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Bridging Theory and Practice: The Importance of Numerical and Statistical Approaches in Electrical Engineering

Noor Hafizah Abdul Aziz[1], Ismarani Ismail[2*], Nur Nabila Mohamed[3], Rozita Mustafa[4]

[1,2,3] *Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM) 40450 Shah Alam, Selangor Darul Ehsan, Malaysia.*
[4] *Electrical Electronics Engineering Department, German Malaysian Institute, Kajang, 43000 Selangor, Malaysia.*

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ABSTRACT

This paper highlights the significance of numerical and statistical techniques in electrical engineering, emphasizing their role in bridging theory with practical problem-solving. Numerical methods such as integration, interpolation, and regression analysis enable accurate modeling, simulation, and optimization of complex systems. Statistical analysis complements these by addressing uncertainty, reliability, and performance evaluation through data interpretation and hypothesis testing. Together, these techniques empower technologists to analyze, design, and optimize electrical systems effectively. Their integration in engineering education enhances computational accuracy, critical thinking, and decision-making, preparing graduates for professional challenges in modern, data-driven technological environments.

1. INTRODUCTION

Numerical techniques and statistical analysis represent two essential pillars in the foundation of electrical engineering, particularly for technologists who must bridge theoretical knowledge with practical problem-solving. Numerical techniques provide systematic approaches to approximating solutions of complex mathematical problems that cannot be solved analytically, such as nonlinear circuit equations, signal processing algorithms, or electromagnetic field modeling. At the same time, statistical analysis offers robust tools to interpret variability, quantify uncertainty, and make informed decisions in scenarios where experimental or observational data dominate. Together, these disciplines enable technologists to analyze, design, and optimize systems with accuracy, efficiency, and confidence. For undergraduates in electrical engineering, mastering these tools is not only an academic requirement but also a professional necessity, as real-world engineering rarely presents problems that are both exact and deterministic.

[2*] Corresponding author. *E-mail address*: ismarani@uitm.edu.my
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The integration of numerical and statistical methods into electrical engineering practice demonstrates their value across a wide range of applications. Numerical techniques such as numerical integration, interpolation, and regression analysis are applied in power systems to approximate load flows, in signal processing to design and test filters, and in control systems to solve differential equations governing system stability. Statistical techniques, on the other hand, play a critical role in quality control, reliability analysis, and performance evaluation of electrical devices. For example, statistical hypothesis testing can guide fault detection in communication networks, while probability distributions are used to model noise in electronic circuits. The relationship of these techniques is tabulated in Table 1.

Table 1. The integration of numerical and statistical methods into electrical engineering practice

Aspect	Numerical Techniques	Statistical Techniques
Primary Role	Approximate solutions to mathematical models	Analyze data, quantify variability, and test hypotheses
Example in Electrical Eng.	Load flow analysis, circuit simulation, signal approximation	Reliability analysis, fault detection, noise modeling
Contribution	Enhances computational accuracy and efficiency	Improves decision-making and risk management

The importance of numerical and statistical techniques extends beyond computation, shaping the mindset and analytical capabilities of technologists in training. Electrical engineering problems often involve large data sets, uncertain parameters, and nonlinear behaviors that demand more than simple algebraic manipulation. Numerical approaches allow students to engage with iterative algorithms, approximations, and error analysis, fostering critical thinking and problem-solving skills. Statistical approaches complement this by equipping students with the ability to handle real-life uncertainties, analyze experimental results, and evaluate the reliability of engineering solutions. In combination, these techniques prepare undergraduates not only to succeed in academic projects and laboratory work but also to transition seamlessly into industry practice, where technological advancement relies heavily on data-driven decision-making and computational modeling. Ultimately, their mastery enables technologists to contribute effectively to innovation in areas such as renewable energy systems, embedded electronics, and intelligent automation, ensuring that engineering solutions are both technically sound and practically viable. The main applications of numerical and statistical techniques in the discipline of electrical engineering, particularly for technologists, are tabulated in Table 2.

