 3. Project Costing 4. Calculations 5. Software outputs 6. Simulations/Modelling	1. PCM – Interim Report 2. PCM – Final Report
5b	CO4-PO9	Reflection Paper	3. PCM - Assignment
6	CO4-PO9	Presentation Slides	4. PCM - Presentation

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To ensure alignment of task deliverables with the requirements for the Performance Criteria Matrix (PCM), several steps are undertaken. Initially, the performance criteria for each type of assessment are clearly defined. This is followed by identifying the characteristics of BDEPs and their corresponding taxonomy levels. Each course in an ETAC-accredited program is then mapped to one or more BDEPs characteristics and taxonomy levels to ensure comprehensive coverage. The performance criteria must align seamlessly with the task requirements to maintain consistency and relevance in assessments. A 5-point Likert scale is employed to develop detailed PCM descriptions for each requirement, providing a nuanced evaluation framework. Additionally, these steps facilitate continuous quality improvement by highlighting areas for enhancement and ensuring that the assessments are robust, fair, and reflective of industry standards. This structured approach not only aids in accurate performance evaluation but also enhances the overall learning experience by aligning educational outcomes with professional competencies. Figure 1 below specifies a sample PCM for the final report that incorporates BDEPs characteristics/ taxonomy level and has a weightage of 40% from the overall course marks. Additionally, Figure 2, 3 and 4 indicates the PCMs for different types of assessments; namely Presentation, Assignment and Interim Report.

Appendix B: Performance Criteria Matrix for Final Report (40%) (CO1-PO2, CO2-PO5, CO3-PO6, CO5-PO11)						
Performance Criteria	**Broadly-Defined Engineering Problem Characteristics / Taxonomy Level**	**Description of Performance Criteria**				
Introduction/ Background of Project **(Task 1)** **CO5-PO11**	**SK1:** A systematic, theory-based understanding of the natural sciences applicable to the sub-discipline and awareness of relevant social sciences **SK2:** Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed consideration and use of models applicable to the sub-discipline. **SK3:** A systematic, theory-based formulation of **engineering fundamentals** required in an accepted sub-discipline **SK4:** Engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for an accepted sub-discipline. **SK6**: Knowledge of **engineering technologies** applicable in the sub-discipline	Ability to identify the **specific or key problems of the situation** within economic, social, cultural, environmental and sustainability contexts and the consequent responsibilities based on specified knowledge profiles namely: **SK1:** Natural and Social sciences, **SK2:** Mathematics, **SK3:** Engineering Fundamentals**, SK4:** Specialist knowledge**, SK6**: Engineering technologies, **SK7:** Comprehension, **SK9:** Ethics				
		1	2	3	4	5
		Very Poor	Poor	Satisfactory	Good	Very Good
		Demonstrate only two (2) or less specified of SKs	Demonstrate only three (3) specified SKs	Acceptable demonstration of all four (4) specified SKs	Good demonstration of all four (4) specified SKs	Excellent demonstration of all four (4) specified SKs
Evaluation of identified key activities during pre-project planning (**Task 1**) **CO5-PO11**		*Ability to evaluate the key activities commonly conducted during pre-project planning stage* ***in an infrastructure project*** *relevant to professional civil engineering practices.*				
		1	2	3	4	5
		Very Poor	Poor	Satisfactory	Good	Very Good
		No evaluation of any key activities	Evaluate 1 key activity with acceptable justification	Evaluate 2 key activities with acceptable justification	Evaluate 3 key activities with acceptable justification	Evaluate more than 3 key activities with acceptable justification
Development of selected documents (Masterwork programmes, Risk Management Plan and Project Cost) **(Task 1)** **CO5-PO11**		*Ability to develop pre-project planning documents based on the information gathered from various sources including stakeholders that are relevant to the current civil engineering practices.*				
		1	2	3	4	5
		Very Poor	Poor	Satisfactory	Good	Very Good
		No development of any pre-project planning documents	Develop 3 pre-project planning documents with incomplete contents	Develop 3 pre-project planning documents with minimum contents	Develop 3 pre-project planning documents with partially minimum contents	Develop 3 pre-project planning documents with complete contents
Interpretation of data and drawings given **(Task 2)**		*Ability to analyze and comprehend data and drawings provided, and draw meaningful conclusions based on the information presented.*				

