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ENHANCING STUDENT PERFORMANCE AND PROBLEM ANALYSIS ATTAINMENT THROUGH INTENSIVE CLASSES IN SOLID MECHANICS

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Abstract:

The Solid Mechanics course offered to undergraduate students of the Diploma in Civil Engineering programme at the Faculty of Civil Engineering, Universiti Teknologi MARA (UiTM) Johor Branch, Pasir Gudang Campus, has consistently recorded high failure rates and persistent challenges in students' attainment of Problem Analysis (PO2), one of the key Programme Outcomes (PO) in engineering education. Intervention by conducting intensive classes prior to the test and final examination was implemented for Semester October 2025-February 2026 (Semester 20254). The first intensive class was conducted one week prior to test; all students were assigned a set of test questions and prepare their solutions in advance before the date of intensive class. Lecturers demonstrated solutions in detail and students cross-checked their solutions, thereby improving their understanding on the application of fundamental concepts in solving problems related to stress and strain, and analysis of beams. Another intensive class prior to the final examination, students were required to solve one set of past final examination paper in group and presented solutions during the intensive class. Lecturer commented and provided feedback on the

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solutions, and the corrected version of answers will be shared with peers through a shared Google Drive folder. The objective of this study is to assess the effectiveness of intensive classes on the overall performance of students in Solid Mechanics and attainment of PO. Comparisons in terms of failure rate, percentage of Grade A, average marks of PO were made with the semester without intervention i.e. Semester October 2024-February 2025 (Semester 20244) that had almost identical cohort. A detailed analysis on the attainment of each PO in three assessments, namely test, assignment and final examination was made. Merits and limitations of the current intervention are discussed in detail, and suggestions on strategies to improve current intervention are made in the framework of Continual Quality Improvement (CQI). The intervention reduced the failure rate from 31% to 23%, increased the proportion of students achieving Grade A from 2% to 7%, and improved overall PO1 attainment from 52% to 60%, while PO2 attainment remained unchanged at 49%.

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Keyword:

Applying knowledge, Failure rate; Problem Analysis; Programme outcomes; Solid Mechanics

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Introduction

Solid Mechanics course (ECS226) is a core course offered every semester by the Faculty of Civil Engineering, Universiti Teknologi MARA (UiTM) for undergraduate students pursuing the Diploma in Civil Engineering (CEEC110) programme. Generally, students are eligible to register this course in their second semester, provided they have successfully passed Physics course during the first semester. The CEEC110 programme admits students through two annual intakes, consisting of a major and minor intake. Consequently, student enrolment for Solid Mechanic course fluctuates between semesters, resulting in alternate large and small number of students enrolled to this course. Typically, Semester March-August is regarded as large cohort and Semester October-February is considered as small cohort.

Solid Mechanics course has consistently been identified as one of the most challenging core courses with higher failure rate if compared with other core courses in the faculty. The highest failure rate was recorded as 65% during Semester March-August 2018 and a forensic investigation on high failure rate was conducted by Wee et al. (2021), found out the most solid reason was students had little time to acquire a deep understanding of the Solid Mechanics course. This finding can be explained through Cognitive Load Theory (CLT), when students were required to learn complex concepts within a limited timeframe, their working memory becomes overloaded, and they may struggle to develop understanding and analytical skills.

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In Malaysia, Outcome-Based Education (OBE) framework is implemented for both local and private universities. Most of the diploma programmes offered by local universities are accredited under the Engineering Technology Accreditation Council (ETAC). The objective of accreditation is to ensure that graduates of the accredited engineering technician education programmes satisfy the minimum academic and practical requirements for registration as engineering technicians or inspector of works with the Board of Engineers Malaysia (BEM). Based on the latest ETAC standard (Standard, 2024), there are eleven (11) programme outcomes (POs) that students need to attain by the time of graduation. Solid Mechanics (ECS226) is considered as fundamental engineering science course which is mapped to the knowledge (PO1) and problem analysis (PO2) under ETAC framework. PO1 is defined as ability to apply knowledge of applied mathematics, science, engineering fundamentals, and civil engineering specialization to practical procedures and practices. PO2 is about problem analysis, ability to identify and analyse well-defined civil engineering problems using codified methods to reach substantiated conclusions.