Table 2. The major application areas where numerical and statistical techniques are applied in the field of electrical engineering

Application	Numerical and Statistical Techniques
Circuit Analysis and Simulation	Solving nonlinear equations, modeling component tolerances
Signal Processing	Designing filters, modeling noise, and pattern recognition
Control Systems	Analyzing system stability, error correction, and adaptive control
Power Systems	Load flow analysis, demand forecasting, and risk management.
Communication Systems	Coding, modulation, error detection, and noise analysis
Electromagnetics	Antenna design, field simulations, and measurement uncertainty
Renewable Energy & Smart Grids	System optimization, efficiency analysis, and energy forecasting

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2. LITERATURE REVIEW

The mastery of numerical and statistical techniques is of paramount importance for undergraduate technologists in electrical engineering, as these methods form the basis of modern engineering practice. Many engineering problems encountered in real-world contexts, such as nonlinear circuit analysis, electromagnetic field modeling, or dynamic system control, are mathematically complex and cannot be solved using closed-form analytical methods. Numerical techniques, through approximation and iterative algorithms, provide practical solutions to these problems, enabling accurate simulations, performance evaluations, and design optimizations (Chapra & Canale, 2021; Burden et al., 2016). Without such methods, many engineering challenges would remain unsolved or require oversimplified assumptions that compromise accuracy.

Equally important, statistical techniques play a vital role in addressing the inherent uncertainty and variability present in engineering systems. Electrical devices and networks are often subject to disturbances such as noise, fluctuations in material properties, or errors in measurement. Statistical analysis equips technologists with the tools to evaluate these uncertainties, analyze experimental data, and quantify reliability and performance (Walpole et al., 2017). Through statistical modeling, engineers can predict system behavior, validate hypotheses, and identify sources of variability that affect device or system functionality.

Recent studies have emphasized the integration of numerical and statistical methods within the design and optimization of electrical and electronic systems. For instance, finite element analysis (FEA) combined with Monte Carlo simulation has been widely adopted in electromagnetic compatibility and reliability studies (Silvester & Ferrari, 1996). Similarly, regression-based models and neural-network-assisted statistical estimation are increasingly applied to improve power system forecasting accuracy and smart grid management (Zhang et al., 2021). In signal processing, numerical Fourier transform algorithms coupled with probabilistic noise models enhance signal reconstruction and compression performance (Proakis & Manolakis, 2020). These examples demonstrate the interdisciplinary nature of numerical and statistical applications in modern electrical engineering, merging computational intelligence with data-driven analysis.

Moreover, in educational settings, the inclusion of numerical and statistical coursework within electrical engineering curricula enhances students' analytical thinking and practical competence. Studies in engineering education research highlight that students exposed to MATLAB-based numerical simulations and experimental data analysis using statistical software develop stronger problem-solving skills and engineering intuition (Palm, 2021; Rhinehart & Bethea, 2022). This alignment between theoretical understanding and computational practice not only fosters deeper comprehension of core concepts such as circuit theory, electromagnetics, and control systems but also prepares graduates for data-centric engineering environments increasingly influenced by artificial intelligence and automation.

The advancement of computational technologies such as MATLAB has revolutionized how numerical and statistical techniques are applied in electrical engineering practice. These tools provide interactive, high-level programming environments that enable engineers and students to model, analyze, and visualize complex systems with enhanced precision and efficiency. The integration of these modern platforms into both educational and industrial settings allows learners to move beyond theoretical understanding toward hands-on, simulation-driven problem solving.

MATLAB remains a dominant tool for engineering computation, widely used for matrix manipulation, signal processing, and control system analysis. Its integrated toolboxes allow students to perform numerical integration, regression analysis, and Monte Carlo simulations with minimal coding complexity (Palm, 2021). By using MATLAB based simulations, students can replicate real-world electrical system behaviors, such as transient analysis in power networks or filter design in communications systems, thereby reinforcing theoretical concepts through computational experimentation.

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Similarly, data-driven energy systems, including smart grids and intelligent power management platforms, rely on numerical simulation, statistical learning, and optimization models to balance demand, forecast generation, and manage distributed resources. Engineers trained in numerical and statistical computation using modern tools are therefore better equipped to handle large-scale data processing, predictive analytics, and decision automation that characterize the next generation of sustainable energy systems (Li et al., 2023).

Incorporating these tools into engineering education ensures that students are not only proficient in mathematical theory but also capable of deploying numerical and statistical reasoning in industrially relevant computational environments. This integration bridges the gap between academic learning and professional practice, fostering a new generation of electrical technologists adept at solving complex, data-rich, and multidisciplinary problems that define the digital transformation of engineering industries.

