34th Australasian Association for Engineering Education Conference
3 - 6 December 2023 – Gold Coast, QLD

A Comparative Study of Different Direct Assessment Methods to Evaluate Attainment of Program Outcomes of Engineering Graduates in an OBE based Curriculum

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ABSTRACT

CONTEXT

Different methods exist to evaluate the program outcomes (PO) attainment level of engineering graduates in Outcomes Based Education (OBE) through direct assessment techniques (Ngu et al., 2022). However, not all methods are equally appropriate for all the POs.

PURPOSE OR GOAL

Each of the methods to evaluate attainment of the POs has its unique advantages and disadvantages. Few studies have so far been conducted to compare relative merits and demerits of these methods and to determine the suitability of a specific method for a particular PO. The goal of this study is to make a systematic comparison of different PO attainment evaluation techniques by applying each technique to the same sample set of graduates.

APPROACH OR METHODOLOGY/METHODS

Recent graduates of the B.Sc. in EEE program of East West University were the subjects of this study. The scores obtained by individual graduates in various assessment tools, mapped to different course outcomes (COs) in different courses were collected. These data were used to calculate and evaluate levels of attainment of each PO following each of the selected PO attainment evaluation method. Results were analysed to compare the usefulness of different PO attainment evaluation methods.

ACTUAL OR ANTICIPATED OUTCOMES

For a few program outcomes, different PO attainment techniques provided different levels of attainment for the same PO for the same graduate. This research identified the similarities and the differences among the evaluation methods. However, for most of the POs, no significant difference in the attainment level were observed for different methods. The research indicates that the selection of appropriate attainment evaluation method for a particular PO should be according to the unique requirements of that PO.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The metrics for selecting a method that reflects a graduate's acquired competencies more reliably remains inconclusive. Further research and analysis should be carried out in this regard, which will provide a deeper insight into each evaluation method. This will help an engineering program to select the most suitable method(s) subject to its specific requirements.

KEYWORDS

Outcome Based Education, Program Outcomes, Direct Assessment, PO attainment evaluation methods.

Introduction

Outcomes-Based Education (OBE) (Spady, 1994) has emerged as a progressive approach to engineering education, reshaping the traditional input-based curriculum and teaching-learning methods. By aligning with the 12 Graduate Attributes (GA) defined by the Washington Accord (WA) (International Engineering Alliance, 2013), OBE emphasizes the desired program outcomes (PO) that engineering graduates should possess upon completion of their studies.

Calculating PO attainment in an OBE curriculum is of paramount importance (Bhagyalakshmi et al., 2015; Chan et al., 2022). It provides a systematic and data-driven approach to evaluate the effectiveness of engineering education in achieving the desired learning outcomes. By assessing students' performance against the established POs, institutions gain valuable insights into the extent to which students are acquiring the expected knowledge, skills, and attributes. This data-driven evaluation enables evidence-based decision-making for curriculum improvement, instructional design, and educational policies (Shuaib et al., 2009). Additionally, calculating PO attainment allows institutions to demonstrate accountability and transparency to stakeholders, including students, employers, accrediting bodies, and the broader engineering community. It facilitates continuous improvement by identifying areas of strength and weakness, enabling targeted interventions to enhance teaching strategies, support mechanisms, and overall student achievement.

When calculating PO attainment in OBE, institutions employ both direct and indirect assessment methods (Bhagyalakshmi et al., 2015; Kaur & Girdhar, 2018; Liew et al., 2021; Mohammad & Zaharim, 2012; Ngu et al., 2022; Rahman et al., 2016; Saad & Haque, 2020). Direct assessment methods involve evaluating students' performance through activities explicitly designed to measure the attainment of specific POs. These methods include exams, projects, rubrics, performance-based assessments, and practical demonstrations. They provide tangible evidence of students' mastery of knowledge, skills, and attributes aligned with the intended outcomes. On the other hand, indirect assessment methods rely on surveys, interviews, focus groups, or self-reflection exercises to gather students' perceptions and self-reported data about their learning experiences and the extent to which they believe they have achieved the POs.