Solid Mechanics course is recognized as primary academic bottlenecks in diploma curriculum, often exhibiting elevated failure rate and unsatisfied PO achievement. Study by Siong et al. (2025) revealed that the average PO2 attainment in final exam assessment had never satisfied the minimum requirement regulated by ETAC (i.e. <50%) for Semesters with large cohort (Semester March-August). To mitigate high failure rate and PO attainment in Solid Mechanics, faculty deployed academic intervention such as intensive classes prior test and final examination during Semester 20254. Therefore, this study aims to assess the effectiveness of the intensive classes on the overall performance of students in Solid Mechanics and attainment of PO. Merits and limitations of the current intervention are discussed in detail and suggestions on strategies to improve current intervention are made.

Literature Review

Cognitive Load Theory (CLT) is an instructional theory grounded in our understanding of human cognitive architecture, particularly the limitations of working memory and excessive cognitive load can hinder learning (Kalyuga & Liu, 2015). This theory is highly relevant for teaching and learning Solid Mechanics due to high cognitive demand in which students are exposed to conceptually dense and mathematically intensive content within a short semester timeline. Solid Mechanics is associated with high intrinsic load due to complexity of concepts such as stress and strain, flexural, shear and deflection of statically indeterminate beam, torsion of shaft and buckling of columns. CLT focuses on breaking down these complex topics into manageable chunks and sequencing them to align with student’s cognitive capacities. Research by Dymon et al. (2023) demonstrated that repeatedly investigating the same structure in varying contexts and across the curriculum able to reduce students’ cognitive load. Another important instructional strategy derived from CLT is the worked-example effect under CLT frameworks. Previous studies (Chen & Kalyuga, 2021; Chen & Woolcott, 2019; Lai et al., 2017) have shown that providing students with solved examples in teaching engineering mathematics and mechanics have successfully reduce cognitive load as well as elevating students’ performance.

The issue of high failure rate and unsatisfied programme outcome attainment in Solid Mechanics have been investigated by Wee at al. (2021). Findings from questionnaire survey have concluded that the primary factor attributed to the high failure rate in Solid Mechanic was that students experienced an overload of working memory due to heavy cognitive load,

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especially complex mathematical procedures are involved in solving well-defined engineering problems. Under ETAC framework, CQI is often required to improve the attainment of programme outcomes at course level. Several studies have highlighted the importance of implementing educational interventions to improve student achievement in engineering courses. Evidence from Mohd Noor et al. (2025) showed that implementing additional tutorials, guided discussions, and examination-focused learning reduced the failure rate of the Solid Mechanics course from 20% to 6%, highlighting the effectiveness of targeted academic interventions. But programme outcome attainment was not evaluated through this study.

Despite previous studies have investigated factors contributing to poor performance in Solid Mechanics and various interventions strategies have been proposed, there remains a need for a study to examine specific interventions that directly affect programme outcome attainment. Furthermore, limited studies have explored the effectiveness of intensive classes in improving both overall performance of students and programme outcome within OBE framework for Solid Mechanics course. Therefore, this study aims to close the gap.

Methodology

To reduce the failure rate of the Solid Mechanics course and improve students' attainment of Programme Outcomes (POs), there were two intensive classes conducted during Semester 20254. For the first intensive class, students were assigned a set of questions (mock test) and students were required to complete all questions independently before attending the intensive class. During the session, all students were gathered in a lecture hall, a detailed demonstration on solving problems including all steps and procedures was given by lecturers. Students were allowed to ask questions during the 2-hours session, discussion between peers was encouraged. Another intensive class was conducted one week prior to final exam, students were divided into a few groups, they must compile past semesters' final examination papers. Each group was assigned to complete a set of past year final examination questions, and they need to present their solutions on the day of intensive class. Lecturers marked their solutions and provided feedback to students. Students were required to share the corrected version of answers to all classmates through a Google Drive platform, enabling all classmates to access the materials and promote collaborative learning. Details of the intensive classed is shown in Table 1.

Table 1: Details of Intensive Classes for Semester 20254

Item	Intensive class prior test	Intensive class prior final examination
When	One-week prior test	One-week prior final examination
Duration	2 hours	4 hours
Preparation	Individual work	Group work
Mode of conduct	Standard format of conducting intensive class. All students gathered in a lecture hall and shared resources among lecturers.	Format of conducting intensive class different, based on individual lecturer's arrangement.

Role of students before the intensive class	Attempted to solve problems from the set (mock test) assigned by lecturer.	Collected one set of past final examination paper and completed solutions for the whole set.
Role of students during the intensive class	Self-checking answer with answer scheme given by lecturers.	Presented solutions to all students during the intensive class. Shared corrected answer scheme to other students via shared google drive after the intensive class.
Role of lecturer	Provided answer scheme and explained in detail on method, steps and procedures on solving problem during the intensive class.	Commented and provided feedback on solutions shared by students during the intensive class.