3. METHODOLOGY

3.1 Research design

This study employed a qualitative descriptive research design to evaluate student performance and learning achievement in the course Numerical Techniques and Statistics for Engineering Technologists (EEE551). The design was selected because it enables systematic analysis of numerical data related to Course Outcomes (COs) and Programme Outcomes (POs), providing measurable evidence of students' mastery. The focus of this study was on determining whether students achieved the minimum Key Performance Indicator (KPI), which required at least 75% of learners to attain a minimum of 50% performance level (Level 2 – Moderate). The methodology also allowed for identifying strengths and weaknesses across different outcomes, forming the basis for targeted recommendations to enhance teaching and learning practices.

3.2 Population and sample

The population of this study comprised undergraduate students enrolled in the Diploma in Electrical Engineering Technology (Programme CEEE260). The specific sample was drawn from students registered in EEE551: Numerical Techniques and Statistics for Engineering Technologists during the March 2024 to August 2025 academic sessions. The sample was considered adequate because it represented the entire cohort undertaking the course within the stated period. No additional sampling technique was applied since all available students were included in the analysis.

3.3 Data collection

Data were collected from official academic records, specifically the assessment results associated with the course learning activities. These included continuous assessments, assignments, quizzes, and final examinations mapped to Course Outcomes (CO1, CO2, and CO3) and Programme Outcomes (PO2 and PO5). The mapping process followed the Outcome-Based Education (OBE) framework, where each assessment task was aligned with the intended COs and POs. Data were collated semester by semester, allowing for longitudinal comparison between March 2024 and March 2025.

3.4 Data analysis

The analysis was conducted using descriptive statistical techniques. Student performance in COs and POs was expressed in percentages, reflecting the proportion of students achieving the minimum benchmark ($\geq$50%). Trends were examined across multiple semesters to identify patterns of improvement or decline. Comparative analysis between COs and POs was also carried out to highlight areas of strength and those

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requiring intervention. Graphical representations, including bar charts and student density plots, were generated to visualize results against the KPI threshold of 75%.

To enhance reliability, the study applied performance gap analysis, where outcomes falling below consistent achievement (particularly CO2, CO3, and PO5) were flagged for further pedagogical review. Additionally, inferential considerations were made to identify possible causes of underperformance, such as curriculum content difficulty, teaching approaches, or assessment design. The analysis was carried out using Microsoft Excel and CanvasJS tools integrated with the institutional learning management system.

3.5 Ethical considerations

The study adhered to academic ethics and institutional guidelines. All data were anonymized, ensuring student identities remained confidential. Only aggregate results were reported, with no individual student information disclosed. Approval to use course performance data for educational research purposes was obtained from the department, ensuring alignment with quality assurance and accreditation requirements.

3.6 Tools and instruments

The primary instruments for this study were the course assessments mapped to the OBE framework. Numerical results were extracted from the institutional Learning Management System (LMS). Microsoft Excel was used for data organization, statistical analysis, and graphical plotting, while CanvasJS was applied for density distribution visualization. These tools were selected because of their accessibility, accuracy, and compatibility with outcome-based reporting practices in higher education.

The research methodology adopted for this study followed a structured process to ensure systematic data collection, organization, analysis, and interpretation. Fig. 1 below illustrates the flow of activities undertaken in this study, beginning with data collection and mapping of Course Outcomes (COs) and Programme Outcomes (POs), followed by organization and statistical analysis. The process concludes with visualization, interpretation of findings, and formulation of recommendations.

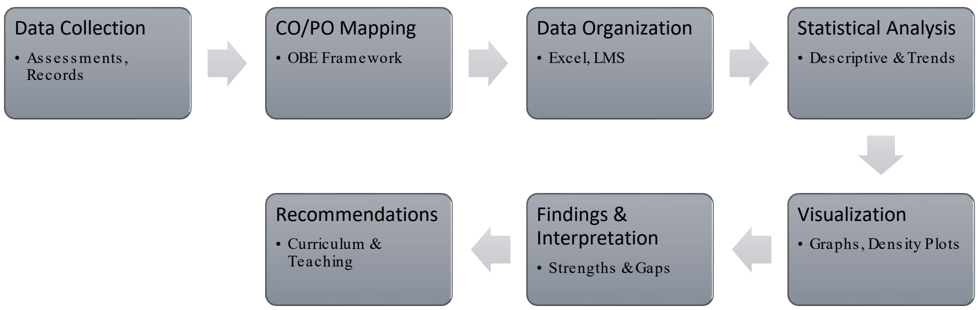

Fig. 1. Flowchart of the research methodology process of numerical and statistical approaches in Electrical Engineering