Figure 1: Sample PCM for Final Project with BDEPs Characteristics/Taxonomy Level

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Appendix C: Performance Criteria Matrix for Presentation (20%) (CO4-PO9)						
Performance Criteria	**Broadly-Defined Engineering Problem Characteristics / Knowledge Profile/ Taxonomy Level**	**1** **Very Poor**	**2** **Poor**	**3** **Satisfactory**	**4** **Good**	**5** **Very Good**
		Description of Performance Criteria				
A. Delivery of Ideas	CO4-PO9 Affective Domain – A4 (Organization) CO4: To demonstrate collaborative work through project ideas, design and final products PO9: Individual and Team Work Function effectively as an individual, and as a member or leader in diverse technical teams. LO4: To present your TDP activities using various assessment tools required (Case studies, interim and final report, group presentation)	*Ability to deliver ideas to solve the identified problems to fulfil the societal needs and requirements.*				
		1	2	3	4	5
		Not able to deliver ideas clearly and no confidences which requires major improvements.	Able to deliver ideas but lack in confidence thus, requires further improvements	Able to deliver ideas fairly, clearly and confidently which requires minor improvements	Able to deliver ideas clearly and confidently	Able to deliver ideas with great clarity and with great confidence
B. Technical/Method/Design of Presentation Material		*Ability to design the method of presentation with creativity and innovativeness (catchy & lively design, facts appropriately highlighted)*				
		1	2	3	4	5
		Design with no creativity (Straight forward bullet points/ cluttered design no graphics)	Design with lack of creativity (Straight forward bullet points/ cluttered design no graphics)	Moderate design with some creativity (simple and informative with appropriate graphics)	Good design with substantial creativity (simple, informative and facts appropriately highlighted)	Excellent design with high creativity (catchy and lively design, facts appropriately highlighted)
C. Presentation Skills		*Ability to present convincingly the creative use of engineering principles in a novel way*				
		1	2	3	4	5
		No creativity and only adapt the current techniques/ processes but not applicable to solve problems	Lack of creativity and only adapt the current techniques/ processes and applicable to solve problems	Creatively use the engineering principles to adapt current techniques/ processes to solve problems	Creatively use the engineering principles to enhance current techniques/ processes to solve problems	Very creatively use the engineering principles to enhance current techniques/ processes in modified (innovation)/

Figure 2: Sample PCM for Presentation with BDEPs Characteristics/Taxonomy Level

Appendix D: Performance Criteria Matrix for Assignment (10%) (CO4-PO9)						
Performance Criteria	**Broadly-Defined Engineering Problem Characteristics / Knowledge Profile/ Taxonomy Level**	**1** **Very Poor**	**2** **Poor**	**3** **Satisfactory**	**4** **Good**	**5** **Very Good**
		Description of Performance Criteria				
A. Role within team	CO4-PO9 Affective Domain – A4 (Organization) CO4: To demonstrate collaborative work through project ideas, design and final products PO9: Individual and Team Work Function effectively as an individual, and as a member or leader in diverse technical teams.	*Ability to understand and fulfil assigned role within the team, actively contributing towards achieving team goals*				
		1	2	3	4	5
		Do not understand assigned role within the team and do not contribute towards achieving team goals	Limited understanding on assigned role within the team and only contribute minimally towards achieving team goals	Moderate understanding of assigned role within the team and contribute adequately towards achieving team goals	Good understanding of assigned role within the team and actively contribute towards achieving team goals	Excellent understanding of assigned role within the team and consistently go above and beyond to contribute towards achieving team goals.
B. Reliability and Accountability		*Ability to demonstrate reliability and accountability by completing assigned tasks on time.*				
		1	2	3	4	5
		Frequently fail to complete assigned tasks on time and struggle with reliability and accountability	Occasionally struggle to complete assigned tasks on time. Reliability and accountability could be improved	Generally complete assigned tasks on time and demonstrate moderate reliability and accountability	Consistently complete assigned tasks on time and demonstrate good reliability and accountability	Always complete assigned tasks on time and consistently demonstrate exceptional reliability and accountability
C. Participation		*Ability to actively participate in team discussions and contribute creative solutions to problems*				
		1	2	3	4	5
		Rarely participate in team discussions and struggle to	Occasionally participate in team discussions and have difficulty	Generally participate in team discussions and contribute	Actively participate in team discussions and consistently	Enthusiastically participate in team discussions and consistently