The direct approach to calculating PO attainment involves aligning assessment tools with Course Outcomes (COs), which in turn are mapped with the desired POs or Graduate Attributes (GA). This approach focuses on evaluating students' performance directly against the COs, which represent specific knowledge, skills, and competencies that contribute to the achievement of the POs.

Three main analysis techniques are commonly followed for direct assessment of PO attainment: the accumulating model, which calculates PO attainment from all mapped COs across the curriculum; the dominating model, which derives PO attainment from selected COs across multiple courses; and the culminating model, which calculates PO attainment from key courses like capstone projects and internships (Ngu et al., 2022). In all these approaches, it is necessary to process assessment data of different COs, coming from different courses and mapped to the same PO, to evaluate the attainment level of that particular PO. The choice of a particular approach to process data from different COs is non-trivial since the outcome of the analysis, i.e., the PO attainment level, depends on this choice. Typically, simple averaging is done for this purpose (Ngu et al., 2022), but the reliability of this approach remains to be shown.

This paper presents a comparative analysis of three different approaches, including simple averaging, to process CO assessment data to evaluate PO assessment using the direct method. The analyses are done with the data from the Bachelor of Science (BSc) program in Electrical and Electronic Engineering (EEE) at East West University, Bangladesh. The program uses the dominating model for demonstrating PO attainment, and the study analyses the same cohort of students for a reliable comparison.

