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ASSESSING PROGRAM OUTCOMES ATTAINMENT IN REINFORCED CONCRETE DESIGN COURSE: A FIVE-SEMESTER LONGITUDINAL ANALYSIS

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Abstract:

This longitudinal study investigates the attainment of two key Program Outcomes (POs), PO2 (Problem Analysis) and PO3 (Design/Development of Solutions) in a third-year undergraduate Reinforced Concrete Design course at a Malaysian public university. Data spanning five semesters, from 20214 to 20234, were collected and analysed using both direct assessment (exam and project scores) and indirect assessment (entry-exit surveys). The study aimed to identify trends, variations, and areas for improvement in the course's effectiveness in achieving its educational objectives. Direct assessment results revealed a fluctuating trend in PO2 attainment, with a significant decline in the most recent semester (20234). Conversely, PO3 attainment showed a generally positive trend, although with some fluctuations. The gap analysis of survey data indicated that most students perceived an improvement in their competencies upon completing the course, with a higher frequency of substantial gains in PO3 compared to PO2. The findings underscore the need for targeted interventions to address the declining trend in PO2 attainment, potentially through revisiting instructional methods and providing additional support for problem-solving skills. The study also highlights the importance of continuous assessment and improvement in engineering education to ensure that graduates are equipped with the necessary skills and knowledge to excel

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in the field of reinforced concrete design. The research contributes valuable insights to the ongoing conversation about enhancing the quality and effectiveness of engineering education in Malaysia.

Keywords:

Program Outcomes (POs), Educational Assessment, Reinforced Concrete Design, Accreditation Standard

Introduction

In the realm of higher education, particularly in engineering education, Outcome-Based Education (OBE) has gained prominence as a pedagogical approach aimed at ensuring graduates possess the necessary knowledge, skills, and attributes for success in their respective fields (Finkelstein et al., 2013). The concept of OBE is globally recognised as an effective educational system to ensure the quality of graduates (Wesarat et al., 2022). OBE shifts the focus from traditional input-based teaching to a student-centric approach that emphasizes measurable outcomes. According to Harden (2002), OBE strongly focuses on achieving predetermined learning goals that prepare students to tackle the challenges of the twenty-first century. In the realm of engineering education, OBE has been embraced by accreditation bodies like the Engineering Accreditation Council (EAC) in Malaysia, as it aligns with the global need for engineers who can address complex societal challenges. The EAC in Malaysia strongly encourages all engineering programs to implement OBE in their curriculum activities, including continuous quality improvement (CQI) regularly (Pasya et al., 2015).

The cornerstone of OBE lies in the articulation of clear and measurable Program Outcomes (POs). These POs define the competencies that graduates are expected to achieve upon completion of their program. The EAC has established a framework of 12 POs that encompass a wide range of knowledge, skills, and attributes deemed essential for engineering graduates:

1. **Engineering Knowledge:** An ability to apply knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem Analysis:** An ability to identify, formulate, research literature, and analyse complex engineering problems to reach substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/Development of Solutions:** An ability to design solutions for complex engineering problems and design systems, components, or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
4. **Investigation:** An ability to conduct investigations of complex problems using research-based knowledge and research methods, including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.
5. **Modern Tool Usage:** An ability to create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering activities, with an understanding of the limitations.
6. **The Engineer and Society:** An ability to apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to professional engineering practice.

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7. **Environment and Sustainability:** An ability to understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.
9. **Individual and Team Work:** Able to function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.
10. **Communication:** Able to communicate effectively on complex engineering activities with the engineering community and with society at large.
11. **Project Management and Finance:** Able to demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life Long Learning:** Able to recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Background of Study

The Reinforced Concrete Design course is a core component of the civil engineering undergraduate curriculum, building upon foundational knowledge acquired in earlier coursework. The course equips students with the theoretical understanding and practical skills necessary to design reinforced concrete structures, a fundamental aspect of civil engineering practice. This study specifically focuses on PO2 (Problem Analysis) and PO3 (Design/Development of Solutions) within the context of a Reinforced Concrete Design course. These two POs are of particular importance in civil engineering, as they directly relate to the core competencies required for designing safe, efficient, and sustainable structures. By assessing student attainment of PO2 and PO3, this research provides valuable insights into the effectiveness of the course in preparing students for the specific challenges of Reinforced Concrete Design. However, it is important to acknowledge that these two POs are just a subset of the broader set of 12 POs outlined in the EAC Standard 2020.

