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# Performance Indicator Based Course Outcome: Question Paper Framing and its Impact on Assessment

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***Abstract*— The paper aims to analyze the impact of defining course outcome (CO) based on the identified performance indicators (PIs) and integrating the assessment process by framing questions based on the specified PIs. For the case study, three courses of different varieties; numerical based, theory based and laboratory courses are selected from Electrical Engineering programme of University of Mumbai, Maharashtra, India. The methodology includes three aspects (i) framing CO based on PIs (ii) framing question paper based on selected PIs and (iii) the impact analysis on performance of students. The clarity obtained from PI based CO helps the teacher to improve the quality of the course content delivery and the setting of the question paper. The performance of the students in the examination also improves by incorporating the expected PI in the question paper. A hypothesis was formulated and statistically tested using a t-test, with the results confirming its validity The performance analysis justifies the adoption of this system across all institutes to enhance the quality teaching learning process.**

***Keywords*—AICTE's Examination reform policy; Assessment process; Course outcome; Electrical engineering; Performance Indicator; Program outcome; Question paper framing.**

***JEET Category* – Case Report**

## I. Introduction

Twelve program outcomes (POs) are to be attained by an engineering graduate as per the outcome based education (OBE) proposed by National Board of Accreditation (NBA) of India. To enhance higher education enrolment and ensure holistic development, Thirumoorthy (2021) emphasizes OBE as the need of the hour. Outcome-Based Teacher Education (OBTE) shifts focus from content delivery to the competency development, preparing teachers for the evolving demands of 21st-century classrooms as mentioned by Ghosh (2025). The paper by Mantri (2008) presents a well-structured design and rigorous evaluation of a project-based learning course in analog electronics, demonstrating clear improvements in student engagement and learning outcomes. The research work by Sarkar (2023) explains that OBE works through a process of translation, mixing different and sometimes conflicting approaches, which is why it is both widely accepted and debated. All India Council for Technical Education (AICTE) has published Examination Reform Policy (2018), on the motive of improving the quality of technical education. The document has listed out the competencies to be identified for each PO and defined the performance indicators (PIs) which are expected from a student in the assessment process. From this process, the teacher is getting a clarity on the expected performance of the student which is to be looked after to decide whether the PO is met or not.

The effectiveness of the process can be improved if the expected PIs are conveyed to the students with the Course Outcomes (COs) since it is the real measurable performance the students should meet. Deciding the possible PIs based on the course content is very essential for deciding the CO/PO attainment through the assessment process. A continuous evaluation process will help the faculty to improve the instructional methods as well as the assessment process. In theory as well as practical courses, depending on the course content, the teacher should identify all the possible learning outcomes which will list out the knowledge and skills expected from the learner. The work by Mulla (2022) presents a clear case study on competency-based CO–PO mapping, showing how performance indicators can be effectively used to improve outcome-based assessment in engineering education.

The action verb in each PI reflects the cognitive level expected from students during the assessment. The paper by Ananda Kumar (2021) presents a CO-PO matrix and attainment analysis for a Big Data Analytics course, proposing a Bloom's Taxonomy (BT) based methodology that uses student assessments and feedback to evaluate course outcomes and enhance teaching strategies. Studies of Choudhary (2022), Lavanya (2022) and Edward (2002) present systematic frameworks for assessing and attaining course and program outcomes in engineering education, demonstrating that structured curriculum delivery and quantitative outcome-attainment methods improve the effectiveness of teaching–learning and evaluation processes. The papers by Abirami (2020), Affia (2022) and Mohiuddin (2020) emphasize improving engineering education quality by showing that well-

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designed assessments aligned with learning outcomes and the use of active learning strategies significantly enhance student engagement and attainment of intended learning outcomes.
The questions in the assessment process are also to be framed with the action verbs for giving clarity about the BT level to both the learner and the assessor. Framing questions for an examination based on PI will increase the clarity to the students belonging to all the category (below average, average and above average) which will help them to score better. The authors were inspired by the published works cited in the references to undertake this research study in education.

The present study investigates the effectiveness of defining and assessing COs through PIs with respect to improving the quality of course content delivery, the precision of question paper design, and the overall performance of students in examinations.

## II. Framing of COs based on PO and PI

Based on the OBE guidelines and referring the examination reforms, COs are framed by giving importance to the defined learning outcomes. In case of theory courses COs are framed based on the theory content in the syllabus and in case of laboratory courses, it is based on the proposed laboratory experiments.

