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A Performance Indicator-Based Framework for CO-PO/PSO Mapping and Attainment Assessment in Engineering Education

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Abstract: *Outcome-Based Education (OBE) has emerged as a transformative, performance-based framework in global engineering education. By emphasizing higher-order cognitive skills and professional competencies, OBE necessitates a fundamental shift in traditional pedagogical approaches—particularly in curriculum design, content delivery, and assessment methodologies. In alignment with this paradigm shift, the AICTE Examination Reform Policy (November 2018) advocates for comprehensive assessment reforms. The policy delineates specific competencies and performance indicators for each Program Outcome (PO), providing a structured interpretation of their intended objectives. This paper presents a novel methodology that leverages higher-order cognitive processes associated with performance indicators to systematically establish the correlation between courses and program outcomes, thereby facilitating a more accurate assessment of PO attainment. Initially, performance indicators are utilized to ensure precise mapping between Course Outcomes (COs) and Program Outcomes. Subsequently, these indicators serve as the basis for evaluating PO attainment through internal assessment mechanisms. This involves an evidence-based mapping of POs to appropriate assessment tools, enabling a valid, consistent, and measurable evaluation of student learning outcomes.*

Keywords: *Outcome Based Education (OBE), Performance Indicators (PIs), Course Outcomes (COs), Program Outcomes (POs), Program Specific Outcomes (PSOs), Bloom's taxonomy, Rubrics, Surveys*

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I. Introduction

In recent years, engineering education has undergone significant transformation, particularly in three critical dimensions: curriculum content (what to teach), pedagogical strategies (how to teach), and assessment methodologies (how to evaluate student learning). Among these, examinations and student assessments play a pivotal role in determining the overall quality of education. The AICTE Examination Reform Policy [1] emphasizes the need to elevate assessments to higher levels of Bloom's Taxonomy, encouraging the evaluation of learners on higher-order cognitive skills. This approach aims to foster critical thinking, creativity, and problem-solving—essential attributes for any competent technical professional.

Outcome-Based Education (OBE) employs a "design-down" methodology, beginning with the Program Outcomes (POs), followed by the development of Course Outcomes (COs), and ultimately, specific outcomes for individual learning experiences. Each level of learning outcome must be intentionally aligned with, and contribute toward, the attainment of the overarching program outcomes. As fundamental components of any academic program, courses must be strategically designed so that teaching methodologies, learning activities, assessment tools, and instructional resources collectively support the achievement of course-level outcomes. Through well-structured assessment activities, students demonstrate the extent to which they have achieved the intended course learning outcomes. In a constructively aligned curriculum, courses are deliberately sequenced and integrated to support a progressive development from introductory knowledge to mastery-level competencies, thereby ensuring systematic attainment of the intended program outcomes and program specific outcomes.

II. Structuring Program Outcomes: Competencies and Performance Indicators

Program Outcomes (POs) serve as essential guiding principles at the program level for curriculum design, instructional strategies, and the assessment of student learning. However, as POs are typically articulated as broad and generic statements, they are not directly measurable. To bridge the gap between these high-level outcomes and specific course content, course outcomes, and assessment practices, it is necessary to enhance the clarity and specificity of POs. This can be effectively accomplished through a structured two-step process involving the identification of Competencies and Performance Indicators (PIs) [1].

1) Identification of Competencies for Each PO: For each Program Outcome, a set of competencies is defined, representing distinct abilities or attributes embedded within the outcome statement. Each competency typically requires a unique method of assessment. The articulation of these competencies facilitates a shared understanding among educators of the specific capabilities students are expected to develop. Moreover, competencies function as an essential intermediate layer that informs the development of measurable performance indicators.

2) Definition of Performance Indicators (PIs): For each identified competency, Performance Indicators are developed as clear, specific statements that articulate the expected student learning outcomes. These indicators serve as measurable descriptors that enable objective assessment of the extent to which outcomes have been achieved. Performance Indicators also facilitate the determination of appropriate levels of achievement or proficiency for each competency. This enables instructors to design targeted instructional strategies and assessment methods, while providing students with clear expectations to reach the desired level of competence.

Consider for example program outcome PO3 – Design / Development of solutions lets list out competencies and performance indicators:

PO3: Design/Development of Solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, and cultural, societal, and environmental considerations.
Competencies:
1. Demonstrate an ability to define a complex, open-ended problem in engineering terms.
2. Demonstrate an ability to generate a diverse set of alternative design solutions.
3. Demonstrate an ability to select the optimal design scheme for further development.
4. Demonstrate an ability to advance an engineering design to the defined end state.

