Performance of Students in Solid Mechanics Course and the Role of Fundamental Courses for Engineering Diploma Programme

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ABSTRACT

This study investigates student performance in Solid Mechanics in a Civil Engineering diploma program in Malaysia that uses Outcome-Based Education (OBE). The study evaluates the association between fundamental course performance and success in Solid Mechanics, using data from 72 students. The study takes a mixed-methods approach that includes grade distribution analysis and assessment component evaluation. Tests and assignments each contribute for 20% of the total score and the final exam accounting for 60% of the total score of Solid Mechanics. Students scored an average of 50.4% on the test evaluation, 81.8% on the assignment and 51.9% on the final exam. The results show an 80.6% of total 72 students pass in Solid Mechanics, with a bell-shaped grade distribution that is somewhat negative. The majority of students received grades in the B to C range, demonstrating adequate course calibration. Individual assessment components had variable success percentages, with 91.7% for assignments, 55.6% for test, and 59.7% for the final exam. Furthermore, the study discovered a connection between performance in foundational courses such as Calculus and Physics with the success in Solid Mechanics. Students with poor Calculus skills were more likely to fail Solid Mechanics, even when they performed quite well in Physics. This finding emphasizes the importance of fundamental courses in understanding and comprehending Solid Mechanics concepts. The study's findings include the need for focused interventions to assist struggling students and the establishment of early intervention programs. These findings contribute to the increasing body of research on engineering education in Malaysia, providing valuable insights for curriculum design and teaching practices in OBE-based engineering programs.

Keywords: Solid Mechanics, Diploma in Engineering, Outcome-Based Education (OBE), Engineering Education, Programme Outcomes (POs)

INTRODUCTION

Outcome-Based Education (OBE) is commonly used in Malaysian engineering schools to ensure that graduates fulfill industry standards and have the necessary skills. There is a range of skills that include technical and job-specific hard skills as well as interpersonal and communication soft skills (Mustapha, Mior Harun, Ismail, Mohd Ishar, & Zoel Fazlee, 2024). According to (Lee, et al., 2021), OBE focuses on obtaining particular learning goals that are relevant to the demands of companies and society.

The establishment of outcome-based education (OBE) in Malaysian higher education institutions has considerably reshaped engineering programs including civil engineering diplomas (Kok, 2020). OBE focuses mainly on three types of learning activities for students which are learning activities that help students achieve these objectives and learning outcome statements that specify the information, comprehension, or abilities that students should be able to do. (Ahmad Zakwan, Ismail, & Endut, 2022) (Abu Bakar, Raja Hussain, & Idris, 2010) (Yasmin & Yasmeen, 2021).

Higher education's method to teaching and learning has recently undergone a substantial shift with the introduction of OBE. Its main goal is to produce graduates who can adjust to changing economic conditions and are well-prepared for job market (Kulkarni & Barot, 2019) (Naqvi, et al., 2019). For each course, the programme outcomes (POs) and course outcomes (COs) should be mapped out upfront so that the students' achievements may be assessed in accordance with the OBE scheme (Le, 2018) (Osman, Jaafar, Wan Badaruzzaman, & Rahmat, 2012). Universiti Teknologi MARA (UiTM) offers a diploma in civil engineering with the following 12 program outcomes:

PO1	–	Apply mathematical, natural science, engineering fundamentals, and engineering specialization knowledge to a wide range of practical procedures and practices.
PO2	–	Identify and analyze well-defined engineering problems reaching substantiated conclusions using codified methods of analysis specific to their field of activity.
PO3	–	Design solutions for well-defined technical problems and assist with the design of systems, components, or processes to meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
PO4	–	Conduct investigations of well-defined problems; locate and search relevant codes and catalogues, conduct standard tests and measurements.
PO5	–	Apply appropriate techniques, resources, modern engineering and IT tools to well-defined engineering problems, with an awareness of the limitations.
PO6	–	Demonstrate knowledge of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering technician practice and solutions to well-defined engineering problems.
PO7	–	Understand and evaluate the sustainability and impact of engineering technician's work in the solution of well-defined engineering problems in societal and environmental contexts.
PO8	–	Understand and commit to professional ethics, responsibilities and norms of technical practice.
PO9	–	Function effectively as an individual, and as a member in diverse technical teams.
PO10	–	Communicate effectively with the engineering community and society at large on well-defined engineering activities by understanding the work of others, documenting their own work, and giving and receiving clear instructions.
PO11	–	Demonstrate knowledge and understanding of engineering management principles and apply these to one's own work, as a member or leader in a technical team and to manage projects in multidisciplinary environments.
PO12	–	Recognize the need for, and have the ability to engage in independent updating in the context of specialized technical knowledge.