4. RESULTS AND DISCUSSION

4.1 CO-PO mapping

Fig. 2 shows the Course Outcome (CO) of EEE551 where CO1 focuses on equipping students with the ability to examine and apply numerical analysis methods to solve complex mathematical problems, particularly non-linear equations and differential models. This outcome emphasizes analytical thinking and problem-solving skills, enabling students to translate theoretical concepts into computational approaches for real world scenarios. Following with CO2 highlights the importance of data analysis and interpretation,

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where students are expected to determine meaningful findings using correlation and regression techniques. By achieving this outcome, students develop the ability to recognize patterns, establish relationships between variables, and draw evidence-based conclusions, which are essential in both research and industry applications.

Subsequently, CO3 is centered on the practical application of statistical tools and inferential methods, where students learn to select and implement appropriate statistical tests to analyze data. This outcome develops their competency in making informed decisions under uncertainty, validating hypotheses, and ensuring the reliability of research or experimental results. Together, these COs build a progressive learning pathway: from mastering computational methods CO1, to analyzing data trends CO2, and finally to applying inferential statistics for decision making CO3.

Course Outcomes

CO1	Examine numerical analysis methods to solve non linear equations and differential models.
CO2	Determine the findings of data analysis using correlation and regression techniques.
CO3	Perform application of appropriate statistical tests and tools in inferential statistics.

Fig. 2. Course outcome of EEE551 (Numerical techniques and statistics for Engineering Technologists)

Fig. 3 shows the Programme Outcome (CO) of EEE551 where PO2 (Problem Analysis) emphasizes a student's ability to critically identify, formulate, and analyze engineering problems by drawing from both research literature and practical contexts. It develops higher-order thinking skills where students are expected not only to recognize challenges but also to deconstruct them into manageable components. Through the application of analytical tools and systematic approaches, students learn to reach well substantiated conclusions. This outcome ensures that graduates can approach broadly defined engineering problems with depth, clarity, and evidence based reasoning.

PO5 (Modern Tool Usage) focuses on preparing students to be competent in the selection and application of modern engineering and IT tools relevant to their discipline. It highlights the use of advanced techniques, digital resources, prediction methods, and modeling tools to support engineering activities. Importantly, this outcome also nurtures an awareness of the limitations of these tools, ensuring that students apply them responsibly and appropriately. By mastering PO5, students gain the technical adaptability required to thrive in a rapidly evolving engineering landscape.

Together, PO2 and PO5 complement one another: PO2 ensures students can analyze and interpret problems effectively, while PO5 equips them with the technical tools to design and implement solutions in an informed and responsible manner.

Programme Outcomes

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.
PO5	Modern Tool Usage: Select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to broadly-defined engineering activities, with an understanding of the limitations.

Fig. 3. Programme outcome of EEE551 (Numerical techniques and statistics for Engineering Technologists)

Fig. 4 shows the mapping between Course Outcomes (COs) and Program Outcomes (POs) reflects a structured alignment between the specific learning goals of the course and the broader competencies

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expected of engineering graduates. CO1, which focuses on examining numerical analysis methods for solving non-linear equations and differential models, is mapped to PO2. This alignment ensures that students not only learn mathematical techniques but also apply them critically in identifying and analyzing broadly defined engineering problems, leading to substantiated conclusions. Similarly, CO2, which emphasizes determining findings from data analysis using correlation and regression, is also mapped to PO2. This shows the strong connection between statistical data interpretation and the ability to analyze complex problems through systematic reasoning supported by research evidence. On the other hand, CO3, which deals with applying appropriate statistical tests and tools in inferential statistics, is mapped to PO5. This highlights the importance of selecting and applying the right statistical tools and modern computational methods while being mindful of their strengths and limitations.

Overall, the mapping demonstrates a balanced approach: CO1 and CO2 strengthen students' analytical and problem-solving capabilities (PO2), while CO3 builds their competency in modern tool application (PO5). Together, these contribute to producing graduates who are both critical thinkers and proficient users of engineering tools in practice.