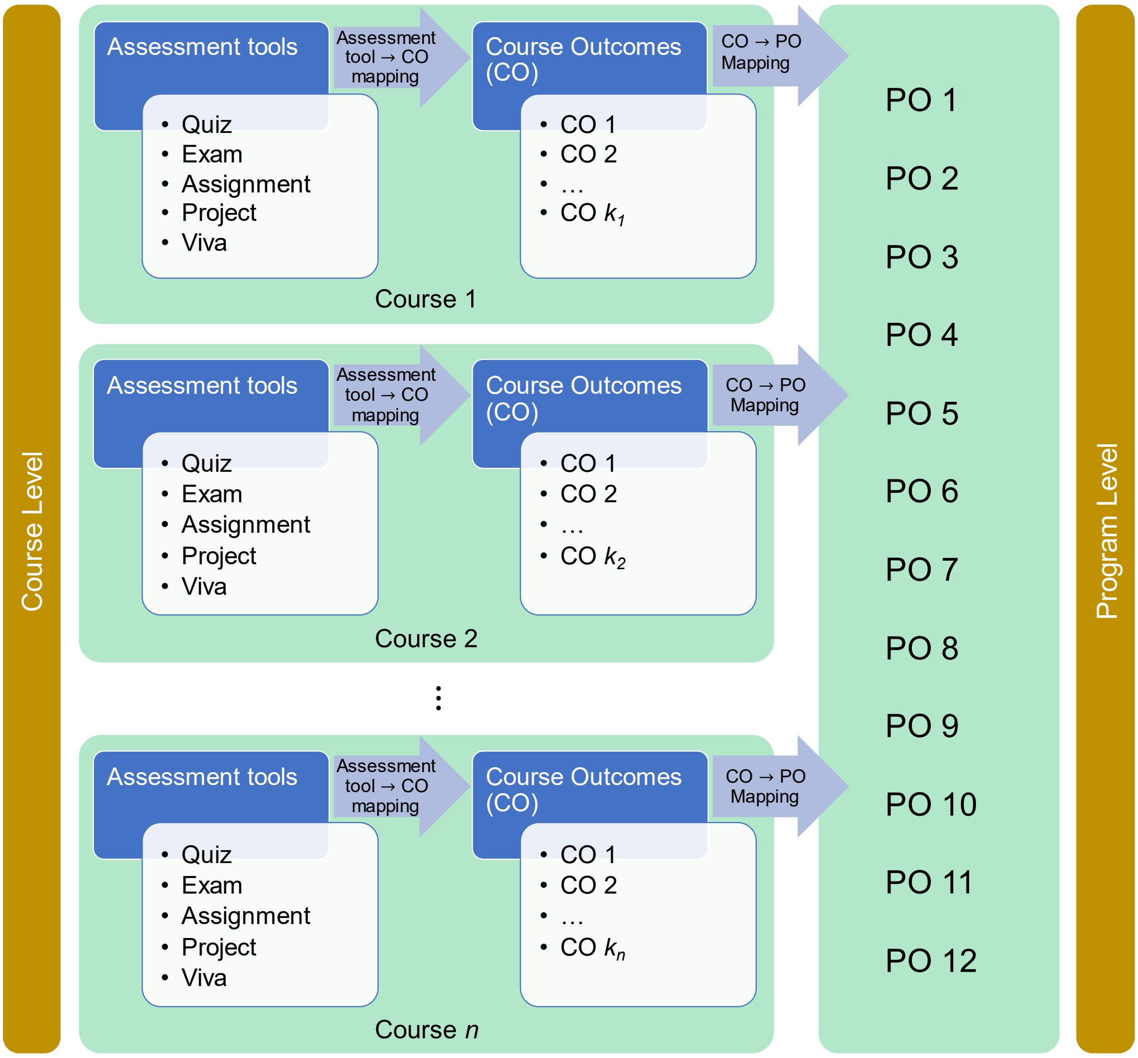

Figure 1: Evaluation of the PO attainment levels through direct method

PO Attainment Calculation Using Direct Approach

To calculate PO attainment through direct approach, the following steps are typically followed:

1. *Define Program Outcomes*: Clearly articulate the desired outcomes or GA that engineering graduates should demonstrate.
2. *Define Course Outcomes*: Identify specific learning outcomes or COs for each course within the program. These COs should align with and contribute to the achievement of the POs.
3. *Design Assessment Methods*: Develop assessment tools, such as rubrics, exams, projects, portfolios, or performance-based assessments, that directly measure students' achievement of the COs.
4. *Map Assessment Tools to Course Outcomes*: Align each assessment tool with the corresponding CO. Ensure that the assessment tasks directly target the intended outcomes of the course.
5. *Map Course Outcomes to Program Outcomes*: Establish the mapping between the COs and the POs. Identify how each CO contributes to the achievement of specific POs.
6. *Evaluate Student Performance*: Assess students' work using the predetermined assessment methods mapped to the COs. Evaluate their performance based on the established criteria and standards.

7. *Aggregate and Analyse Data*: Collect and aggregate the assessment data to determine the level of attainment for each CO and subsequently the POs. This can be done at various levels, such as individual student, course, program, cohort, or institution.
8. *Calculate Attainment Rates*: Calculate the attainment rates for each CO and PO by comparing the number of students who have met the desired outcomes against the total number of students assessed. This is typically expressed as a percentage.

For the direct method of PO attainment evaluation, steps 6 – 8 are focused on data collection and analysis as shown in Figure 1. CO attainment levels are calculated based on scores in individual assessment tools mapped to that particular CO, expressed as a percentage. These CO attainment levels are then used to calculate the PO attainment through the CO-PO mapping. Cohort performance analysis can be conducted using individual student performance data.

Methodology

Mapping of CO to PO

In the BSc in EEE program at East West University, the assessment process follows the mapping of assessment tools → CO → PO as depicted in Figure 1. Each course in the program has specific COs that are aligned with one of the 12 POs, as detailed in the Appendix. For instance, Table 1 shows the mapping between COs and POs for the year-3 course EEE305 (Electromagnetic Fields and Waves).

Table 1: Mapping of CO to PO of EEE305

CO	PO
1. Solve engineering problems on electro- and magnetostatics	PO1
2. Apply electromagnetic theories to study time-varying electromagnetic phenomena	PO1
3. Analyse interactions of electromagnetic waves with materials and interfaces	PO2
4. Demonstrate the ability for continuous learning of topics and issues related to electromagnetic fields and waves	PO12

Table 2: Mapping between COs and POs for PO attainment evaluation

PO / Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
EEE204	X_3	X_1										
EEE300			X_2			X_1				X_1		
EEE302			X_1	X_1	X_1							
EEE304	X_3				X_1							
EEE305	X_2											X_1
EEE307		X_1			X_1							
EEE308							X_1					X_1
EEE309		X_1		X_1					X_1			
EEE399										X_1	X_4	
EEE402			X_1						X_1			
EEE403						X_1	X_1	X_1		X_1		
EEE400		X_1	X_3	X_1	X_1	X_1	X_1	X_3	X_3	X_1	X_3	X_1

PO attainment evaluation methods

This paper presents the following three methods for processing CO level data to assess PO attainment.