The Solid Mechanics course (ECS226) is available to second-year students pursuing a Diploma in Civil Engineering at UiTM. This course is a prerequisite for Basic Structural Analysis, Structural Concrete and Steel Design, and Civil Engineering Design Project. This course is associated with two out of the 12 mentioned POs which are PO1 and PO2. In terms of course outcomes (COs), this course encompasses only two COs, as follows:

CO1	–	Apply basic understanding of stresses and strains in the solid body, beam, shafts and column.
CO2	–	Develop solutions for problems related to statically determinate beams.

The primary purpose of OBE is to improve student learning outcomes by highlighting the precise achievements that students are expected to attain by the end of their studies (Mausoom & Vengadeshwaran, 2021). Research has showed that OBE can significantly boost student engagement and academic accomplishment, but it requires constant curriculum revision to match industry demands (Jamaludin, et al., 2023). Universiti Teknologi MARA's OBE system has successfully aligned the curriculum with industry requirements, resulting in increased graduate employability. (Sun & Lee, 2020).

Solid mechanics is a basic subject in Civil Engineering courses that helps students understand material behavior and structural analysis. However, many students struggle with this subject because of the abstract concepts and mathematical depth. The performance of students in Engineering studies often reflects their grasp of fundamental concepts from prerequisite courses (Chang, Lin, Wang, & Tseng, 2022) (Xu, Xing, & Van Der Schaar, 2016). For the Solid Mechanics course that offered in UiTM, the most direct fundamental courses are Calculus and Physics.

In several studies, the factors affecting student performance in a certain course was depending on previous academic achievements. The findings emphasized the importance of prior knowledge and cognitive abilities particularly in fundamental courses for success in further courses (Namoun & Alshanqiti, 2020) (MORENO-MARCOS, PONG, MUÑOZ-MERINO, & KLOOS, 2020). The study highlights that students' understanding of Solid Mechanics is significantly influenced by their performance in foundational courses such as mathematics and physics. This correlation underscores the importance of a solid grounding in these subjects to facilitate success in more advanced engineering topics.

In the discipline of Civil Engineering education, the introduction of OBE has resulted in the development of curriculum that is more in line with industry demands. This relationship ensures that graduates have the necessary skills and knowledge to succeed in the workplace. Research has demonstrated that applying OBE in Civil Engineering programs leads to good effects in terms of student achievement and satisfaction. (Khan, Salele, Hasan, & Abdou, 2023).

METHODOLOGY

The study encompassed students who were actively engaged in the pursuit of a Diploma in Civil Engineering at the Faculty of Civil Engineering, UiTM Johor Branch Campus Pasir Gudang, over the academic year spanning from October 2023. The pupils were enrolled in the academic course Solid Mechanics (ECS226). The student population totalled 72 individuals, comprising 32 males and 40 females.

Table 1: Demography of students taking Solid Mechanics Course

	Gender		Total
	Male	Female	
Number of students	32	40	72

This study's objective is to assess the academic performance of students who are enrolled in a course that focusses on solid mechanics course. This particular course was selected since it is a mandatory course that is made available to students during the second semester of their studies. In addition, this course is well recognised as being among the most difficult courses that are included in the Diploma in Civil Engineering program that is provided by UiTM. This course covered four different topics: one-dimensional and two-dimensional linear stress and strain, stresses and deflection of statically determinate beams, torsion of circular shafts, and elastic buckling of columns. Each of these topics was discussed in detail during the

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course.

The Solid Mechanics course assessment framework is designed to precisely evaluate students' skill and competence by employing several assessment methods. By aligning each assessment type with designated Course Outcomes (CO) and Programme Outcomes (PO), a thorough evaluation of students' learning is guaranteed. To do this, various assessment types are integrated, as shown in Table 2. Through ensuring that assessments are aligned with both course and programme outcomes, the framework improves the achievement of specific educational goals and competences.

Table 2: Course Assessments for Solid Mechanics

Assessment	CO-PO	Assessment Marks (%)
Test	CO1-PO1 CO2-PO2	20
Assignment	CO1-PO1 CO2-PO2	20
Final Examination	CO1-PO1 CO2-PO2	60
TOTAL		100

Test accounts for 20% of the total evaluation score. A test was conducted to evaluate the students' achievement and understanding of the course. This evaluation focusses on particular subjects and course objectives, providing important insight into areas where students may need further improvement. The examination was designed to correspond with the learning outcomes CO1-PO1 and CO2-PO2 to ensure a balanced evaluation method.