All campuses of Faculty of Civil Engineering in Universiti Teknologi MARA (UiTM) utilise the Revolution on Assessment for Student Monitoring System (i-RAS) after completing the assessment of students' result in every semester. To assess the effectiveness of intensive classes on the performance of students in Solid Mechanics, data obtained from the i-RAS system were used in this research. Semester without intervention (Semester 20244) was treated as the control sample and comparison was made with the semester with intervention (Semester 20254). In this study, semesters with small cohort sizes were selected because the intervention commenced in Semester 20254 and the similar cohort sizes allow for a more meaningful comparison of student performance across semesters.

Figure 1 illustrates the overall research framework adopted in this study. A detailed analysis of PO1 and PO2 attainment in each assessment was discussed and hence merits and limitations of current interventions are justified based on performance of PO1 and PO2. Finally, several Continuous Quality Improvement (CQI) strategies are proposed to improve attainment of POs in Solid Mechanics course.

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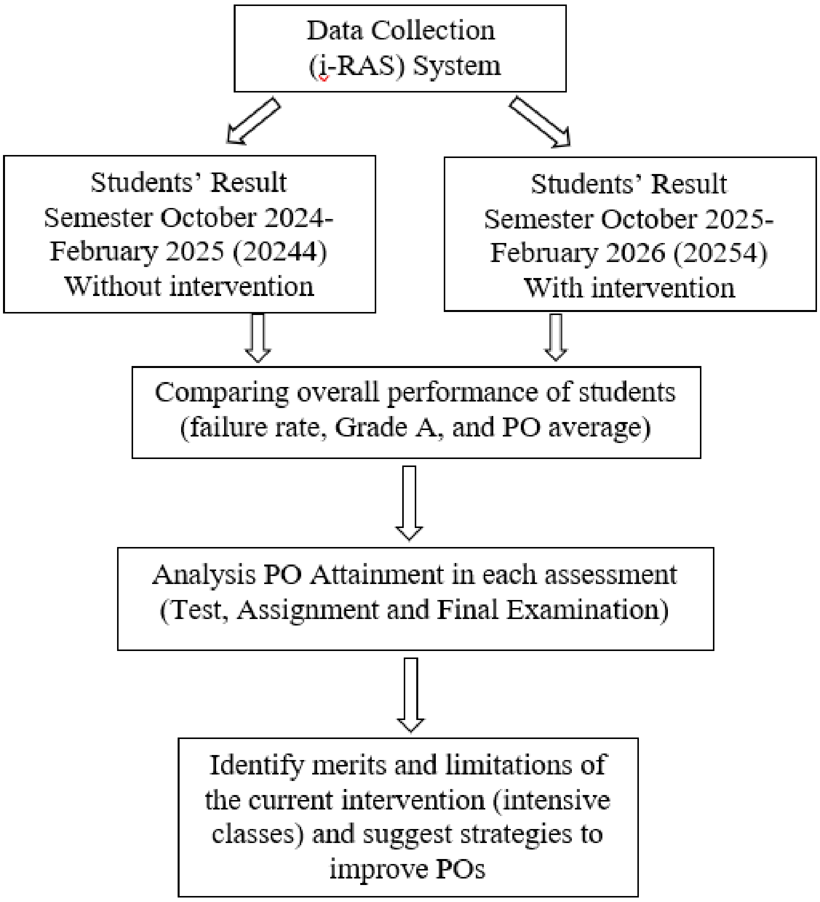

Figure 1: Research Framework

Results and Discussion

Evaluation of Students Performance and Programme Outcomes

Table 2 shows the overall performance of students in Solid Mechanics Course ECS226 for Semester 20244 and Semester 20254 respectively. There was a drop in number of students (-10 students) enrolled to this course in Semester 20254 compared to Semester 20244. Nevertheless, additional 2 students (equivalent to +5%) successfully obtained Grade A result for this course in the later semester. A very positive impact of intervention can be seen from the overall failure rate of 31% in Semester 20244 has been reduced to 23% in Semester 20254. In addition, students enrolled in Semester 20254 were able to improve overall PO1 attainment up to 60% with the intervention program. Achievement of students in PO2 yielded no change, remained at 49%.

Figure 2 provides breakdown performance of PO1 and PO2 in different assessments namely test, assignment and final examination. It is found that 19% surge in PO1 final examination scores, which rose from a failing baseline of 34% (Semester 20244) to a clear passing average of 53% (Semester 20254). The effectiveness of the late-semester intensive classes in consolidating students' knowledge is proven from PO1 achievement. Whereas for PO2, students enrolled Solid Mechanics Course in Semester 20254 demonstrated an enhancement of

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4% i.e. in final examination scores compared to the Semester 20244, credit to the late-semester intensive classes.