(i) Simple average
(ii) Weighted average (weights according to course levels)
(iii) Weighted average (weights according to the number of CO occurrence)

These methods are discussed in the following subsections.

Simple average

In this method, the following equation is used to calculate the PO attainment (Ngu et al., 2022).

$$PO_k = \frac{\sum_{i=1}^{n} PO_{ki}}{n} \quad (1)$$

where k denotes the order of PO ($k = 1 \sim 12$), PO_k denotes the attainment of k-th PO, PO_{ki} denotes the attainment of k-th PO in i-th course, n denotes the number of courses used to map the k-th PO. For example, PO3 is calculated from 4 course, namely EEE300, EEE302, EEE402 and EEE400. Thus, in this case, $k = 3$, $n = 4$ and PO_{k1} is the PO attainment in EEE300, PO_{k2} is the attainment in EEE302, and so on.

Weighted average (weights according to course levels)

In this method, the following equation is used to calculate the PO attainment.

$$PO_k = \frac{\sum_{i=1}^{n} w_i PO_{ki}}{\sum_{i=1}^{n} w_i} \quad (2)$$

where w_i denotes the weight of the i-th course in the equation. Table 2 shows that one 2nd year course, eight 3rd year courses and three 4th year courses (including the capstone project EEE400) are used to calculate the PO attainment in the selected program. It is expected that the students will acquire better competency in each PO in the later courses than in the earlier courses. Therefore, the relative weights of the later courses are considered more than the earlier courses. Relative weights of years 2, 3 and 4 are considered 1, 2 and 3 respectively to calculate PO attainment with eq. (2).

Weighted average (weights according to the number of CO occurrence)

Eq. (2) is used in this method, but the weights are considered in a different manner. In this method, the weight is assigned to a course according to the number of occurrences of COs in that course mapped to a particular PO. For example, from Table 2, PO3 attainment is calculated from the CO attainment of one CO from EEE302 and EEE402 each, two COs from EEE300 and three from EEE400 (denoted by the numbers shown in the subscripts). Therefore, the weights of the CO attainment from both EEE302 and EEE402 are considered 1 and those of EEE300 and EEE400 are considered 2 and 3, respectively.

Selection of the sample of students

The graduating cohort of 2021 was chosen for this analysis. 20 random students were chosen from the group having a CGPA of ($\mu \pm \sigma$), where μ are σ the mean and standard deviation of the cohort CGPA respectively.

Results and Remarks

We have analysed the attainment of all POs by the aforementioned 20 students using the three PO attainment evaluation methods (results are not shown). It is found that for POs 1, 2, 3 and 10, attainment levels of certain students are dependent on the selected method. We show results for 5 students in Figure 2. Notable differences are observed in the attainment of these four POs for the five students. These differences arise due to (i) selection of COs to assess a PO, (ii) the assessment tools selected to evaluate each CO, and (ii) the method selected for calculating the PO attainment scores.