For the Competency - 2: Demonstrate an ability to generate a diverse set of alternative design solutions.
Performance Indicators:
1. Apply formal idea generation tools to develop multiple engineering design solutions.
2. Build models, prototypes, algorithms to develop a diverse set of design solutions.
3. Identify the functional and non-functional criteria for evaluation of alternate design solutions.

At first glance, certain Program Outcomes (POs) may appear to be attainable only through a limited set of courses, such as internships or capstone projects. However, when competencies and their corresponding performance indicators (PIs) are taken into account, it becomes evident that opportunities to address and contribute to PO attainment exist across a broader range of courses within the program.

III. Correlation between the courses and the Program Outcomes & Program Specific Outcomes

Course Outcomes (COs) are clearly defined, measurable statements that reflect the knowledge, skills, and professional competencies students are expected to acquire upon successful completion of a course. These outcomes are formulated in alignment with Bloom's Taxonomy to ensure appropriate cognitive rigor. Each CO is systematically mapped to relevant Program Outcomes (POs) at varying levels of correlation, using Performance Indicators to establish the strength and nature of the relationship. This mapping enables a structured and evidence-based evaluation of how individual courses contribute to the program outcomes.

Procedure for CO - PO/ PSO Articulation Matrix:

- State course outcomes for each course.
- Map each course outcomes with relevant POs / PSOs through proper understanding of PIs.
- Identify the 'm' number of PIs addressed by CO out of 'n' total number of PIs defined for the mapped PO.
- Calculate the %ge of PO using formula - (m/n) *100.
- Assign the levels based on %ge of PIs as stated below.
- Level of mapping may be calculated based on % of mapping Level:
    - Above 60% - 3
    - 41% - 60% - 2

- 20% - 40% - 1
- Less than 20% not addressed

i) Course Outcomes

Course name: MINI PROJECT-I			
Semester: III			
Course Outcomes - PO/ PSO addressed			
CO	Student will be able to :	Cognitive Level	PO/ PSO addressed
CO1	Interpret literature with the purpose to formulate a problem statement.	Apply	PO1 to PO3, PO6 to PO8, PO10, PO12, PSO1
CO2	Analyze the design and implement the solution.	Analyze, Apply	PO1 to PO4, PO6 to PO12, PSO1, PSO2
CO3	Assess the solution of identified problem with the help of modern tools & technology.	Evaluate	PO1 to PO5, PO7 to PO12, PSO1, PSO2
CO4	Plan to work as a team to exhibit team skills to meet deadlines.	Apply	PO2, PO4, PO5, PO7, PO8 to PO12,
CO5	Prepare and submit the report and deliver presentation.	Create	PO9, PO10

ii) Mapping Course Outcomes to POs using PIs - sample for 2 POS

Performance Indicators		**Course Outcomes**				
		CO1	**CO2**	**CO3**	**CO4**	**CO5**
S. No.	**PIs**	Interpret literature with the purpose to formulate a problem statement.	Analyze the design and implement the solution.	Assess the solution of identified problem with the help of modern tools & technology.	Plan to work as a team to exhibit team skills to meet deadlines.	Prepare and submit the report and deliver presentation.
PO 1	**PO1: Engineering knowledge - Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialisation for the solution of complex engineering problems.**					
1	Apply basic / advance mathematical techniques to solve engineering problems		y	y		
2	Apply laws of basic sciences to solve engineering problems		y			
3	Apply fundamental engineering concepts to solve engineering problems	y	y	y		
4	Apply core engineering concepts to solve engineering problems	y	y	y		
	Total	2	4	3	0	0
	Percentage	50	100	75	0	0
	Level	2	3	3	0	0
PO 2	**PO 2 : Problem analysis - Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.**					
1	Articulate problem statements and identify objectives	y	y	y		y
2	Identify the mathematical, engineering and other relevant knowledge that applies to given problem	y	y	y		
3	Identify existing solutions; compare and contrast alternative solution processes to select the best process	y	y	y	y	
4	Formulate a model or process that is appropriate to execute solution process and analyze and interpret results using contemporary tools	y	y	y	y	y
	Total	4	4	4	2	2