Assessing POs presents unique challenges, including the complexity of defining and measuring complex competencies, the need for longitudinal tracking of student progress, and the potential for bias in self-assessment. In investigating the challenges face by employing OBE in undergraduate curriculum, Deutscher & Winther (2018) highlighted the significance of ensuring that assessment practices are aligned with instructional goals and learning objectives, in order to enhance the relevance and usefulness of the assessment data. Shuman et al. (2005) discussed the teaching and assessment of professional skills, which are essential components of OBE. Passow (2012) explored the competencies deemed important for engineering graduates, aligning with the focus on measurable POs in OBE. Liew et al. (2021) and Liew & Kiew (2022) emphasised the evaluation of learning outcomes and sustainable assessment practices, crucial aspects in OBE implementation. While, Noh et al. (2023) specifically addressed the correlation of student attainment in civil engineering design projects, reflecting the practical application of OBE principles in engineering courses. These references collectively contribute to the understanding of how OBE, particularly in the context of engineering education, can be effectively implemented, assessed, and continuously improved to ensure graduates are equipped with the necessary knowledge, skills, and attributes for professional practice.

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In the specific context of Reinforced Concrete Design, PO2 is crucial for understanding structural behaviour, identifying design challenges, troubleshooting and mitigation in the event of structural failures or performance issues in civil engineering practices. On the other hand, PO3 is crucial for designing safe and durable structures, optimising material usage, and incorporating emerging technologies. Study by Kumar et al. (2021) provided insights into course and program outcomes attainment, which can be applied to evaluate student attainment of specific learning outcomes like PO2 and PO3. In addition, Rajak et al. (2019) discussed on conducting the evaluation on programme outcomes, which can be useful in assessing the effectiveness of educational interventions in improving student attainment of PO2 and PO3.

While there is a growing body of research on PO assessment in engineering education, studies specifically focusing on reinforced concrete design courses in the Malaysian context remain limited. This study aims to fill this gap by conducting a longitudinal analysis of PO attainment in a Reinforced Concrete Design course, utilising both direct and indirect assessment methods. The findings will provide valuable insights into the effectiveness of the course and offer recommendations for improvement, contributing to the ongoing efforts to enhance engineering education quality in Malaysia.

Methodology

This study encompasses a comprehensive assessment of program outcomes (POs) attainment within the third-year undergraduate course "Reinforced Concrete Design" at a Malaysian public university. The research specifically focuses on two critical POs: PO2 (Problem Analysis) and PO3 (Design/Development of Solutions), which are central to the development of competent civil engineers. This study involved all students enrolled in the Reinforced Concrete Design course over five consecutive semesters, spanning from 20214 to 20234 (most recent semester). The total sample size consisted of 567 students, providing a substantial dataset for analysis.

In the pursuit of effective engineering education, the assessment of Program Outcomes (POs) plays a pivotal role in gauging the knowledge and skills acquired by students. This analysis delves into the assessment tools employed in a Reinforced Concrete Design course over five semesters at a Malaysian public university, examining their effectiveness in measuring student attainment of PO2 (Problem Analysis) and PO3 (Design/Development of Solutions).

Three primary assessment tools were utilised throughout the five semesters:

1. **Common Test:** This standardised assessment measuring students' foundational knowledge and understanding of key concepts in reinforced concrete design. This test was typically administered midway through the semester and provided a snapshot of students' grasp of theoretical principles and problem-solving design cases, providing insights into students' grasp of core principles.
2. **Mini Project:** This tool offered a more hands-on and practical evaluation of students' abilities. Mini projects involved designing reinforced concrete elements such as slabs, beams, and columns, analysing different load scenarios, and applying theoretical knowledge to real-world applications. This assessment likely provided a deeper understanding of students' capacity to integrate and apply their learning.
3. **Final Examination:** As the cumulative assessment, the final examination encompassed a comprehensive analysis and design skills covered throughout the course. The final

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examination evaluated students' ability to synthesize information, analyse complex problems, and demonstrate mastery of reinforced concrete design principles.