In Semester 20254, despite an intensive class was conducted for students few days prior the test, no improvement for both POs attainment in the test score. Refer to Figure 2, there are 2% and 3% drops in average PO1 and PO2 respectively for Semester 20254. It may be attributed to the lack of confidence and readiness of students to sit for the test. However, overall performance of PO1 and PO2 in test yields a better result compared to final examination due to the less complexity of the questions as well as lesser syllabus have been covered in test. Students attained an average PO1 score of 70% in Semester 20244 and 68% in Semester 20254 based on the test assessment. Meanwhile, the average PO2 attainment was comparatively lower, at 51% and 48% for Semester 20244 and Semester 20254, respectively.

For assignment, students were able to achieve satisfied average PO1 (86% and 76%) and PO2 (85% and 75%) in both semesters. Even though a 10% drop in assignment assessment can be seen for Semester 20254, but the gap between coursework and final assessment gently been closed for a more validity and reliability of assessment methods. In other words, the closing of this gap indicates that the assignment difficulty was calibrated more rigidly to reflect the actual cognitive weight of exams for Semester with intervention.

Table 2: Performance of Students in Solid Mechanics Course

Parameter	**Semester 20244 (Baseline)**	**Semester 20254 (Intervention)**	**Remark/change**
Total students enrolled	54	44	-10 students
Failure rate (%)	31	23	-8%
Grade A (student count)	1	3	+2 students
Grade A (%)	2	7	+5%
Overall PO1 Attainment (%)	52	60	+8%
Overall PO2 Attainment (%)	49	49	No change

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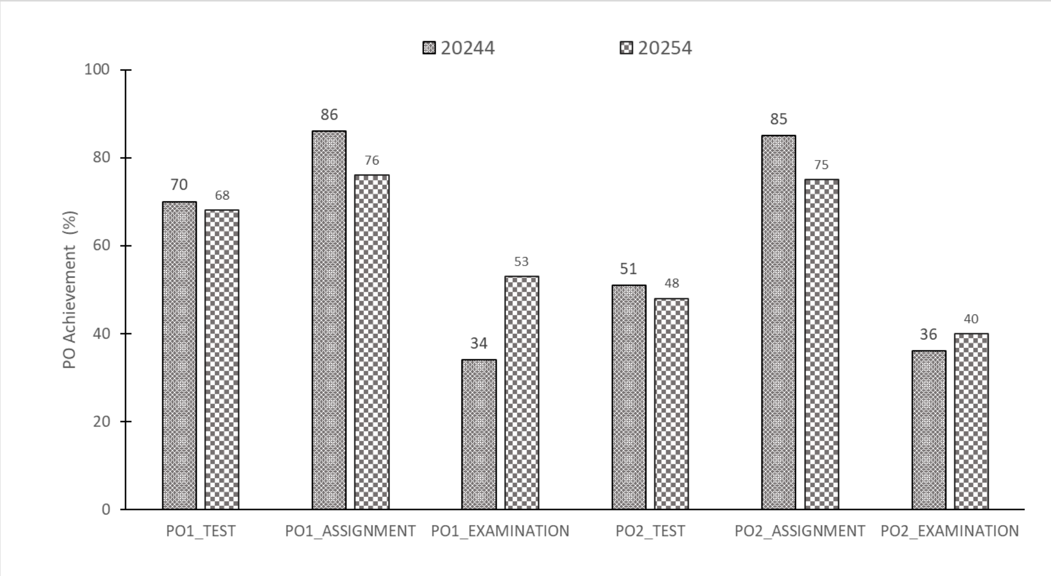

Figure 2: Breakdown Performance of PO1 and PO2 in Different Assessment

Based on OBE frameworks regulated by ETAC, all students are required to satisfied minimum 50% of each programme outcomes at course level. As observed in Table 2, students were able to obtain more than 50% of overall PO1 in both semesters. Even with intervention program, the performance of overall PO2 is still below minimum requirement of ETAC. PO2 is about ability of students to identify and analyze well-defined engineering problems. In Solid Mechanics, students are required to develop high-level cognitive solutions for problems related to statically determinate beams, including structural free-body diagram isolation, calculating support reactions, determining shear force and bending moments, accurately navigating bending and shear stress as well as deflections under exam constraints.