	Percentage	100	100	100	50	50
	Level	3	3	3	2	2

iii) CO- PO/PSO Mapping using above table

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO12	PSO 1	PSO 2
CO1	2	3	1	1	0	3	3	1	1	1	0	3	1	0
CO2	3	3	3	3	3	1	2	3	2	2	3	3	3	3
CO3	3	3	3	3	3	0	3	3	3	2	3	3	3	3
CO4	0	2	3	3	3	0	2	3	3	3	2	1	1	1
CO5	0	2	2	0	2	2	0	3	3	3	0	0	0	0
Sum of levels	8	13	12	10	11	6	10	13	12	11	8	10	8	7
No. of Cos mapped	3	5	5	4	4	3	4	5	5	5	3	4	4	3
Avg level	2.6	2.6	2.4	2.5	2.7	2	2.5	2.6	2.4	2.2	2.6	2.5	2	2.3
Course level correlation	3	3	2	3	3	2	3	3	2	2	3	3	2	2

iv) CO- PO/PSO Mapping for the course

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO12	PSO 1	PSO 2
CO1	2	3	1	1	0	3	3	1	1	1	0	3	1	0
CO2	3	3	3	3	3	1	2	3	2	2	3	3	3	3
CO3	3	3	3	3	3	0	3	3	3	2	3	3	3	3
CO4	0	2	3	3	3	0	2	3	3	3	2	1	1	1
CO5	0	2	2	0	2	2	0	3	3	3	0	0	0	0
Course level correlation	**3**	**3**	**2**	**3**	**3**	**2**	**3**	**3**	**2**	**2**	**3**	**3**	**2**	**2**

A **Course Articulation Matrix** is developed to map all courses against the relevant POs.

IV. Attainments

In the context of Indian engineering education, written examinations continue to serve as the primary mechanism for evaluating student learning and determining academic grades. Institutions typically assign significant weight to the outcomes of these examinations in the computation of overall student performance. Consequently, the nature and quality of questions posed in examination and test papers play a pivotal role in shaping the level of cognitive engagement expected from students at both the course and program levels.

Given that assessment drives learning, the construction of examination papers must transcend rote memorization and aim to evaluate higher-order cognitive skills. However, written examinations often assess only a narrow spectrum of learning outcomes and cognitive domains. In courses where the defined Course Outcomes (COs) encompass a broad array of skills and competencies, reliance solely on written assessments may result in an incomplete and potentially invalid evaluation of student achievement.

To ensure that assessment practices are aligned with the full scope of expected learning outcomes, a diverse array of evaluation methods—such as term papers, open-ended problem-solving tasks, laboratory or course project rubrics, and experiential components like internships—should be integrated into the assessment framework. These methods help ensure that the assessment tools are appropriately matched to the nature of the intended learning outcomes.

When employing Bloom's Taxonomy as a framework for the design and planning of assessment activities, several considerations must be kept in mind. Typically, the lower-order cognitive levels—Remembering, Understanding, and Applying, and to some extent Analyzing—are assessed through Continuous Internal Evaluation (CIE) and Semester-End Examinations (SEE), where time constraints limit the complexity of tasks. In contrast, the higher-order cognitive levels—Analyzing, Evaluating, and Creating—are better assessed through extended learning activities such as course projects, mini or minor projects, internships, and final-year capstone projects.

The assessment of Course Outcomes (COs) is carefully structured by aligning individual assessment items—such as internal test questions, assignments, and examination problems—with clearly defined Performance Indicators (PIs). This alignment ensures that each assessment component directly targets measurable competencies, thereby enhancing the objectivity, granularity, and clarity of CO and PO attainment.

Mapping examination and assessment tasks to relevant PIs enables a systematic and transparent evaluation of student learning in relation to the defined educational objectives.

An attainment for the sample course Mini projects is shown below.

i) Attainment of Course Outcomes

Course Outcome (CO) attainment can be determined by assuming that each CO is uniformly assessed throughout the entire Semester End Examination (SEE) paper. The student's final grade in the course is considered to represent their overall performance across all COs. Hence, the final grade is uniformly mapped to each CO.

Steps to Calculate CO Attainment from SEE Grades:

Step 1: Grade to Grade Point Conversion:

Grade	Grade Score	Grade	Grade Score
F	<40	B	70-80
E	40-50	A	80-90
D	50-60	A+	90-100
C	60-70		

Step 2: Set Target Criteria:

Procedure for setting targets for courses:

- Define targets based on the historical data and expected competency of the course.
- If a course is newly introduced then the target will be set as 60%.
    - Expecting that 60% of students score more than 60% of marks.