The procedure adopted for the theory course is as follows:

1.The university prescribed syllabus content is categorized into 5-6 sections. 2. By giving importance to the learning outcomes (LOs) in each section, POs are determined. 3. By referring the examination reforms, suitable PIs are selected corresponding to the PO. 4. COs are framed using suitable bloom's taxonomy level (BTL) verbs and with respect to the selected PIs.

The laboratory courses follow a similar procedure, with the following exceptions: The experiments to be conducted are finalized in accordance with the prescribed syllabus. These experiments are grouped into 3 to 5 sections, each aligned to form the corresponding COs. For each section, the Learning Outcomes (LOs) are identified by considering both the practical aspects and the skills to be developed by the learners. The POs and the PIs are then derived from the identified LOs.

The above procedure is explained with case studies of a few theory and laboratory courses such as control system design (CSD), power system protection and switchgear (PSPS) and electrical AC machines lab1 (EACM Lab1).

### *CO Formulation for Theory Courses*

CSD and PSPS are the courses of third year (Semester VI) Electrical Engineering program under University of Mumbai. CSD is a numerical based theory course while PSPS is more of theoretical analysis. Thus they are selected intentionally to find the influence of PI on performance. Main objective of the course CSD is to familiarize students to analyze transient and steady state response of systems and design a suitable compensator to achieve the desired response using various techniques such as root locus, bode plot and state space. Similarly, the objective of PSPS is to teach the students the protective equipment, its location, operation and selection, which are used in electrical generation, transmission, and distribution. The CO formulation for these theory courses are explained in the following subsection.

### *CO Formulation for CSD*

The syllabus for CSD is categorized into five sections for framing the course outcomes. These are introduction to the compensator, design of compensators using root locus technique, frequency response technique (bode plot) and state variable approach and the design of digital compensators. Design of compensator cover the major portion of the syllabus, hence a design process using the tool Root Locus techniques is chosen for elaborating the CO formulation process. The learning outcomes expected from this section are: identifying the current dominant poles for a given design parameter using the root locus method, performing transient and steady-state analysis based on these dominant poles, designing a suitable compensator to achieve the desired performance, and verifying the results through further analysis. It is observed that PO-1 (Engineering knowledge), PO-2 (Problem analysis), PO-3 (Design/Development of Solutions) and PO-12 (Lifelong learning) can be mapped to this section based on the expected learning outcomes.

Students will be able to demonstrate competency in electrical engineering concepts by analyzing system behavior with test inputs and determining suitable compensators using the root locus technique, thereby substantially mapping to PO-1. PO-2 is also mapped, as students gain the ability to execute the solution process and systematically analyze results using root locus. The competency to identify multiple feasible solutions for achieving the desired response maps to PO-3. Furthermore, this section enables students to understand the significance of root locus and its role in the design of compensators for various systems, in line with current developments, thereby mapping to PO-12.

TABLE I
SELECTED PIs FOR THE COURSE 'CSD'

| PI | Statement |
|---|---|
| 1.4.1 | Apply Electrical engineering concepts to solve engineering problems. |
| 2.4.2 | Produce and validate results through skillful use of contemporary engineering tools and models |
| 3.2.1 | Apply formal idea generation tools to develop multiple engineering design solutions |
| 12.2.2 | Recognize the need and be able to clearly explain why it is vitally important to keep current regarding new developments in your field |

To enhance clarity in framing the COs, appropriate PIs are selected from the AICTE examination reforms corresponding to the mapped POs. The PIs for the above mentioned section of the syllabus are shown in Table I. Highest BTL expected is 'Analysis' because the expected skill-set is their ability to break down the compensator design with root-locus into various parts and identify the relationship between them. Based on the combined characteristics of all these PIs with expected blooms taxonomy level, course outcome for this section is framed as,

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'Learner will be able to analyze the system and select a suitable compensator to achieve the desired performance using root locus technique'. Using similar technique all the five COs for this course are framed.

*CO Formulation for PSPS*

Syllabus content is categorized into six sections which are substation equipment and switching devices, circuit breaker and fuses, introduction to protective relaying, protection schemes provided for major apparatus, protection of transmission lines and introduction to static and numerical relays. The majority of the content covers circuit breakers and fuses, along with an introduction to protective relaying. Three other sections are directly linked to the topics covered in the introduction to protective relaying, hence the course outcome formulation of third section is elaborated.