Furthermore, assignments contribute to 20% of the total evaluation score. The objective of these assignments is to evaluate students' ability to implement theoretical concepts of Solid Mechanics in real-world scenarios. Academic tasks require the use of analytical thinking and problem-solving skills, aligning with the learning outcomes CO1-PO1 and CO2-PO2. The use of this continuous assessment method encourages a long-term dedication to academic advancement and the acquisition of knowledge over the duration of the educational course of study.

It is important to note that the Final Examination accounts for sixty percent of the total score on the assessment. The purpose of this examination is to assess the students' comprehensive understanding of Solid Mechanics, encompassing both CO1-PO1 and CO2-PO2. The final exam is given a substantial amount of weight, which highlights the relevance of the examination in terms of evaluating the overall skill of students in the subject as well as their ability to retain information.

RESULT AND DISCUSSION

Figure 1 shows the mean percentage of scores obtained on all assessments for the ECS226 course, including exams, assignments, and the final exam. Tests and assignments each contribute for 20% of the total score, with the final exam accounting for 60%. Students scored an average of 50.4% on the test evaluation. These findings indicate that students regard test as relatively tough, and their performance is slightly above average. For the assignment, students show significant development, with an average score of 81.8%. The high score implies that students are more proficient at completing assignments, most likely because they have more time to work on them and may have access to resources and collaboration possibilities.

The average score on the final exam drops to 51.9%, indicating that students believe the final exams are as challenging as the initial test. The scores show a tiny increase when compared to the exam scores, indicating somewhat superior performance, which could be attributed to the acquisition of knowledge over the course. The overall score, derived as the weighted average of all assessments, is 57.6%. The total score reflects students' overall performance, indicating a positive outcome when tests, assignments, and final exams are combined. The total score exceeds the scores of the individual test and the final exam, but falls short of the assignment score, demonstrating that assignments have a significant impact on overall performance.