Figure 3: Sample PCM for Assignment with BDEPs Characteristics/Taxonomy Level

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Appendix A: Performance Criteria Matrix for Interim Report (30%) (CO1-PO2, CO2-PO5, CO3-PO6, CO5-PO11)						
Performance Criteria	**Broadly-Defined Engineering Problem Characteristics / Taxonomy Level**	**Description of Performance Criteria**				
Introduction/ Background of Project **(Task 1)** **CO5-PO11**	**SK1:** A systematic, theory-based understanding of the natural sciences applicable to the sub-discipline and awareness of relevant social sciences **SK2:** Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed consideration and use of models applicable to the sub-discipline. **SK3:** A systematic, theory-based formulation of **engineering fundamentals** required in an accepted sub-discipline **SK4:** Engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for an accepted sub-discipline. **SK6**: Knowledge of **engineering technologies** applicable in the sub-discipline	Ability to identify the **specific or key problems of the situation** within economic, social, cultural, environmental and sustainability contexts and the consequent responsibilities based on specified knowledge profiles namely: **SK1:** Natural and Social sciences, **SK2:** Mathematics, **SK3:** Engineering Fundamentals, **SK4:** Specialist knowledge, **SK6**: Engineering technologies, **SK7:** Comprehension, **SK9:** Ethics				
		1	2	3	4	5
		Very Poor	Poor	Satisfactory	Good	Very Good
		Demonstrate only two (2) or less specified of SKs	Demonstrate only three (3) specified SKs	Acceptable demonstration of all four (4) specified SKs	Good demonstration of all four (4) specified SKs	Excellent demonstration of all four (4) specified SKs
Evaluation of identified key activities during pre-project planning (**Task 1**) **CO5-PO11**		*Ability to evaluate the key activities commonly conducted during pre-project planning stage* ***in an infrastructure project*** *relevant to professional civil engineering practices.*				
		1	2	3	4	5
		Very Poor	Poor	Satisfactory	Good	Very Good
		No evaluation of any key activities	Evaluate 1 key activity with acceptable justification	Evaluate 2 key activities with acceptable justification	Evaluate 3 key activities with acceptable justification	Evaluate more than 3 key activities with acceptable justification
Development of selected documents (Masterwork programmes, Risk Management Plan and Project Cost) **(Task 1)** **CO5-PO11**		*Ability to develop pre-project planning documents based on the information gathered from various sources including stakeholders that are relevant to the current civil engineering practices.*				
		1	2	3	4	5
		Very Poor	Poor	Satisfactory	Good	Very Good
		No development of any pre-project planning documents	Develop 3 pre-project planning documents with incomplete contents	Develop 3 pre-project planning documents with minimum contents	Develop 3 pre-project planning documents with partially minimum contents	Develop 3 pre-project planning documents with complete contents
Interpretation of data and drawings given **(Task 2)**		*Ability to analyze and comprehend data and drawings provided, and draw meaningful conclusions based on the information presented.*				

Figure 4: Sample PCM for Interim Report with BDEPs Characteristics/Taxonomy Level

This study employed a qualitative approach to gather comprehensive data from a cohort of 88 students enrolled in the IDTP course. This method facilitated a deeper understanding of quality improvements in teaching, learning, and assessment within the ITDP course. Each student was evaluated using four PCMs as shown in Figure 1,2,3 and 4, and their marks were systematically recorded in the Integrated Management System (IMS) for Academic at the IHL. The IMS serves as a centralized platform for storing academic data, including teaching plans, student evaluations, course reports, and final results from various programs. This system analyses the data based on several criteria necessary for grade endorsement at the end of each semester. These criteria include Course Outcome (CO) and Program Outcome (PO) attainment, mark distribution, and the Continual Quality Improvement (CQI) report. Furthermore, this structured data management and analysis process ensures that the academic performance and progress of students are meticulously tracked and reviewed, contributing to enhanced educational outcomes and institutional accountability.