Learner are expected to realize 1. the causes of and effect of fault, 2. the importance of protective relaying, 3. the desirable qualities of protective relaying, 4. analysis of different type of time current characteristics and select suitable relay setting for specific application and 5. demonstrate the operation of various type of relays. 1-4 covers the knowledge related to protective relaying. However, 5th LO covers development of protective solution for specific application and analysis of its performance under different conditions. Program outcomes related to Engineering knowledge PO-1, Problem analysis PO-2 and Design/development of solution PO-3 are identified and mapped to the respective sections. Form AICTE examination reforms, PIs suitable for the LOs are identified, as given in Table II.

TABLE II
SELECTED PIs FOR THE COURSE 'PSPS'

| PI | Statement |
|---|---|
| 1.4.1 | Apply theory and principles of Electrical engineering to solve an engineering problem |
| 2.1.3 | Identify the mathematical, engineering and other relevant knowledge that applies to a given problem |
| 2.2.3 | Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions. |
| 3.1.6 | Determine design objectives, functional requirements and arrive at specifications |

The course outcome framed from the identified PIs is 'Students will be able to select suitable relay and adjust its setting based on application and analyse its operation'. The same methods are adopted to frame the COs for other sections.

*CO Formulation for Electrical AC Machines Lab*

The EACM Lab–I syllabus in Semester IV of the Electrical Engineering program covers experiments on single-phase and three-phase transformers as well as induction motors. In line with the syllabus requirements, a total of nine performance-based experiments and five demonstration-based experiments have been planned to be completed within the allotted course time.

The first four experiments are grouped under Course Outcome 1 (CO1), as detailed below:

- Demonstration of different parts and working principle of a three-phase transformer
- Open-circuit and short-circuit test on a single-phase transformer
- Load test on a three-phase transformer
- Sumpner's test on 2 identical single-phase transformers

The LOs of these experiments are defined as the abilities that students will acquire:

- Identify the various parts of single-phase and three-phase transformers and explain their functions (PI: 1.3.1, 1.4.1).
- Apply scientific principles and electrical engineering concepts to develop a steady-state model of a transformer by performing different tests (PI: 2.3.1, 2.3.2)
- Select and use appropriate procedures, tools, techniques, and measuring instruments for conducting tests, including justifying the choice of HV/LV side connections (PI: 4.3.1).
- Perform open-circuit (OC) and short-circuit (SC) tests to derive the steady-state equivalent circuit of a transformer for predetermining voltage regulation and efficiency (PI: 2.3.1, 9.2.1).
- Analyze how voltage regulation and efficiency vary with changes in power factor and load conditions (PI: 4.3.3).
- Present experimental data effectively in tabular and/or graphical form to support analysis, interpretation, and conclusions (PI: 4.3.3).
- Recognize and state the assumptions required for transformer modelling at a desired level of accuracy (PI: 2.3.2).
- Evaluate transformer performance characteristics and draw logical conclusions (PI: 4.3.3).
- Prepare a clear, well-structured laboratory report with justified conclusions and inferences (PI: 10.1.2).

The PIs have been selected based on these learning outcomes

TABLE III
SELECTED PIs FOR THE COURSE 'EACM LAB 1'

| PI | Statement |
|---|---|
| 1.3.1 | Apply fundamental engineering concepts to solve engineering problems |
| 1.4.1 | Apply Electrical engineering concepts to solve engineering problems |
| 2.3.1 | Combine scientific principles and electrical engineering concepts to formulate steady state model of transformer by conducting different tests |
| 2.3.2 | Identify assumptions (mathematical and physical) necessary to allow modelling of a system at the level of accuracy required |
| 4.3.1 | Use appropriate procedures, tools and techniques to conduct experiments and collect data |
| 4.3.3 | Represent data (in tabular and/or graphical forms) so as to facilitate analysis and explanation of the data, and drawing of conclusions |
| 9.2.1 | Demonstrate effective communication, problem solving, conflict resolution and leadership skills |
| 10.1.2 | Produce clear, well-constructed, and well-supported written engineering documents |

and are presented in Table III. Based on the PIs, course outcome for this section is framed as, 'Learner will be able to analyze the operation and performance of single/three phase transformer.'