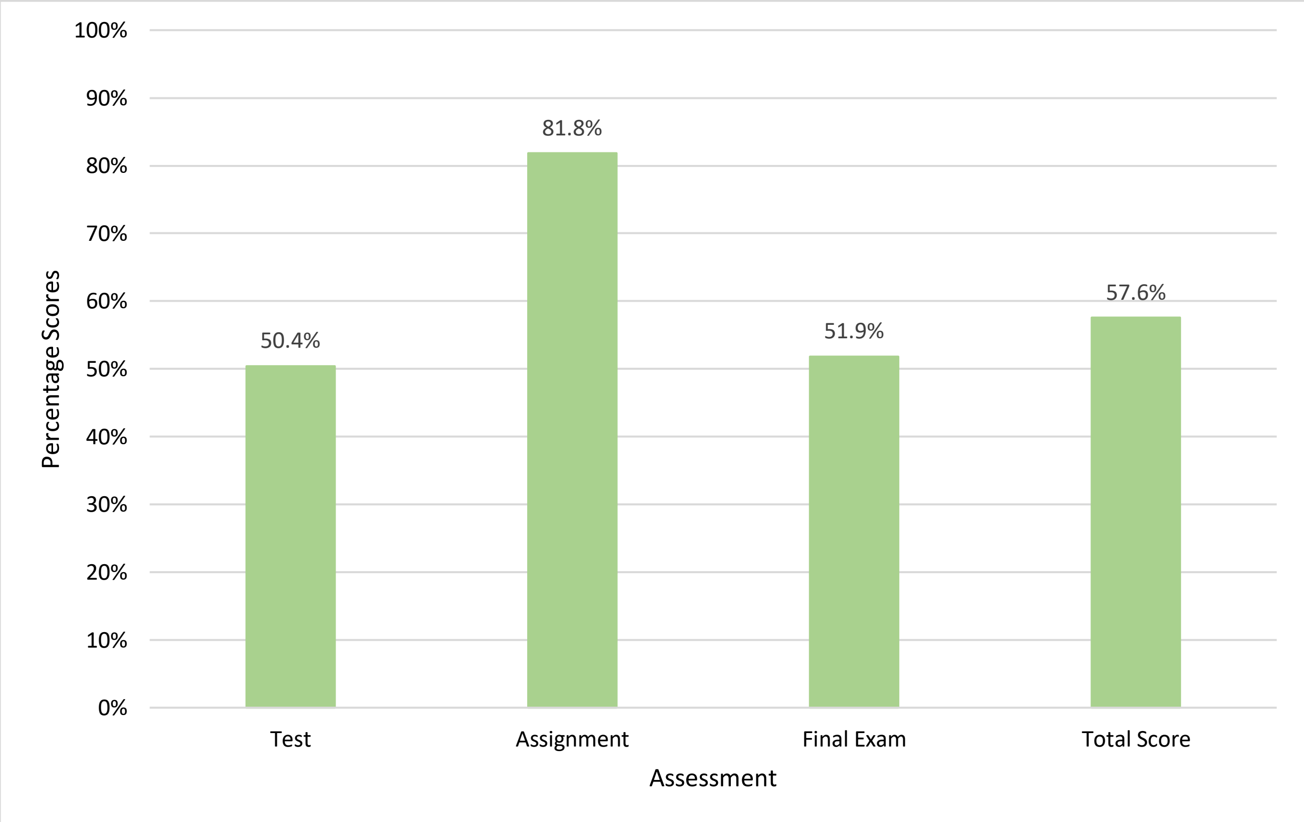

Figure 1: Average Score Attainment for Different Assessments of Solid Mechanics

On the other hand, Figure 2 illustrates the average achievement of two Program Outcomes (PO1 and PO2) in the solid mechanics course. The data is presented as percentage scores for multiple assessment components, including the test, assignment, and final exam. PO1 students averaged 32.0% on the Test exam, whereas PO2 students averaged 68.9%. The assignment assessment has an average attainment of 81.6% for PO1 and 82.0% for PO2. Finally, the average score for PO1 on the Final Exam is 46.5%, whereas PO2 has an average score of 57.2%. The Total Score may be obtained using these three assessments, which shows that the average attainment for PO1 is 50.6% and for PO2 is 64.5%.

The Test assessment scores in Programme Outcome PO2 are significantly higher than those in PO1, at 68.9% against 32.0%. Both PO1 and PO2 in the Assignments exam demonstrate a high level of achievement, with scores of 81.6% and 82.0%, which are nearly identical. PO2 outperformed PO1 with 57.2% on the Final Exam assessment. The overall result for PO2 is 64.5%, which is higher than PO1's score of 50.6%.

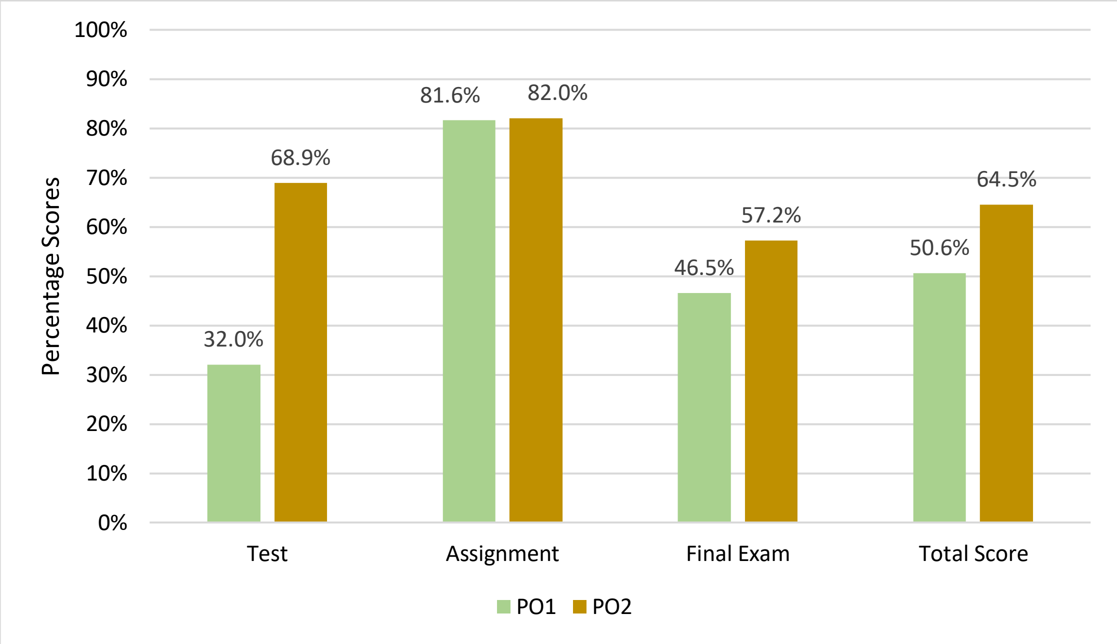

Figure 2: Average Score Attainment according to Programme Outcomes for Different Assessment

Figure 3 shows the grade distribution for a group of 72 students taking a Solid Mechanics course. The distribution is shown in percentages, representing the proportion of students who complete each grade level. The grading scale goes from A+ to F, with C as the minimal passing mark. The results show a bell-shaped distribution with a minor negative skew. The majority of students received grades in the B level. Specifically, 19.4% of students received a B- grade, which corresponds to scores between 60 and 64. This was closely followed by 18.1% of students who received a C+ grade (scores between 55 and 59). C was the third most frequent grade, accounting for 15.3% of students and representing marks ranging from 50 to 54.