Findings and Discussion

Figure 5 illustrates a bar chart depicting the normalized attainment of course outcomes (COs) with three distinct data sets for each outcome within the ITDP course for the specified semester. The height of each bar indicates the percentage achievement of a particular course outcome, reflecting the average performance of students.

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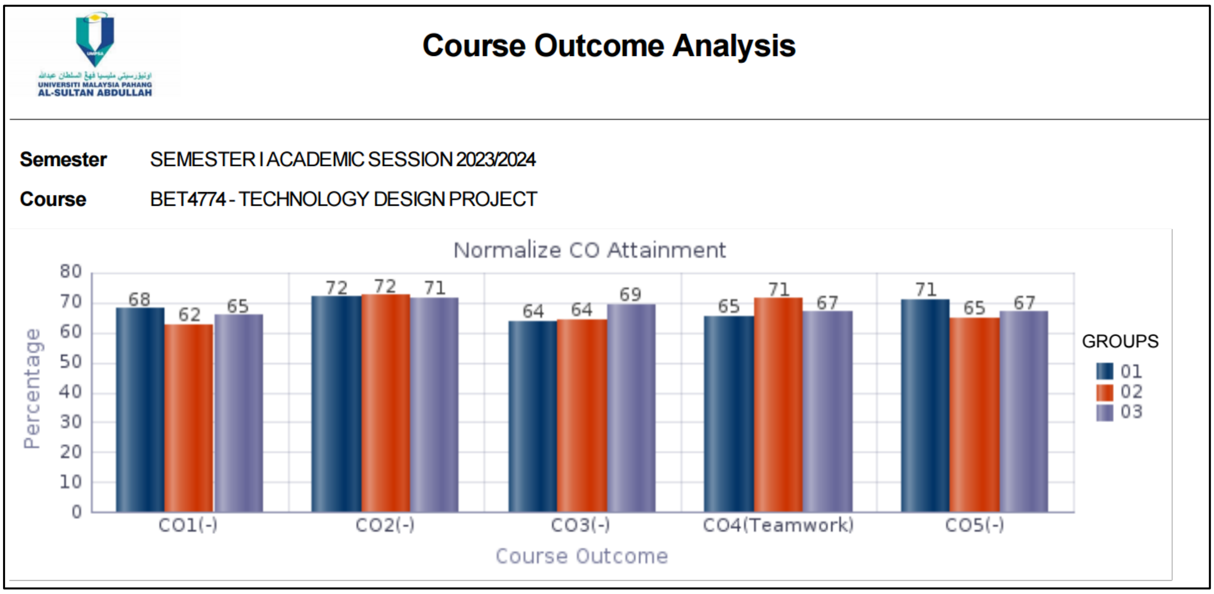

Figure 5: Normalized Course Outcome Attainment

As shown in Figure 5, each CO is aligned with specific POs, namely PO2, PO5, PO6, PO8, and PO12. CO2 shows the highest overall attainment across all groups, with Groups 1 and 2 achieving 72% and Group 3 achieving 71%. CO1 shows the most variation between groups, with Group 1 achieving 68%, while Group 2 has the lowest score at 62%. Additionally, CO3 shows improvement from Group 1 and 2 (both at 64%) to Group 3 (69%). CO4, which is specifically labeled as "Teamwork", indicates Group 2 performing the best at 71%, followed by Group 3 at 67%, and Group 1 at 65%. CO5 shows Group 1 performing the best at 71%, while Groups 2 and 3 are lower at 65% and 67% respectively. Overall, the attainment levels across all COs and groups range from 62% to 72%, indicating generally consistent performance with some areas for potential improvement. No group consistently outperforms the others across all outcomes, suggesting that each group has different strengths and weaknesses in relation to the course outcomes.