Course CO-PO mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CO2	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CO3	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐

Fig. 4. Course CO-PO mapping of EEE551 (Numerical techniques and statistics for Engineering Technologists)

4.2 Course performance achievement (CPA) and programme outcome achievement

The performance trends for the three course outcomes (COs) show varying patterns between March 2024 and March 2025 as shown in Fig.5. CO1 demonstrates a positive improvement, rising from 70.56% in March 2024 to 80.49% in March 2025, indicating better student achievement over time. In contrast, CO2 shows a gradual decline, dropping from 80.68% in March 2024 to 76.79% in March 2025, suggesting a potential challenge in sustaining student mastery in this outcome. Similarly, CO3 decreases slightly from 79.29% to 75.42% over the same period, reflecting a minor dip in performance consistency. The inference is that while targeted interventions for CO1 were effective, CO2 and CO3 may require additional focus, such as curriculum review, enhanced teaching strategies, or improved assessment methods. The insight here is that continuous monitoring and differentiated instructional approaches are necessary to balance performance across all COs and ensure consistent achievement levels.

Fig. 6 shows the programme outcome achievement for EEE551. PO2 illustrates a positive trend with an overall increase from 75.62% in March 2024 to 78.64% in March 2025, despite a slight dip in October 2024. This suggests gradual improvement in student achievement related to this programme outcome. Conversely, PO5 demonstrates a decline, moving from 79.29% in March 2024 to 75.42% in March 2025, despite a temporary peak in October 2024. The inference is that while strategies supporting PO2 appear effective over time, PO5 requires closer attention as performance is not consistently sustained. The insight is that targeted interventions such as strengthening learning activities, refining assessment methods, or integrating additional support for PO5 may help balance outcomes and ensure that improvements are achieved across both program outcomes.

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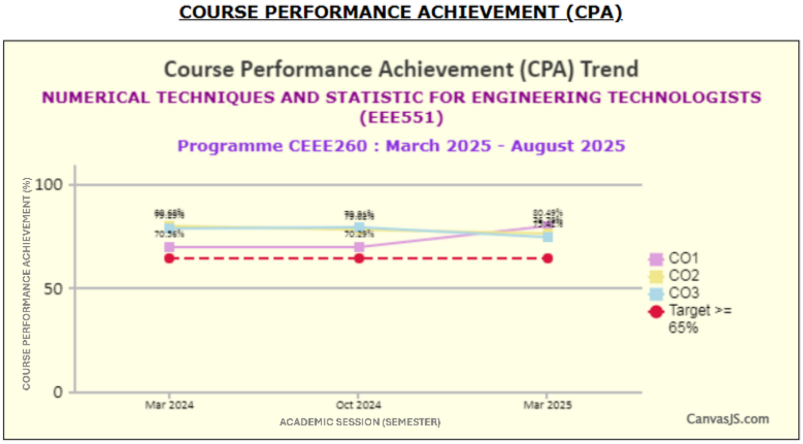

Fig. 5. Course performance achievement (CPA) trend for EEE551 (Numerical techniques and statistics for Engineering Technologists)

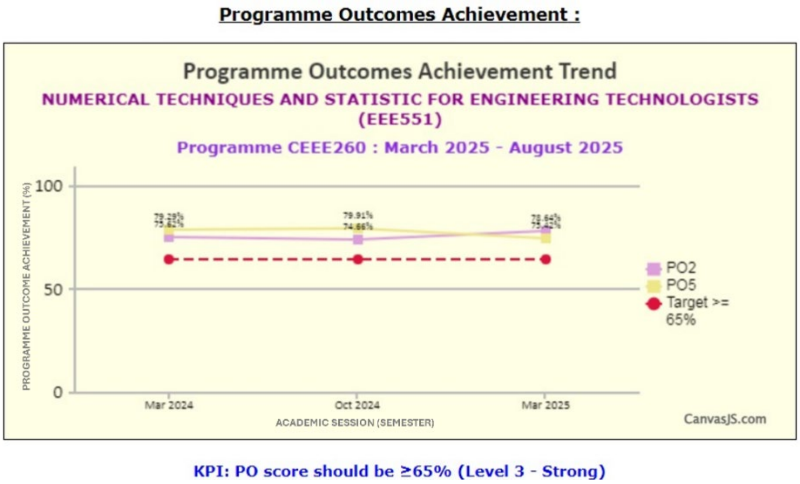

Fig. 6. Programme outcome achievement trend for EEE551 (Numerical techniques and statistics for Engineering Technologists)