At the higher end of the grading range, no students received an A+ score (90-100 marks). Only 1.4% of students received an A grade (80-89 marks). The percentage rises significantly for A- grades, with 8.3% of students earning between 75 and 79 points. In the B range, 5.6% of students achieve B+ (70-74 marks), while 12.5% achieve B (65-69 marks). On the lower end of the passing grades, 5.6% of students scored a D+ (44-46 marks), while another 5.6% received a D (40-43 marks). The lowest grades were less common, with 5.6% of students obtaining an E (30-39 marks) and 2.8% receiving a F (0-29 marks). There was no students received a C- (47-49) grade.

Overall, 80.6% of students passed the course with a grade of C and above. This passing rate is consistent with the total success rate given in the previous discussion of evaluation components. The remaining 19.4% of pupils did not satisfy the minimum passing standards. This grade distribution gives essential information about student performance in the Solid Mechanics course. It implies that, while the vast majority of students understand the course material well enough to pass, there is still space for growth, notably in assisting students to earn higher grades. The concentration of marks in the B to C range suggests that the course level is appropriate for the majority of students. However, the lack of A+ scores and the low percentage of A grades indicate that success in this subject is difficult.

These findings can help shape future teaching initiatives. Educators may explore providing additional support systems for challenging students in order to lower failure rates. Simultaneously, they may explore techniques to push high-achieving students to reach the highest grade levels. This balanced approach has the potential to increase overall student performance and distribute grades more evenly across the entire course.

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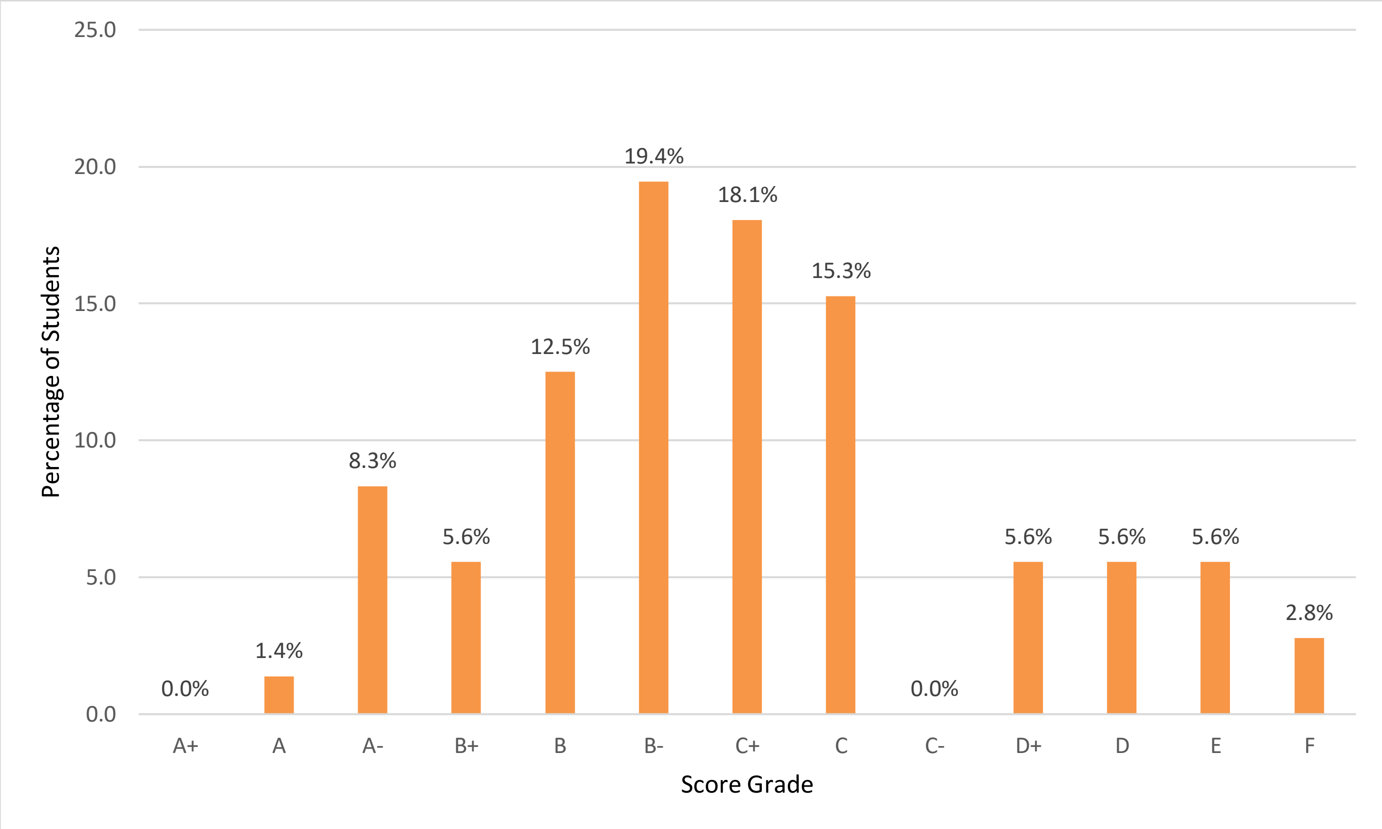