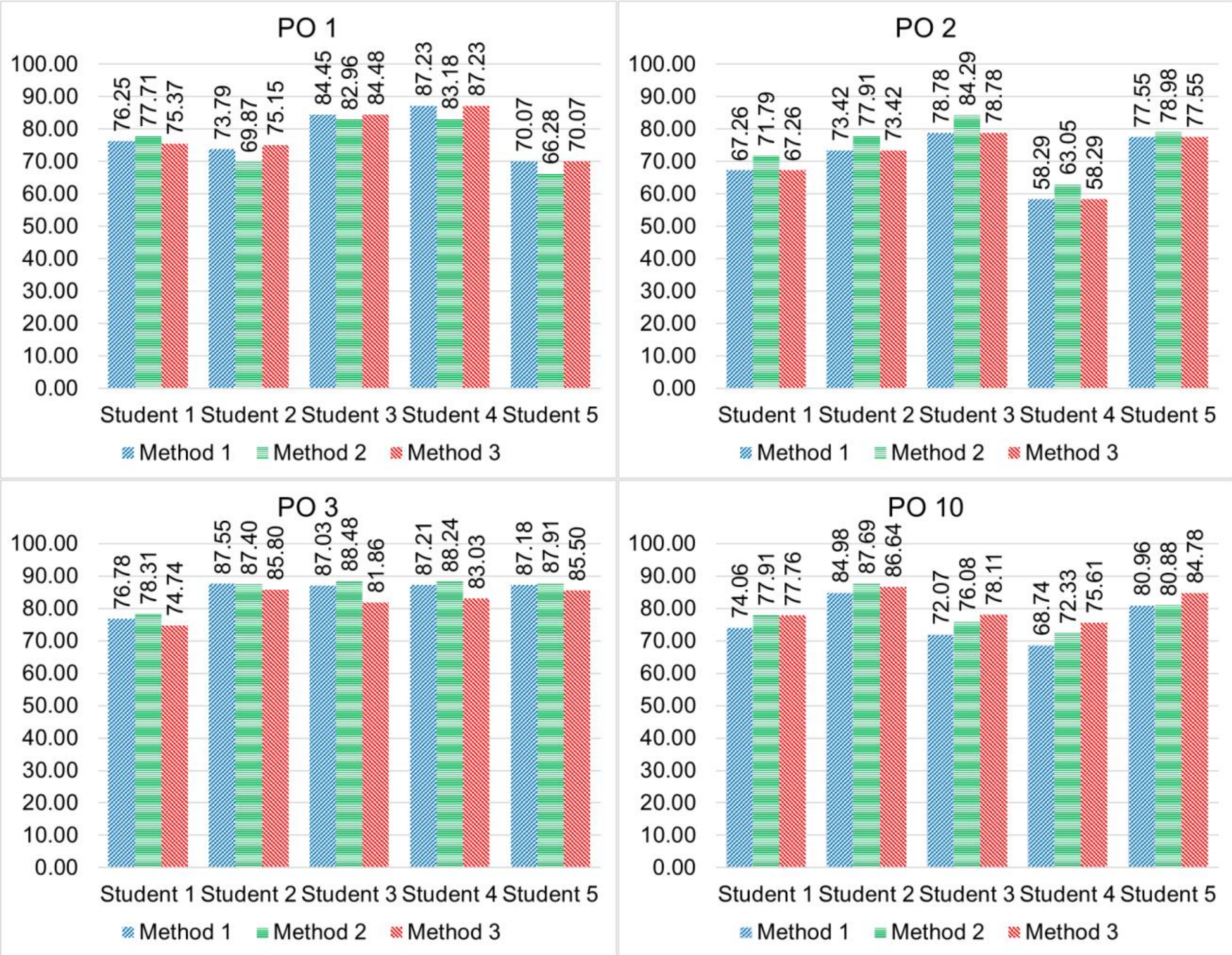

Figure 2: PO attainment scores of five selected students in four selected POs

Figure 2 illustrates the impact of selection of the PO attainment method on the attainment calculation of the same PO for individual graduates. For instance, for student 1, the PO2 attainment scores using the three methods are 67.26%, 71.79%, and 67.26%, respectively. Similarly, student 5 achieves PO1 attainment scores of 70.07%, 66.28%, and 70.07% for the three methods, respectively. The threshold for attaining a PO in the BSc in EEE program at East West University is set at 70% which corresponds to the C grade. These examples demonstrate that there can be notable differences (~4%) in the PO attainment scores calculated with different methods. Such difference can be crucial if the scores are close to the threshold value of PO attainment.

According to this threshold, in the mentioned examples, student 1 attains PO2 on the basis of method 2 only, while student 5 attains PO1 according to methods 1 and 3, but not on the basis of method 2. These marginal binary decisions can significantly impact a graduate's PO attainment classification. If the PO attainment calculation is not conducted reliably, it can lead to misinterpretations and adversely affect students' progress and achievement. It is essential for the assessment process to be precise to ensure fair and reliable evaluations of graduates' PO attainment, particularly when attainment levels are close to the established threshold values.

Table 3 provides a comparison between results from different PO attainment calculation methods and the average % marks of the five selected students from the respective courses (based on the CO-PO mapping shown in Table 2). Interestingly, PO2 attainment for student 1 using method 2 is closest to the attained marks, suggesting a stronger correlation between the two. On the other hand, PO1 attainment for student 5, according to methods 1 and 3, closely matches the attained marks, indicating a similar correlation. However, upon comparing the marks and PO attainment across all five students, no conclusive correlation can be observed.