4.3 Student density for PO achievement

The student density analysis for POs achievement in the EEE551 course, conducted from March to August 2025, reveals encouraging yet varied results. The Key Performance Indicator (KPI) requires that at least 75% of students attain a minimum score of 50% (Level 2 – Moderate). Fig. 7 shows student density analysis and Fig. 8 displays student density breakdown analysis based on POs for EEE551. Fig. 7 shows the outcome is highly satisfactory for PO2, with 95.24% of students achieving a pass while only 4.76% did not meet the benchmark. This surpasses the 75% target by a wide margin, indicating strong student mastery and effective instructional strategies for this learning outcome. The results suggest that students were able to grasp the associated skills and knowledge with considerable confidence and consistency.

In comparison, PO5 also achieved above the KPI but with slightly lower performance levels. Here, 85.71% of students passed, while 14.29% fell below the required threshold. Although the pass rate still

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exceeds the target of 75%, the relatively higher proportion of students failing indicates that challenges remain in sustaining consistent achievement for this outcome. This may highlight the need for additional academic support, refined teaching methods, or targeted learning activities to ensure more students can attain mastery.

To strengthen PO5, several recommendations can be considered. First, curriculum adjustments may be required to ensure the content is scaffolded more progressively, giving students better opportunities to master complex topics. Second, enhanced teaching strategies, such as problem-based learning, guided practice, and collaborative projects, could be introduced to improve engagement and deeper understanding. Third, supplementary tutorials or remedial sessions may help students who are struggling by providing more focused support on difficult concepts. Finally, assessment redesign for instance, incorporating more formative assessments and practical applications would provide students with continuous feedback and opportunities to improve before summative evaluations.

Overall, the analysis shows that both PO2 and PO5 surpassed the KPI benchmark, with PO2 demonstrating exceptional results and PO5 achieving satisfactory but improvable performance. The findings emphasize the importance of continuous monitoring and tailored interventions to maintain high standards across all programme outcomes, ensuring students are consistently supported in achieving success.

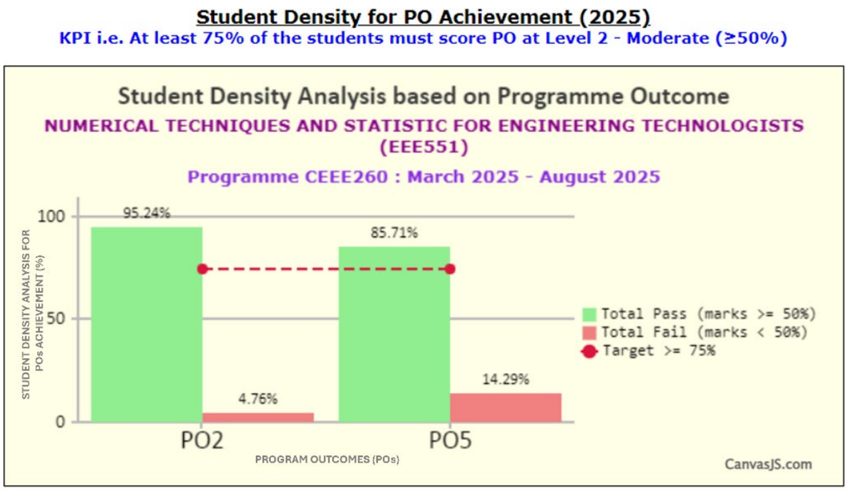

Fig. 7. Student density analysis based on POs for EEE551 (Numerical techniques and statistics for Engineering Technologists)

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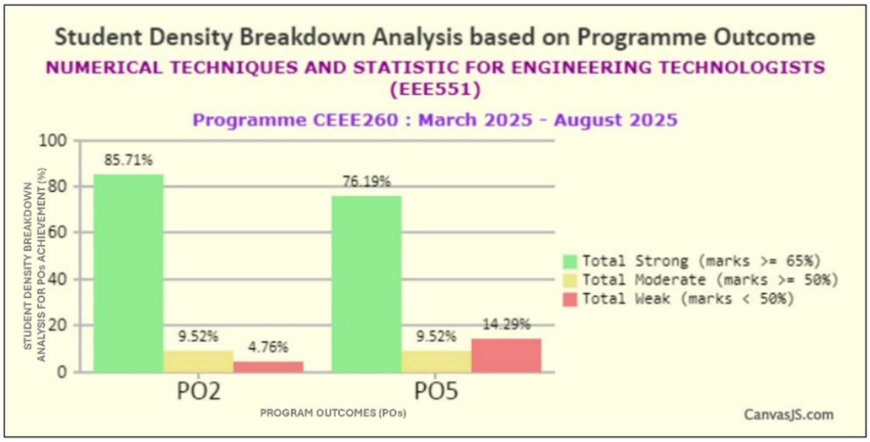