Figure 3: Students Score Grade Achievement for Solid Mechanics

Figure 4 presents a comprehensive picture of student performance outcomes in the Solid Mechanics course. This visual representation clearly divides the student cohort into two categories which are those who passed and those who failed the course. The findings demonstrate that the vast majority of students passed the Solid Mechanics course. Specifically, 80.6% of students received a passing grade. This equates to around 58 of the total 72 students enrolled in the course. These students received a grade of C and better, which equates to a final score of 50 and higher.

In contrast, 19.4% of students failed to achieve the course's passing standards. This percentage indicates around 14 students who obtained grades below C, including C-, D+, D E, and F. These students received less than 50 marks in their final results, which included performance throughout the test, assignment, and the final exam. The high pass rate of 80.6% indicates that the majority of students understood the essential concepts and successfully applied their knowledge in the various evaluation components of the Solid Mechanics course. This finding suggests that the course structure, teaching approaches, and support systems were effective for the majority of the class.

However, the 19.4% failure rate is also worth noting. While it represents a small proportion of students, it is important enough to deserve study. This set of students struggled to satisfy the course's basic criteria, despite the numerous assessment opportunities provided throughout the semester. This pass-fail distribution provides essential information to course educators as well as administrators. While the high pass percentage is gratifying, it also provides an opportunity to strive for even higher results. Educators may consider adopting targeted interventions for difficult students earlier in the semester. This could potentially lower the failing rate while improving overall student performance. Figure 4 provides a concise and clear depiction of overall student achievement in the Solid Mechanics course. It illustrates both the success of the majority and the challenges experienced by a considerable minority, giving an outline for both honoring achievements and focusing attention on areas that require development.

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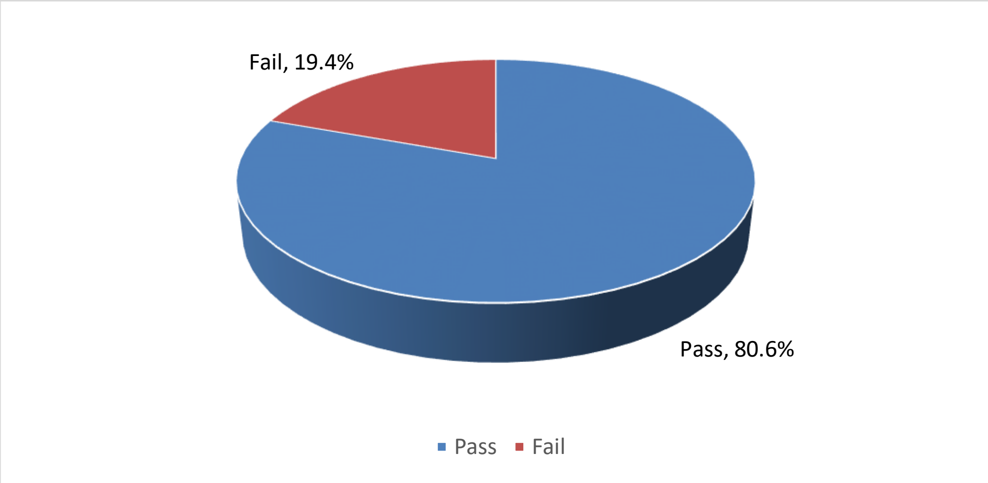

Figure 4: Performance of students for solid Mechanics

Figure 5 shows student performance in a Solid Mechanics course for each assessment types. It displays pass and fail rates for various assessment components. The course has three primary assessment methods. A test and an assignment both contribute 20% to the final grade. The final exam carries the highest weight of 60%. To pass each of the assessment, students must score at least 50% in each component. The findings show variable levels of student achievement across these assessments. The test, which counted for 20% of the overall grade, had a pass percentage of 55.6%. This suggests that almost half of the class found this component difficult.