A similar procedure is followed to articulate the remaining Course Outcomes. For instance, the second Course Outcome (CO2) is framed as: 'The learner will be able to analyze various transformer connections and the parallel operation of transformers.' This outcome is derived from the following three experiments:

- Parallel operation of two single phase transformers
- Open delta connection of Transformer
- Demonstration of Dy11 Transformer and Scott Connections

## III. Assessment process

For the theory courses, Internal Assessment (IA) test is conducted as an evaluation tool for finding the internal mark, which is counted for calculating the semester grade. The assessment tool considered for the theory courses CSD and PSPS is IA-1. The questions are set for IA-1 based on the 40% of the syllabus of each course which completely covers CO2 of CSD and CO3 of PSPS. Questions for assessing the achievement of course outcomes are framed based on suitable BTL by keeping the respective PIs for each course outcome in mind. For the EACM lab course, practical examinations are conducted which covered CO1 with a BT level of 4.

### *Assessment Process for CSD*

Table IV shows the questions framed during internal examination corresponding to CO2 for the course CSD with the corresponding maximum BTL and PIs. As an example in Q1, PI-1.4.1 is assimilated to measure student's capability to identify the relationship between dominant pole location and transient behaviour which is one of the basic electrical engineering concepts related to CSD. PI-2.4.2 is used to assess the students' ability to systematically apply contemporary engineering tools to determine new closed-loop poles for achieving the desired system behavior. Q 2 is framed to measure two more PIs. PI-3.2.1 is included to assess students' ability to explore and develop multiple solutions using root locus through its graphical approach. PI-12.2.2 is implicitly included to evaluate students' understanding of the advantages and ease of compensator design using root locus compared to other available techniques.

TABLE IV
SAMPLE QUESTION PAPER FOR THE COURSE CSD

| S.N | Question | BTL | PIs |
|---|---|---|---|
| Q1 | Dominant closed loop poles of a given system is at -4±j6. Determine the new desired dominant pole location, if the objective of the compensator design is to reduce the peak time by a factor of 2 with the same percentage overshoot. | BTL-3 | 1.4.1<br>2.4.2 |
| Q2 | A unity feedback system that has forward path transfer function G($s$)= K/(s(s+3)(s+5) need a PD controller to reduce the settling time by half by maintaining 16% overshoot. Draw the uncompensated root-locus, analyze it to determine the desired dominant closed loop pole location and the PD controller angle contribution. | BTL-4 | 1.4.1<br>2.4.2<br>3.2.1<br>12.2.2 |

### *Assessment Process of PSPS*

TABLE V
SAMPLE QUESTION PAPER FOR THE COURSE PSPS

| S.N | Question | BTL | PIs |
|---|---|---|---|
| Q1 | The fault current during earth fault is 16000 A. The IDMT relay at the location are fed via a CT, and its CT ratio is 400/5. The relay has a plug setting of 200% and Time multiplier setting of 0.4, Determine operating time of the relay.<br>For TMS=1 the relation between PSM and operating time is given below<br>PSM 2 4 5 8 10 20<br>t 10 5 4 3 2.8 2.4 | BTL-3 | 2.2.3 |
| Q2 | Prove that a directional relay with 30 $^{o}$ delay with maximum torque angle of 0$^{o}$ connection is used for sensing fault condition with power factor <60$^{o}$ | BTL-3 | 1.4.1,<br>2.1.3,<br>2.2.3,<br>3.1.6 |

Questions framed for CO3 of PSPS is shown in Table V. PI 2.2.3 perfectly suit for Q1 since in each questions students are required to understand an existing process in Electrical Engineering and suggest a suitable solution. Q2 is a design oriented numerical, wherein students are asked to find out the operating time of the relay for a particular setting, hence PI 3.1.6 is included. To solve the above problem, they need to have the basic knowledge and a skill to apply the mathematical and Engineering knowledge to find the solution, Hence PI 1.4.1 and PI 2.1.3 are mapped.

### *Assessment Process of EACM Lab1*

During the learning process, care is taken to avoid overburdening students with repetitive calculations and drawings. Accordingly, the aim of each experiment is carefully defined so that the LOs are distributed across various experiments.