Average scores for each assessment tool (common test, mini project, and final examination) were compiled for all five semesters. This quantitative data served as the primary basis for analysing PO attainment trends and variations across semesters. Table 1 presents the true PO attainment for the three assessment tools used which are common test, mini project and final examination.

Table 1: Raw Data of PO Attainment for 5 Semesters

	20234		20232		20224		20222		20214	
	PO2	**PO3**	**PO2**	**PO3**	**PO2**	**PO3**	**PO2**	**PO3**	**PO2**	**PO3**
Common Test	32.61	62.78	46.47	58.31	58.80	45.17	50.99	35.81	70.11	30.38
Mini Project	83.54	82.75	83.99	84.15	87.73	88.41	83.18	81.64	53.16	57.30
Final Examination	39.13	50.68	52.69	46.88	52.13	35.48	61.19	49.58	59.78	68.25

Results and Discussions

Comparative Analysis of Assessment Tools:

By analysing the average scores across the five semesters reveals intriguing patterns in student performance, the evaluation can be conducted from the mini project consistency, common test variation and the final examination fluctuation observations. The mini project consistently yielded the highest average scores across all semesters, indicating that students generally excelled in applying their knowledge to practical design tasks. This suggests that the mini project effectively assessed students' ability to integrate and utilise their learning in a meaningful way. The consistent success of students in mini projects underscores the importance of hands-on, application-oriented assessments in engineering education. Educators should continue to incorporate and potentially expand project-based learning experiences to reinforce theoretical knowledge and enhance practical skills.

The second direct measurement tool is the common test. The common test scores exhibited the most significant variation across semesters, particularly for PO2 (Problem Analysis). This fluctuation could be attributed to several factors, such as differences in test difficulty, variations in student preparedness, or changes in instructional approaches between semesters. Further investigation is needed to pinpoint the exact causes of this variability. As there are variability in common test scores, especially for PO2, it is suggesting the need for a more standardised approach to this assessment. Educators should carefully review the test content and format to ensure consistency across semesters. Additionally, providing targeted support and resources to students before the test could help mitigate performance fluctuations.

The largest component in the assessment tool is the final examination. The final examination scores also showed some fluctuation across semesters. This could be due to the cumulative nature of the exam, which may amplify any existing gaps in student understanding. Additionally, the final exam might be more susceptible to external factors, such as stress or time constraints, which could impact performance. Educators may consider implementing

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more comprehensive review sessions, practice exams, or other strategies to help students consolidate their knowledge and prepare effectively for the cumulative assessment.

In terms of assessment, the variability in common test and final exam scores reflects the ongoing challenges in evaluating higher-order thinking skills within engineering curricula. Existing literature underscores the difficulty of accurately measuring these skills, as traditional assessment methods often fail to capture the depth of students' analytical and evaluative capabilities (Yusnadi et al., 2020; Setyowati, 2023). For example, Oduro-Okyireh's study revealed that while mathematical knowledge is crucial for engineering success, the application of this knowledge through higher-order thinking is what ultimately mediates student achievement. This aligns with findings from Kelley et al., who noted that engineering design courses significantly enhance students' conceptual understanding and performance in standardized assessments, suggesting that the design process itself is a critical factor in developing higher-order thinking (Oduro-Okyireh, 2023).

Overall, the mean scores across all semesters and POs reveal that students performed exceptionally well in the Mini Project (mean = 79.25), showcasing their proficiency in applying theoretical knowledge to practical design scenarios. The Common Test and Final Examination yielded comparable mean scores (52.03 and 51.03, respectively), suggesting a balanced assessment of foundational knowledge and cumulative understanding in reinforced concrete design.

Average PO Attainment

The consistent assessment of POs serves as a cornerstone for evaluating the effectiveness of academic programs, particularly in engineering disciplines where specific competencies are crucial for professional success. This longitudinal analysis focuses on the average attainment of two critical POs, i.e. PO2 (Problem Analysis) and PO3 (Design/Development of Solutions) in a Reinforced Concrete Design course offered at a Malaysian public university over five semesters. The data, meticulously gathered and analysed, unveils intriguing trends and provides valuable insights into student learning outcomes and the course's overall efficacy.