This variation shows that in addition to project-based evaluations or performance tasks, it is effective to use performance criteria matrix together and get a more comprehensive look at the students' learning process. Each CO probably corresponds to specific learning outcomes, design abilities, technical content, and collaborative effort, for instance, which are evaluated differently. The performance criteria matrix assists in measuring performance and making it reasonable to compare the achievements. It also uses information to pinpoint areas that may require more support from the students or where instructions could modify to improve the degree of the course outcomes. Although the normative data of the assessments have not been defined comprehensively, CO4 which focuses on teamwork implies that collaborative skills are important in this course, and that different forms of assessment might be more useful than standardized tests in the assessment of those skills.

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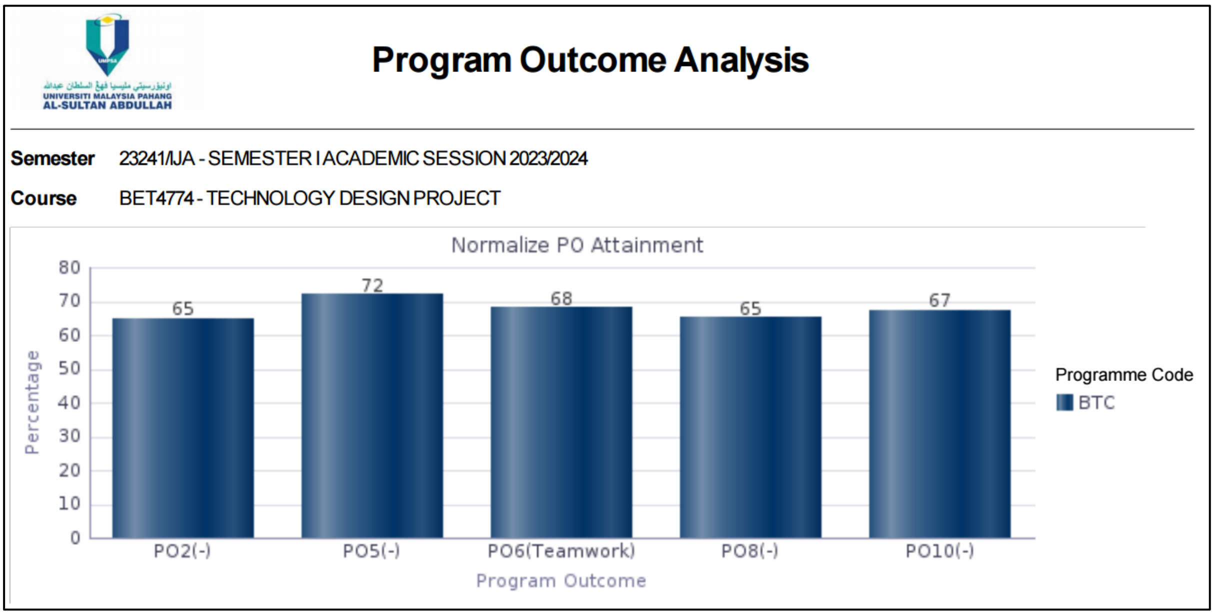

Figure 6: Normalized Programme Outcome Attainment

The analysis of the PO attainment for the BET4774 Technology Design Project in Figure 6 indicates that the program attained different outcomes unevenly at different degrees with five program outcomes established. The overall mean attainment achieved for all the POs is 67.4%. The highest attainment is as observed in PO5 at 72% while the lowest outcomes are observed in PO2 & PO8 which both stand at 65%. From this data, one can surmise that the programme overall is effective in fulfilling most of its educational goals and objectives although there is a slight variation in the effectiveness of achieving all the intended outcomes. The high percentage in PO5 shows that the course does well in this area of learning while the low one in PO2 and PO8 tells it could improve on the curriculum delivery or use other approaches to enhance lessons.