TABLE VI
SAMPLE QUESTION PAPER FOR THE EACM LAB COURSE

| S.N | Question | BTL | PIs |
|---|---|---|---|
| Q1 | Conduct proper test on the given transformer and predetermine the voltage regulation versus power factor curve for R, RL, RC, L and C loads. Determine the power factor at which voltage regulation is (i) zero and (ii) maximum.<br>Machine Details: 415/208V, 1kVA, 50Hz, 1Φ transformer. | BTL-4 | 1.4.1<br>2.3.1<br>2.3.2<br>4.3.1<br>4.3.3<br>10.1.2 |

Table VI presents a sample question framed during the first practical examination corresponding to CO1 for the course EACM Lab–I, along with the BTL and PIs. The PIs for CO1 include:

- Demonstrating fundamental knowledge,
- Analyzing observed and calculated data,
- Performing approximate/accurate modelling,

- Applying appropriate procedures and tools for experimentation,
- Representing data in tabular/graphical form to support conclusions,
- Communicating effectively with peers, instructors, and teachers, and
- Preparing clear, structured reports with supporting evidence.

The rubrics for evaluating the experiment (total: 25 marks) are as follows:

- Circuit diagram with selected meters, procedure, oral test – 05 Marks
- Connections, performance, observation table – 05 Marks
- Calculations, result tables, graphs – 05 Marks
- Report writing with conclusions and inferences – 05 Marks
- Oral test on the above aspects – 05 Marks

Some of the sample oral questions used for CO1 to comprehensively assess the identified PIs are:

- Draw the equivalent circuit of a transformer with reference to the L.V. side.
- What is the approximate equivalent circuit?
- How does the equivalent circuit differ when referred to the H.V. side?
- Why is the input power in the OC test considered as only iron loss, while in the SC test it is taken as only copper loss?
- What will be the percentage error if (i) no-load copper loss is neglected, (ii) iron loss in the SC test is neglected?
- State the importance of the polarity test in Sumpner's test. In this test, explain the wattmeter and ammeter readings connected to the primary winding when current is injected into the secondary circuit.

## IV. Result Analysis

Analysis is done to verify the impact of defining COs and setting question paper based on PIs for three typical courses considered.

### *Result Analysis of Theory Courses*

The undergraduate class of Semester VI consist of 67 students and all were present for the IA-1 examination. The students are categorized into three groups based on their previous semester SGPA. The students who scored 8.5 and above in the previous semester are segregated as above average, between 6.5 to 8.5 are average and below 6.5 as below average. It is observed that 21 students are there in above average, 32 in average and 14 in below average. The marks scored by them for each theory courses for the identified CO is analyzed and is tabulated in Table VII. Column-1 shows the category of students, column-2 shows the number of students in each category, column-3 shows the average SGPA of previous semester obtained by each category student. Column-4 and 5 indicates the average marks obtained by each category student for the courses CSD and PSPS respectively.

TABLE VII
AVERAGE MARKS OBTAINED FOR EACH CATEGORY STUDENTS

| Cate-gory | Number of Students in each category | Average of previous semester SGPA | Average marks obtained for CSD | Average marks obtained for PSPS |
|---|---|---|---|---|
| Below Average students | 14 | 5.1 | 6.2 | 5.8 |
| Average students | 32 | 7.2 | 7.2 | 7.2 |
| Above average students | 21 | 9.1 | 8.9 | 8.3 |

Improvement in marks is observed for below average students for both the courses. In case of average students, performance remained same as that of the previous semester SGPI. A slight reduction is observed in the average marks for the students in the above average category as compared to their previous semester SGPI. However, this SGPI was calculated including their performance in the laboratory courses where score is excellent for the above average students. Hence, the analysis implies that for both the courses, theoretical one and the numerical one, questions framed based on PIs, overall performance of the students is improved.

These observations are compared for each courses in the form of a bar chart as shown in Fig. 1 and Fig. 2. Fig. 1 compares the average marks of each courses scored by three category of students. However, Fig. 2 shows the comparison for the same course by all the three category students as mentioned in Table VII. The performance improvement is more for CSD as compared to PSPS, may be because scoring is better for numerical subject.