Figure 1 shows the average attainment percentages for PO2 and PO3 across five different semesters (20234, 20232, 20224, 20222, and 20214). The data reveals a notable decline in the average attainment of PO2 over the five semesters. In the initial semester (20214), students achieved an average of 62.59%, demonstrating a relatively strong grasp of problem analysis in the context of reinforced concrete design. However, this proficiency steadily decreased, reaching a low of 41.18% in the most recent semester (20234). Several factors could contribute to this decline, including potential changes in instructional strategies, variations in assessment rigor, or shifts in the student cohort's overall preparedness. A deeper investigation is warranted to pinpoint the exact causes and implement targeted interventions. As demonstrated by Zahid et al. (2023), the study provides insights into the effectiveness of intervention strategies in improving student outcomes, which could be valuable in understanding how interventions may impact the attainment of PO2 in addressing the decline in PO2 attainment. The declining trend in PO2 attainment necessitates immediate attention by investigating potential causes and implementing remedial measures. This could involve revisiting instructional strategies, enhancing problem-solving exercises, or providing additional support resources to students who struggle with problem analysis.

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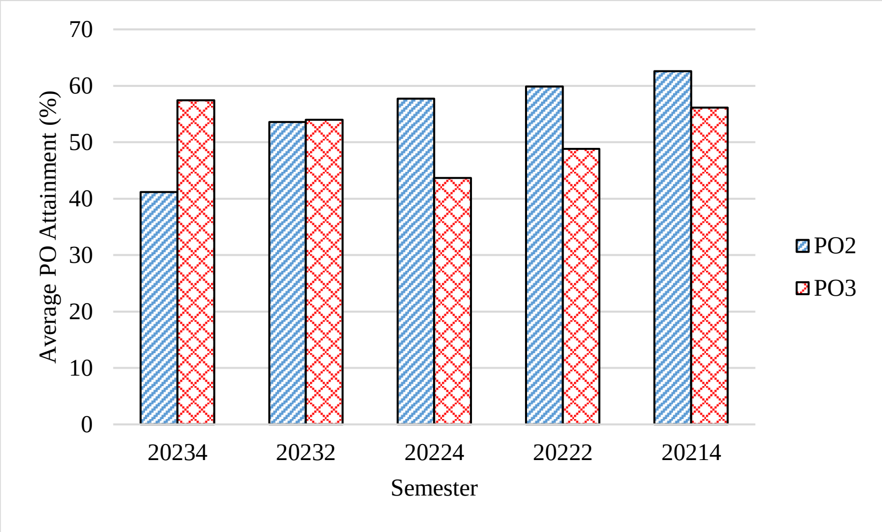

Figure 1: Average PO Attainment for 5 Consecutive Semesters

On the other hand, the attainment of PO3 exhibits a less linear pattern compared to PO2. The highest average (57.45%) was observed in the 20234 semester, while the lowest (43.66%) occurred in the 20224 semester. This fluctuation suggests that students' ability to design and develop solutions for reinforced concrete structures may be influenced by factors beyond the course itself, such as individual learning styles, external commitments, or variations in project complexity. This finding aligns with the notion that different components of a course can influence student outcomes differently (Lewis et al., 2020).

Overall, the mean scores across all semesters and POs reveal that students performed exceptionally well in the Mini Project (mean = 79.25), showcasing their proficiency in applying theoretical knowledge to practical design scenarios. The Common Test and Final Examination yielded comparable mean scores (52.03 and 51.03, respectively), suggesting a balanced assessment of foundational knowledge and cumulative understanding in reinforced concrete design. However, the standard deviations, ranging from 10.21 to 24.31 for PO2 and 14.56 to 25.14 for PO3, highlight the variability in student performance across these assessments, indicating a need for further investigation into the factors influencing this fluctuation.