In contrast, the assignment worth 20% had an amazing pass rate of 91.7%. This implies that students succeeded at this applicable task. The final exam, worth 60%, had a pass rate of 59.7%. This indicates the thorough and tough character of this evaluation. The final score incorporates all three components and reflects an overall course pass percentage of 80.6%. This greater overall success rate implies that, while some students struggled with individual assessments, the course's weighted structure resulted in superior end outcomes. Strong performance on the assignment may have compensated for poorer marks in other assessments.

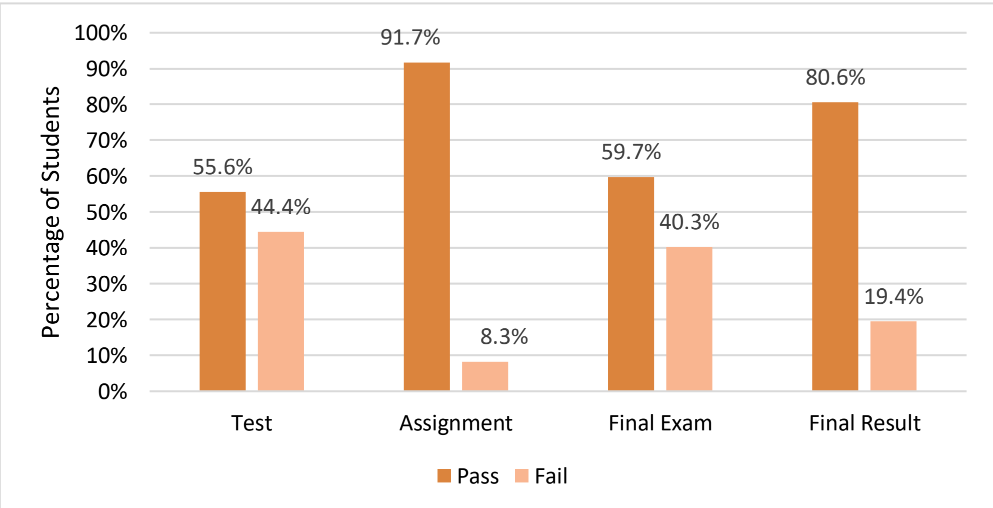

Figure 5: Performance of students on different Assessments for solid Mechanics

Table 3 depicts the relationship between student performance in Solid Mechanics and their grades in two fundamental courses which are Calculus and Physics. Based on data from 14 students who failed the Solid

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Mechanics course shows a high correlation between poor performance in these preparatory subjects and subsequent failure in Solid Mechanics. Table 3 shows a similar pattern of poor performance across all three courses for the vast majority of students. This strongly shows that a weak foundation in Calculus and Physics is a contributor to Solid Mechanics failure. The findings show that students who struggle with these fundamental concepts are more likely to struggle in the more advanced Solid Mechanics course.

A closer look at the data reveals that poor Calculus performance appears to have a greater impact on failure in Solid Mechanics than in Physics. Despite passing Physics, several students failed Solid Mechanics due to poor Calculus performance. For example, Student 4 and Student 6 both had a C in Physics, but their D marks in Calculus corresponded to their failure in Solid Mechanics. Table 4 emphasizes the vital significance of a firm basis in Calculus for success in Solid Mechanics. While proficiency in Physics is also vital, data suggests that students with poor Calculus skills are more likely to fail Solid Mechanics, even if they perform well in Physics. This emphasizes the critical significance that mathematical concepts and problem-solving skills from Calculus possess in understanding and applying Solid Mechanics principles.

These findings suggest that educators should prioritize developing students' Calculus skills as a main method for improving Solid Mechanics outcomes. This could entail developing additional assistance mechanisms for students who are struggling with Calculus concepts. Educators might explore incorporating more Calculus-based problem-solving exercises into the Solid Mechanics curriculum to teach these fundamental abilities.

Furthermore, the data suggests that identifying students who are suffering with Calculus early on could be an effective strategy to predict and prevent future Solid Mechanics failures. Implementing early intervention programs for students who struggle with Calculus could greatly improve their chances of succeeding in more complex engineering courses such as Solid Mechanics. These findings should influence instructional practices that focus on reinforcing these fundamental abilities to improve student performance in advanced engineering courses.