Fig. 8. Student density breakdown analysis based on POs for EEE551 (Numerical techniques and statistics for Engineering Technologists)

4.4 Recommendations for improvement PO

To sustain the high performance in PO2 and address the identified gap in PO5, the following measures are recommended:

1. Curriculum Enhancement – Review and refine content linked to PO5 to ensure greater clarity, relevance, and alignment with students' learning needs.
2. Active Learning Strategies – Integrate problem-based learning, case studies, and simulation exercises to strengthen students' applied knowledge and problem-solving skills.
3. Assessment Review – Revisit assessment design for PO5, ensuring an appropriate balance between theoretical understanding and practical application.
4. Targeted Student Support – Provide additional tutorials, remedial sessions, and peer-assisted learning activities to support students struggling with PO5 content.
5. Continuous Monitoring – Implement ongoing formative assessments and feedback mechanisms to identify learning gaps early, enabling timely intervention before final evaluations.

Overall, while both PO2 and PO5 surpassed the KPI benchmark, the results highlight the need for sustained focus on PO5. Through targeted instructional improvements and enhanced support systems, future cohorts can achieve more balanced and consistent success across all programme outcomes.

5. CONCLUSION & RECOMMENDATIONS

This study underscores the essential role of numerical and statistical techniques in modern electrical engineering education and practice. By bridging the gap between theoretical principles and practical applications, these methods empower students and professionals alike to address the complexities of real-world engineering problems. The integration of numerical techniques and statistical provides engineers with the tools necessary to model, simulate, and analyze complex systems with greater accuracy and confidence.

The research findings demonstrate the significant impact that numerical and statistical training has on student performance in the course Numerical Techniques and Statistics for Engineering Technologists (EEE551). Despite the overall achievement of the performance KPI in PO2, a gap was identified in PO5,

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which relates to practical application and problem-solving in real-world scenarios. This gap highlights the need for targeted improvements in the curriculum, teaching strategies, and student support mechanisms.

The study's results emphasize that a strong foundation in numerical and statistical methods not only enhances students' technical abilities but also fosters critical thinking, problem-solving, and data-driven decision-making, skills that are vital in a rapidly evolving technological landscape. By incorporating these techniques into electrical engineering curricula, educational institutions can ensure that graduates are well-prepared for the challenges they will face in professional settings, including those influenced by automation, artificial intelligence, and data science.

To improve student performance, particularly in PO5, and to strengthen the application of numerical and statistical techniques in electrical engineering education, the recommendations are curriculum enhancement, active learning strategies, assessment design review, targeted student support, and continuous monitoring and feedback.

Future research could explore longitudinal studies on the impact of integrated numerical and statistical training in electrical engineering curricula on long-term career outcomes. Investigating the correlation between hands-on practice in industry and academic learning might provide additional insights into how these techniques are applied in professional engineering contexts. Moreover, research into the development and effectiveness of adaptive learning platforms for teaching numerical and statistical methods could provide valuable information on how to best deliver these critical skills in a diverse and dynamic classroom environment. By implementing the recommendations outlined above, educational institutions can ensure that students not only meet the minimum performance benchmarks but are also better equipped to solve complex, data-driven engineering problems in their future careers.

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7. CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

8. AUTHORS' CONTRIBUTIONS

Noor Hafizah Abdul Aziz: Conceptualization, system design, development, methodology, formal analysis of testing, validation, investigation, supervision and writing original draft; **Ismarani Ismail**: Investigation, supervision, validation, paper review, editing, and industrial expertise advisor; **Nur Nabila Mohamed**: Conceptualization, system design, development, methodology, formal analysis of testing, validation, and supervision; **Rozita Mustafa**: Paper review, validation, editing, and academic expertise advisor.

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