Across all five semesters, the average attainment of PO2 consistently exceeded that of PO3. This indicates that students generally find problem analysis more challenging than design and development within the context of this course. This observation may stem from the inherent complexity of problem analysis, which often requires a deeper understanding of theoretical principles and the ability to apply them to novel situations. Given the consistent gap between PO2 and PO3 attainment, educators should consider strategies to bridge this divide. This could involve incorporating more design-oriented activities into problem-solving exercises, providing more explicit guidance on problem-solving methodologies, or adjusting assessment weights to strategise a more balanced development of both skills. In the 20232 semester, the attainment of PO2 and PO3 was nearly identical (53.59% and 53.98%, respectively). This suggests that, during this particular semester, students demonstrated a more balanced proficiency in both problem analysis and design. Further investigation is needed to determine the specific factors that contributed to this outcome.

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Percentage Passes for PO Attainment > 50%

The effectiveness of educational programs, particularly in engineering disciplines where specific competencies are crucial for professional success. This longitudinal analysis delves into the attainment rates of two key POs. Figure 2 demonstrates the percentage passes of PO attainment which exceeds 50%. The percentage of students achieving PO2 above 50% fluctuated considerably across semesters. The highest percentage (91.49%) was observed in semester 20214, while the lowest (18.52%) occurred in the most recent semester, 20234. This substantial variability underscores the need for a deeper investigation into the factors influencing student performance in problem analysis. Several potential factors could contribute to this fluctuation, including changes in instructional methods, variations in assessment difficulty, student preparedness, or even external factors such as academic workload or personal circumstances. A comprehensive analysis of these factors is crucial for developing targeted interventions to improve PO2 attainment. Given the fluctuating and, in the most recent semester, low attainment of PO2, targeted interventions are necessary to improve students' problem-solving skills which may include revising instructional methods to explicitly teach problem-solving strategies and critical thinking skills, providing more diverse and challenging problem-solving exercises throughout the semester and ensuring that assessments adequately test students' ability to analyse complex problems and apply theoretical knowledge to real-world scenarios.

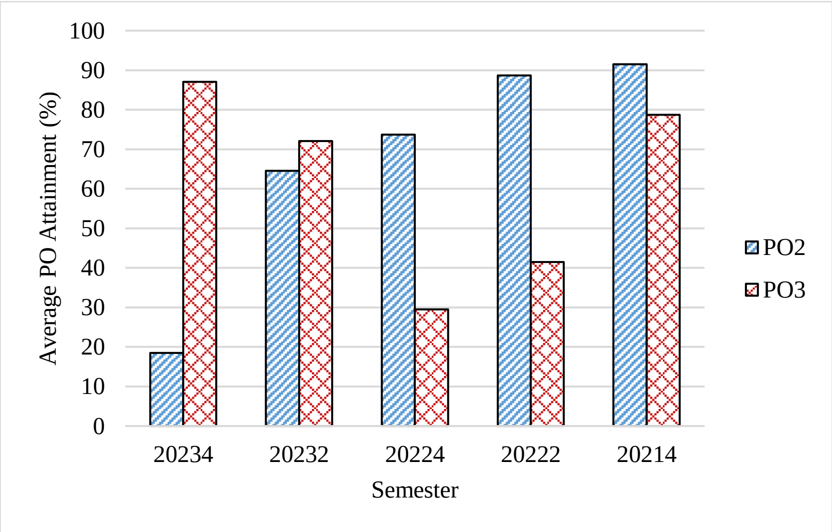

Figure 2: Percentage Passes for PO Attainment Across 5 Semesters

Despite some fluctuations, the percentage of students achieving PO3 above 50% generally remained above 40%, with an increasing trend observed over time. The most recent semester (20234) recorded the highest percentage (87.04%), indicating that a significant majority of students are demonstrating proficiency in designing and developing solutions for reinforced concrete structures. While the overall trend is positive, there is still room for improvement. The lowest percentage (29.47%) occurred in semester 20224, suggesting that specific cohorts may require additional support or targeted interventions to ensure consistent achievement of PO3. Study by Espinoza & Genna (2021) demonstrated the effectiveness of interventions, such as teaching self-regulatory strategies, in improving Grade Point Averages (GPAs) suggesting that implementing interventions tailored to address the challenges faced by students in achieving PO3 could lead to enhanced outcomes.