The empirical evidence confirms that while late-semester intensive classes are highly efficient at strengthening basic understanding of students in applying fundamental knowledge of mathematics, natural science and engineering (PO1), they are insufficient for developing deep analytical pathways that are required to solve multi-step problem analysis (PO2) under independent testing conditions. Apparently, analytical competence cannot be effectively crammed within a short period of time, a new approach of intervention programme must be planned and implemented across the 14 weeks of academic semester. Students need a longer time frame to sharpen their analytical skills in Solid Mechanics,

Proposed Strategies: Continual Quality Improvement (CQI)

To improve PO2 attainment, which has remained below the minimum target (49%), interventions precaution should not be implemented during the late semester. It is suggested to have “Well-Defined Problem-Solving Clinics” weekly and it may take about one hour for students to self-correct basic structural steps such as practice and refine fundamental problem-solving procedures free-body diagram construction for axially loaded members, beams under bending and shear, columns under axial and bending as well as circular shaft subjected to torsion. This clinic may start from week 2 or week 3 of the academic semester and all students enrolled in Solid Mechanics course are compulsory to join.

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Xu (2008) introduced in-class paper demonstrations and experiments by employing only simple materials such as copy paper, staples, scissors and a paper punching machine. Students gained understanding of the complicated concepts of Solid Mechanics and these simple mechanics experiments can be easily repeated in anywhere, indeed it is impactful for long term learning. Another hands-on experience for problem solving in engineering education was proposed by Vargas & Jawaharlal (2018). They developed a nature-inspired problem solving based on trees and plants in teaching structural mechanics, so that students were able to understand and emulate structures and functions of the plant to develop structural solutions in engineering. These strategies can be implemented in teaching Solid Mechanics, encourage creative and deep thinking of students in solving well-defined engineering problems specifically in beam related problems.

Integration of technology, computational and simulation tools (Condoor et al., 2007; Vieira et al., 2023; Mueller, 2003) in teaching Solid Mechanics allow students to visualize behaviour of solid structures under different actions. From finite element analysis, students explore the concept of mechanics interactively and they can develop deep understanding on the structural behaviour specifically on beam modelling. Moreover, students are expected to improve their ability to analyze and validate solutions for well-defined engineering problems, reinforce long term cognitive skill and directly accelerate PO2 capability.

A well-structured problem-solving framework should be established in view of the below average PO2 attained by students in Solid Mechanic course. One of the critical reason students are unable to master their analytical skill in Solid Mechanics is lack of an effective framework that led them to problem analysis. Papadopoulos et al. (2007) adopted multiple-method solutions to enhance students' flexibility and understanding of mechanics concepts. Study by Lampe (2024) suggested strategy problem-solving training including schema-based approaches and collaborative reflection improved problem-solving competence and application skills for Static course. Besides, time management training (Siong et al., 2025) can be implemented during the tutorial class, lecturers can set a suggestion time for students to answer and solve problems. It is believed that students will be better prepared and achieve better scores for PO2 in Solid Mechanic course through a well-structured problem-solving framework.

Conclusion

The efficacy of implementation of intensive classes in Solid Mechanic course is evaluated by comparing the semester with and without intervention for programme Diploma in Civil Engineering (CEEC110) offered in University Teknologi MARA. The intervention successfully enhanced overall students' performance, pulling down overall course failure rate from 31% to 23% and tripling Grade A achievers from 2% to 7%. The findings indicate that the intervention contributed positively at consolidating baseline in engineering knowledge (PO1), supported by a tremendous 19% surge in final examination assessment. Performance of students in well-defined problem analysis (PO2) remained below expectations (49%) for both studied semesters, unsuccessfully meeting the target as required under ETAC framework. Therefore, challenges persist in students' ability to analyse and solve well-defined engineering problems.

Findings of this study suggest that intensive class framework can be maintained for academic retention (PO1) in Solid Mechanic course, but the current form of retention requires improvement especially in consolidating student's ability in problem analysis (PO2). A structured Continuous Quality Improvement (CQI) framework is therefore recommended; future cycles must implement a structural continual quality improvement (CQI) framework. Some strategies such as introducing active learning “Well-Defined Problem-Solving Clinics”, hands-on learning, integration of technology and engineering tools, and a well-structured problem-solving framework are proposed in this study for bridging the analytical competency gap. However, some of the suggestions may not be feasible due to limited resources and the policy of university. The authors are of the view that sustained improvement in PO2 attainment can be realized through the active collaboration of all stakeholders, including the university, lecturers, students, parents, and support staff, each playing a vital role in supporting students' academic and professional development.

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