Table 3: Grade Attainment of Failed Students of Solids Mechanics and Fundamental Courses

Failed Student	Solid Mechanics Grade	Fundamental Courses	
		Calculus Grade	Physic Grade
Student 1	F	E	C
Student 2	E	D+	C+
Student 3	D	E	D
Student 4	D+	D	C
Student 5	D	E	C
Student 6	E	D	C
Student 7	E	C	E
Student 8	D+	B-	B-
Student 9	D	C+	D+
Student 10	F	B-	E
Student 11	D	C	C
Student 12	D+	B+	C
Student 13	D+	C+	C+
Student 14	E	C	D

CONCLUSION AND RECOMMENDATION

The overall pass rate for Solid Mechanics is 80.6%, indicating that the majority of students understand the course's basic principles. This success rate is encouraging, indicating that current teaching approaches and course structure are generally effective. The bell-shaped grade distribution, with a minor negative skew, represents a typical performance pattern in engineering courses. The concentration of grades in the B to C range indicates that the course level is appropriate for the majority of students.

The investigation of different evaluation components indicated varying levels of student achievement. The high pass rate in the assignment component (91.7%) indicates that students perform well in applied activities. The lower success rates in the test (55.6%) and final exam (59.7%) components suggest that students face more substantial hurdles, probably due to the more theoretical and comprehensive nature of these assessments.

This study provides insights on student performance in Solid Mechanics within the framework of a Civil Engineering diploma program in Malaysia. The findings suggest a complicated relationship between foundational courses and advanced engineering subjects, which is consistent with previous studies conducted by (Bowers & Zhou, 2019) (Iatrellis, Savvas, Fitsilis, & Gerogiannis, 2021) that found the performance of students in certain course depends on student's previous academic achievements. The study discovered an obvious connection between performance in foundational courses, particularly Calculus and Physics with the success in Solid Mechanics. The finding that students with limited Calculus skills are more likely to fail Solid Mechanics emphasizes the importance of mathematical concepts in understanding and applying Solid Mechanics principles.

A solid foundation in mathematics and physics is widely recognized as essential for engineering, especially in the subject of engineering mechanics. This is due to the belief that mathematical and physical notions serve as foundational or preliminary to those typically acquired in the initial stages of engineering mechanics. For instance, requisite knowledge for understanding the use of free-body diagrams encompasses proficiency in equation manipulation, acquaintance with Newton's Laws, and the ability to create mathematical representations of physical entities. Consequently, students lacking a foundation in mathematics and physics would exhibit significantly lower performance in engineering mechanics. A study conducted in Australia by (Dwight & Carew, 2006) revealed a disparity in entry quiz scores for engineering mechanics amongst individuals who had completed physics or math extension courses. Students having a solid foundation in physics scored approximately 13 percentage points higher than those without, while students with a strong background in math averaged 10 percentage points over their counterparts lacking such a foundation.

The 19.4% failure rate, which represents a minority of students, demands attention. Furthermore, the findings encourage the establishment of early intervention programs for students who struggle with fundamental courses, particularly Calculus. To address the issues in engineering education, some recommendation to improve the student's performance is to create intervention programs for example a mentor-mentee system where a good performance student will be assigned to guide and help several poor performance students. Such programs could be tailored to help students dealing with the mathematical components of Solid Mechanics.

Previous research has proposed a learning technique for challenging engineering courses, particularly those that need extensive calculations. The technique involved collaborative learning in groups and the application of theories and concepts to real-world scenarios. Based on the study by (Gamez-Montero, et al., 2015), most students are driven to learn various concepts in theory when the principles are applied in real life, where they are comprehended collaboratively. Relevant research demonstrated that students excelled in practical

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work, particularly in teams, compared to individual assessments. Consequently, students are motivated to enhance their learning when subjects are elaborated upon through direct real-world application. (Aliligay, Rendon, Villarias, & Mercado, 2022).

Students demonstrated exceptional performance in experiential activities, particularly in collaborative learning as a pedagogical approach. The implementation follows a discussion of the concept, during which students engage in a real-life action to enhance their understanding of its application. Moreover, practical exercises encompass course content, problem-solving, case analyses, and other relevant methodologies. Hands-on activities as pedagogical tactics involve team collaboration, wherein students are organized into groups, and each member contributes ideas to address the assigned challenge.

The implementation of creative teaching methods, as opposed to standard lectures, can significantly enhance student performance. Active learning is one of the most utilized methodologies. The concept of active learning proposes that an interactive, learner-centered approach can enhance knowledge production through profound and meaningful learning experiences (Bazelais & Doleck, 2018). The active learning strategy enhances subject-specific knowledge and elevates students' examination performance. Furthermore, the methodology will facilitate the enhancement of professional competencies, including design, analytical, and problem-solving skills, which are essential for engineers (Hartikainen, Rintala, Pylvas, & Nokelainen, 2019).

Future research could look into establishing tailored interventions to increase student success in Solid Mechanics depending on their performance in prerequisite courses, as well as investigating the usefulness of new educational technology in improving student learning.

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