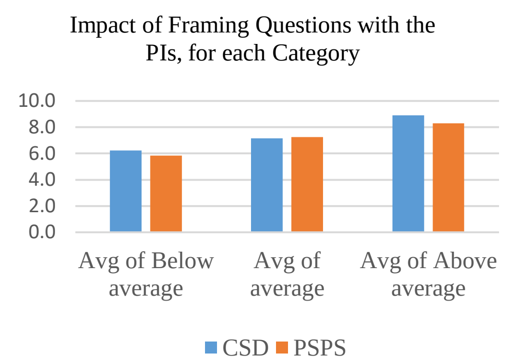


Fig. 1. Impact of framing questions with the PIs in mind for each category with both courses

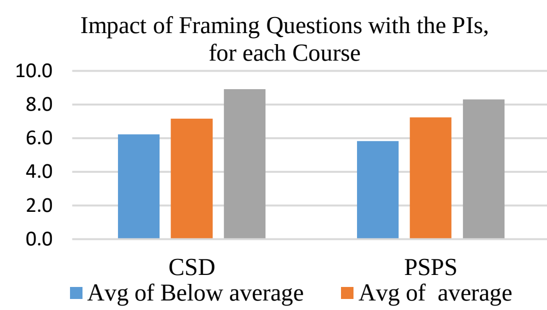


Fig. 2. Impact of framing questions with the PIs in mind for each course with all category.

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An analysis is carried out to find the shift of each category students (Table VII) to the other category based on the test result considered, IA-1, for both the courses and is listed in Table VIII. By comparing with the second column of Table VII (gives the number of students in each category based on their previous semester SGPI), it is clear from Table VIII that in case of below average category for CSD, 7 students remain in the below average category itself, 5 could move up to average category and 2 could move further to above average. Similarly, in case of PSPS, 8 remains in the same below average category, 4 could move up to average category and 2 could move further to above average. This reinforce the hypothesis for below average students.

TABLE VIII
PERFORMANCE ANALYSIS OF ALL STUDENTS IN EACH CATEGORY AFTER THE EXAM FOR THE COURSES CSD & PSPS

| Transition | To Below average category | To Average category | To Above Average category |
|---|---|---|---|
| No. of students from below average category | 7 (CSD)<br>8(PSPS) | 5 (CSD)<br>4 (PSPS) | 2 (CSD)<br>2(PSPS) |
| No. of students from Average category | 7 (CSD)<br>7 (PSPS) | 16 (CSD)<br>20 (PSPS) | 9 (CSD)<br>5 (PSPS) |
| No. of students from Above Average category | 0 (CSD)<br>5 (PSPS) | 4 (CSD)<br>4 (PSPS) | 17 (CSD)<br>12 (PSPS) |

However, in case of average students, for the course CSD, 16 remains in the same average category, 9 moved up to above average category, but 7 moved down to below average category. Similarly, for PSPS, 20 remains in the same category, 5 moved up but 7 moved down to below average category. In case of above average students, only 4 students moved down to average category in case of CSD, however, 9 moved down for PSPS.

This indicates that in case of theoretical courses questions framing with more clarity expect the answers more precisely, leads to comparatively less scoring for the above average and average. However, affected students in the above average category is less for numerical courses because for such courses basically clarity helps for better performance.

The inspection of the nature of the matrices of Table VIII indicates that, total numbers in lower triangular portion is small as compared to the numbers in diagonal and upper triangular portions. It indicates that number of students moving to upper level or remains same is more as compared to moving to lower level. However, tendency to move to higher level is more with numerical courses like CSD as compared to theory courses such as PSPS.

Impact analysis of the results with that of similar subject in the previous semester is also done for the same batch of students and is shown in Table IX. The table represents the comparative analysis for subject CSD in comparison with control system subject in semester V and PSPS in comparison with power system II subject in semester V. Both the analysis is reinforcing the previous observations.

In summary, numerical courses like CSD benefit from clarity in problem framing, as it helps students perform better. The tendency to move to a higher category is more pronounced in CSD, indicating that students are more likely to improve or

TABLE IX
IMPACT ANALYSIS OF PI BASED QUESTIONS FOR SUBJECT CSD IN COMPARISON WITH CONTROL SYSTEM (CS) AND PSPS IN COMPARISON WITH POWER SYSTEM-II (PS2)

| Transition | To Below average category | To Average category | To Above Average category |
|---|---|---|---|
| No. of students from below average category | 15 (CSD to CS)<br>17 (PSPS to PS2) | 11 (CSD to CS)<br>23 (PSPS to PS2) | 9 (CSD to CS)<br>5 (PSPS to PS2) |
| No. of students from Average category | 0 (CSD to CS)<br>3 (PSPS to PS2) | 13 (CSD to CS)<br>7 (PSPS to PS2) | 12(CSD to CS)<br>9 (PSPS to PS2) |
| No. of students from Above Average category | 0 (CSD to CS)<br>1 (PSPS to PS2) | 2 (CSD to CS)<br>0 (PSPS to PS2) | 5 (CSD to CS)<br>2 (PSPS to PS2) |

maintain their performance in numerical courses. In theoretical courses like PSPS, questions framed with high precision and expectation of exact answers lead to comparatively lower scores for above average and average students. Improvement is less pronounced in theoretical courses due to the nature of assessments requiring precise answers rather than analytical or numerical problem-solving.