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In all semesters except 20224, a higher percentage of students achieved PO3 above 50% compared to PO2. This indicates that, in general, students find it easier to demonstrate proficiency in designing and developing solutions than in analysing complex problems related to reinforced concrete design. The 20224 semester stands out as an anomaly, with a high percentage of students achieving PO2 above 50% (73.68%) but a significantly lower percentage achieving PO3 above 50% (29.47%). This discrepancy warrants further investigation to understand the specific circumstances that led to this outcome and to identify potential areas for improvement in both PO2 and PO3 instruction and assessment.

Indirect PO Attainment for Entrance – Exit Survey

The assessment of POs in engineering education relies on both direct (e.g., exams) and indirect (e.g., surveys) measures. This analysis delves into the entry-exit survey data, examining student self-perceived learning gains over five semesters. The gap analysis methodology used here offers unique insights into the course's effectiveness in fostering specific competencies. Gap analysis is a method of evaluating the difference between the desired state (what students should know or be able to do) and the actual state (what they currently know or can do). In this context, students were asked to rate their competency in various areas related to Reinforced Concrete Design on a scale of -1 to 4, both at the beginning and end of the course. A positive gap indicates perceived improvement, while a negative gap suggests a perceived decline in competency.

Table 2 summarises the frequency distribution of gap scores across the five semesters. Most students in all semesters reported positive gaps, indicating that they perceived an improvement in their competencies related to reinforced concrete design after completing the course. This is an encouraging finding, suggesting that the course is generally effective in achieving its educational objectives. Over the five semesters, there seems to be a gradual shift towards higher gap scores, particularly in the 3 and 4 categories. This could imply that the course has become more effective over time in fostering significant learning gains for students. However, it's also important to consider that students' self-assessments might be influenced by external factors, such as increased confidence or familiarity with the subject matter.

Table 2: Entrance-Exit Survey Gap Analysis for both POs

Semester	-1	0	1	2	3	4
20234	0	19	69	98	209	242
20232	0	5	51	74	166	208
20224	0	6	32	61	146	141
20222	0	0	2	35	68	171

From Table 2, each semester exhibits unique patterns in the gap distribution. For example, in semester 20234, the most frequent gap score is 4, indicating that many students reported substantial improvements in their competencies. Conversely, in semester 20222, the distribution is more evenly spread across the positive gap categories, suggesting a more diverse range of perceived learning gains. Notably, there are very few or no instances of negative gaps across all semesters. This implies that students generally do not feel that their competencies have declined after taking the course. This is a positive finding, as it suggests that the course does not inadvertently hinder students' learning or confidence.

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Conclusion

This study investigated the attainment of two critical POs, i.e. PO2 (Problem Analysis) and PO3 (Design/Development of Solutions) in a Reinforced Concrete Design course at a Malaysian public university across five semesters. Employing both direct assessment (exam scores, projects) and indirect assessment (entry-exit surveys), the research aimed to provide a comprehensive understanding of student learning outcomes and course effectiveness. The consistent success in mini projects highlights the effectiveness of project-based learning, while the variability in common test and final exam scores suggests areas for improvement in assessment design and student support. While the course has generally been effective in fostering the development of design and development skills (PO3), the fluctuating and declining trend in problem analysis skills (PO2) raises concerns. The data suggests that while most students perceive an improvement in their competencies upon completing the course, there is a need for targeted interventions to address the specific challenges related to problem analysis.

The findings underscore the importance of continuous assessment and improvement in engineering education. Educators should consider revisiting instructional methods for PO2, potentially incorporating more problem-solving exercises, workshops, or tutorials. Additionally, the curriculum could be revised to ensure a more balanced emphasis on both problem analysis and design skills, potentially through integrating problem-solving elements into design projects. Further study could delve deeper into the factors influencing the variability in PO attainment, such as individual learning styles, teaching methods, and assessment design. By understanding these factors, educators can tailor their instructional strategies to better support student learning and ensure consistent attainment of POs. Ultimately, the goal is to equip graduates with the comprehensive skillset needed to excel in the field of reinforced concrete design and contribute to the advancement of the civil engineering profession. This study serves as a valuable contribution to the ongoing conversation about engineering education in Malaysia, highlighting the importance of continuous assessment and improvement of course curricula and pedagogical approaches to ensure that graduates are well-prepared for the challenges of the modern engineering landscape.

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