The lack of a consistent correlation between PO attainment level and the method of calculation may be attributed to the complexity of assessing PO attainment through the dominating model, which considers specific selected COs from specific selected courses. Additionally, other factors, such as dependence of a student performance on the selected assessment tools, variations in course difficulty, and relative weights of different assessment tools, also influence the outcomes. As a result, achieving a strong correlation between % marks and PO attainment in this context may prove challenging. It is crucial to further investigate and fine-tune the assessment methods and mappings to achieve more reliable and consistent correlations. Reliable PO attainment evaluation and setting up of the threshold value are essential to make fair judgments regarding students' progress.

Table 3: Comparison of PO attainment (%) and marks attainment (%)

	PO1				PO2				PO3				PO10			
	Method 1	Method 2	Method 3	Marks	Method 1	Method 2	Method 3	Marks	Method 1	Method 2	Method 3	Marks	Method 1	Method 2	Method 3	Marks
Student 1	76.25	77.71	75.37	81.00	67.26	71.79	67.26	78.00	76.78	78.31	74.74	74.00	74.06	77.91	77.76	77.75
Student 2	73.79	69.87	75.15	82.33	73.42	77.91	73.42	82.00	87.55	87.40	85.80	86.17	84.98	87.69	86.64	81.50
Student 3	84.45	82.96	84.48	85.67	78.78	84.29	78.78	81.20	87.03	88.48	81.86	80.00	72.07	76.08	78.11	74.25
Student 4	87.23	83.18	87.23	81.00	58.29	63.05	58.29	81.40	87.21	88.24	83.03	81.00	68.74	72.33	75.61	75.00
Student 5	70.07	66.28	70.07	69.00	77.55	78.98	77.55	86.60	87.18	87.91	85.50	87.17	80.96	80.88	84.78	84.00

The data analysis yields the following observations:

- The PO attainment levels exhibit a few percent variations depending on the calculation methods, but these differences can significantly impact stakeholders' perception of a graduate's acquired competencies.
- Relying solely on the simple average method may not always accurately represent a graduate's actual PO attainment.
- No single method can be deemed universally appropriate for calculating attainment of all POs.

Conclusion

This paper offers a comparative analysis of three PO attainment calculation methods under the dominating model, revealing the variations in attainment levels for the same PO of individual students. However, determining which method reflects a graduate's acquired competencies more reliably remains inconclusive. Each program should identify the most suitable method to calculate PO attainment for each PO. Determination of the suitability can be the topic of another study. This can be determined, among different approaches, by comparing a student's PO attainment level against his/her performance under that PO in the culminating course(s), such as the Capstone Project.

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Appendix

Program Outcome statements of BSc in EEE program of East West University

PO1 – Engineering knowledge: Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialization as specified in K1 to K4 respectively to the solution of complex electrical and electronic engineering problems.

PO2 – Problem analysis: Identify, formulate, research literature and analyze complex electrical and electronic engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences. (K1 to K4)

PO3 – Design/development of solutions: Design solutions for complex electrical and electronic 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. (K5)

PO4 – Investigation: Conduct investigations of complex electrical and electronic engineering problems using research-based knowledge (K8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.

PO5 – Modern tool usage: Create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex electrical and electronic engineering problems, with an understanding of the limitations. (K6)

PO6 – The engineer and society: Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex electrical and electronic engineering problems. (K7)

PO7 – Environment and sustainability: Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex electrical and electronic engineering problems in societal and environmental contexts. (K7)

PO8 – Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice. (K7)

PO9 – Individual work and teamwork: Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.

PO10 – Communication: Communicate effectively on complex electrical and electronic engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11 – Project management and finance: Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12 – Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

K1: Natural Sciences; K2: Mathematics; K3: Engineering Fundamentals; K4: Specialist Knowledge; K5: Engineering Design, K6: Engineering Practice, K7: Comprehension (ethics, professional responsibility to public safety; economic, social, cultural, environmental and sustainability); K8: Research Literature