*Result Analysis of Laboratory Course*

The undergraduate Semester IV group consisted of 69 students, all of whom appeared for the EACM Lab 1 practical examination. To evaluate its impact, the outcomes were benchmarked against the results of the Electrical Machines and Measurements (EMM) Lab examination held in Semester III.

TABLE X
IMPACT ANALYSIS OF PI BASED QUESTIONS FOR EACM LAB1 IN COMPARISON WITH EMM LAB

| Variation in EACM Lab1 compared to EMM Lab | To Below average category | To Average category | To Above Average category |
|---|---|---|---|
| No. of students from below average category | 10 | 10 | 0 |
| No. of students from Average category | 4 | 17 | 13 |
| No. of students from Above Average category | 0 | 3 | 12 |

Analysis of the transition matrix in Table X demonstrates a trend consistent with that of the theory courses (Table IX). The relatively smaller number of entries in the lower triangular portion, compared to the diagonal and upper triangular portions, suggests that a majority of students either retained their performance level or progressed to higher achievement categories, with fewer students exhibiting decline. This upward shift is further substantiated by the observation that 10 students advanced from the below average to the average category, while 13 students transitioned from the average to the above average category.

*Hypothesis testing using t-test*

The hypotheses formulated for this study are as follows:

Null Hypothesis ($H_0$): The adoption of PI-based COs has no significant effect on the quality of course content delivery, question paper design, or student performance in examinations. Alternative Hypothesis ($H_1$): The adoption of PI-based COs significantly enhances the quality of course content delivery, question paper design, and student performance in examinations.

The hypothesis was tested across all three subjects by comparing the results of subjects after implementing PI-based Course Outcome (CO) evaluation with those of similar subjects from the previous academic year. For the selected subjects, the sampling means were found to follow a normal distribution in both datasets. Table XI shows the mean, standard deviation, variance and t test results for all the three subjects. The standard deviation values for all the subjects are relatively small, indicating that the data points were closely clustered around the mean, demonstrating consistency in the dataset.

TABLE XI
STATISTICAL ANALYSIS & DATA INTERPRETATION

| Sr No | Subject | Mean | Standard Deviation | t-test value & Remarks |
|---|---|---|---|---|
| 1 | CSD | 7.63 | 1.82 | t value is 4.619> t critical |
| | CS | 6.17 | 1.79 | |
| 2 | PSPS | 6.98 | 1.94 | t value is 3.318> t critical |
| | PS2 | 6.02 | 1.32 | |
| 3 | EACM Lab1 | 7.26 | 1.63 | t value is 2.62 > t critical |
| | EMM Lab | 6.55 | 1.53 | |

A t-test was conducted at a 5% significance level with 9 degrees of freedom. The critical t-value was found to be 2.262. Table XI shows the calculated t-values for all subjects, which are higher than the critical value; hence, the null hypothesis is rejected. This outcome indicates that the implementation of PI-based CO evaluation significantly enhances the quality of course content delivery, question paper design, and student performance in examinations.

## CONCLUSION

In alignment with the Program Outcomes, which articulate the expected competencies of engineering graduates, performance indicators and course outcomes are systematically derived. The identification of appropriate PIs for each course is a critical element of the effectiveness of both course delivery and assessment. The defined hypothesis, when tested using a t-test, was validated by the results, thereby reinforcing the reliability of the study's findings. Evidence from this study suggests that employing PIs to define COs and design assessment instruments significantly enhances the transparency and objectivity of the evaluation process for both teachers and learners. Furthermore, the improvement in student performance was found to be more pronounced in numerically intensive subjects compared to theoretical courses.

To ensure that learning outcomes are achieved at the course level, it is imperative that teachers adopt a continuous evaluation approach, supported by timely modifications in teaching–learning strategies and assessment methods. Post-assessment discussions of measured COs with students provide formative feedback, enabling learners to recognize and address their deficiencies. The findings reinforce that a reliable, structured assessment framework, supported by well-defined PIs, plays a pivotal role in strengthening the validity of evaluations and contributing to the overall success of the program.

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