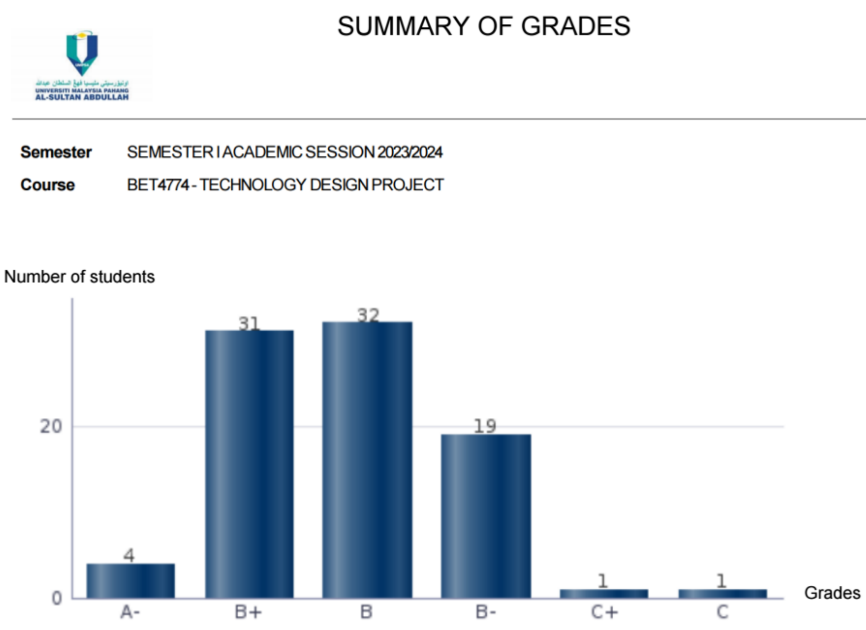

Figure 7: Grade Distribution

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The grade analysis of BET4474 Technology Design Project in Figure 7 shows a bell-shaped curve with a right-skewed distribution. Most of the students seem to have done well since 32 of them scored B+ while 32 others scored B which is the highest frequency in the distribution. At the lower extreme, 19 students got B- while 2 students got C+ and 1 student got C At the higher extreme, 4 students got A and these are top performing students. With this distribution, it can be concluded that the level of difficulty was properly set in order not to allow all the students to easily score high, although demanding enough to set a differentiation between the student’s performance. This pattern highlights the need for further analysis to understand the factors influencing this distribution and to ensure that the assessment methods accurately reflect student performance and learning outcomes.

Conclusions

The study presents an assessment tool that is developed by the principles of a performance criteria matrix that refers to the course and program objectives, as well as BDEP (SP) and related SK characteristics. The studies prove that the assessment methods facilitated the intended learning outcomes fulfilling the current ETAC Standard 2020 while aligning to the new GAPC201 requirements which are incorporated in the new ETAC Standard 2024. However, the study becomes relevant in encouraging lecturers to embark on Continual Quality Improvement (CQI) to improve not only the delivery of instructional content but also the assessment of instructional content in subsequent assessment cycles. This is in accord with the current literature, which emphasizes the effect of the assessment instruments like rubrics as being crucial in enhancing students learning, making sure that the end-product developed meets the employer's expectations, and availing a mechanism for bridging the gap between what is taught in the classroom and the real-world practice. Therefore, rubrics or PCM not only explain what is expected of civil engineering learners but also enhance accountability of education and sustainable development. Consequently, the study calls for a continuous assessment and modification of the strategies towards enhancement of the inevitability of achievement of the intended learning outcomes within the engineering education sector to correspond to the lofty set standards.

Future research should focus on exploring additional innovative assessment methods that further enhance the alignment with new ETAC Standard 2024 which has been released recently in 2024 and improve the attainment of learning outcomes. One area of exploration could be the integration of advanced digital tools and simulations to provide more immersive and practical assessment experiences. Additionally, longitudinal studies tracking the performance and professional success of students who have undergone these alternative assessments could provide valuable insights into their long-term effectiveness. It is also recommended to involve industry stakeholders in the assessment design process to ensure that the skills and competencies being evaluated are directly relevant to current professional demands. Moreover, expanding the sample size and including diverse engineering disciplines could help generalize the findings and identify specific areas for improvement across different contexts. Lastly, fostering a feedback loop involving students, educators, and industry experts can drive the continuous improvement of assessment strategies, ensuring they remain dynamic and responsive to evolving educational and industry needs.

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