Below is the table representing the levels and percentages

Level
1 – 50% of students score more than 60% marks
2 – 60% of students score more than 60% marks
3 – 80% of students score more than 60% marks

Below is the Attainment and target (levels and percentages):

Attainment Levels			
%	Level	%	Level
50	1	60&61	2
51	1.1	62&63	2.1
52	1.2	64&65	2.2
53	1.3	66&67	2.3
54	1.4	68&69	2.4
55	1.5	70&71	2.5
56	1.6	72&73	2.6
57	1.7	74&75	2.7
58	1.8	76&77	2.8
59	1.9	78&79	2.9
		>=80	3

Set Levels	
%	Level
60&61	2
62&63	2.1
64&65	2.2
66&67	2.3
68&69	2.4
70&71	2.5
72&73	2.6
74&75	2.7
76&77	2.8
78&79	2.9
>=80	3

Step 3: Use Same Value for All COs

Since all COs are assessed uniformly through the SEE:

- The **same percentage of attainment** will apply to **each CO**.
  That means, for example, if 72% of students got **grade ≥ C**, then: **CO1 to CO5** all get **Attainment Level 2.6**.
- 80% of co attainment is taken as direct attainment level(dal).

Indirect Attainment to a course through Course Exit survey:
A **Course Exit Survey** is a feedback tool conducted at the end of a course to understand how well students feel the **Course Outcomes (COs)** have been achieved. A 20% of average value of CES is considered to be indirect attainment level (ial).
The overall attainment of a course is calculated as a sum of 80% of Average value of dal+20% Average value of ial.

S. No.	Roll No.	Grade
1	2451-21-737-001	A
2	2451-21-737-002	A
3	2451-21-737-003	C
	. . .	
211	2451-21-737-318	B
212	2451-21-737-319	B
213	2451-21-737-320	C
	CIE & SEE max marks (Grade)	A+
	CIE & SEE - 70% of max marks (Grade)	B
	No. of students > = 70% of max marks	144
	CIE & SEE - % of Attainment	67.61
	Direct Attainment Level	2.3

The final attainment for a course is shown below

80% direct + 20% indirect					
CO attainment					
CO	**t l**	**d a l**	**i a l**	**o a l**	**s**
CO1	2	2.3	2.4	2.32	M
CO2	2	2.3	2.4	2.32	M
CO3	2	2.3	2.4	2.32	M
CO4	2	2.3	2.4	2.32	M
CO5	2	2.3	2.4	2.32	M
	2	2.3	2.4	2.32	M

tl	Target level
dal	Direct attainment level
ial	Indirect attainment level
oal	Overall attainment level
s	Status

Target - x% of students scoring >=70% max marks	
Target – CO Attainment set %	**60%**
Target – CO Attainment set Level	**2**
Obtained – Direct CO Attainment %	**67.61**
Obtained – Direct CO Attainment Level	2.3
Obtained – Indirect CO Attainment	2.4
Obtained – Overall CO Attainment	**2.32**
Status	**Met**

ii) Attainment of Program Outcomes & Program Specific Outcomes
Calculating PO attainment for a course:
PO target of a course is calculated as CO target Average * CO-PO mapping (for each PO) and PO attainment is calculated as CO attainment average * CO-PO Mapping (for each PO)

Course	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO12	PSO 1	PSO 2
Correlation	3	3	2	3	3	2	3	3	2	2	3	3	2	2
Target	2	1.73	1.6	1.67	1.83	1.33	1.67	1.73	1.6	1.47	1.78	1.67	1.33	1.56
Attained	2.32	2.01	1.86	1.93	2.13	1.55	1.93	2.01	1.86	1.7	2.06	1.93	1.55	1.8
Status	M	M	M	M	M	M	M	M	M	M	M	M	M	M

A **Programme Articulation Matrix** is developed to list direct attainments all courses against the relevant POs / PSOs. Rubrics and Surveys are included as part of indirect assessment for attainment of POs / PSOs.

V. Conclusion

The proposed methodology underscores the significance of using performance indicators grounded in higher-order cognitive skills as a foundation for meaningful CO-PO mapping and accurate assessment of Program Outcome attainment. By aligning with the AICTE Examination Reform Policy and embedding these indicators into internal assessment practices, the approach ensures that outcome evaluation is not only structured and evidence-based but also reflective of actual student competencies. This systematic alignment enhances the credibility and effectiveness of the Outcome-Based Education framework, enabling institutions to make informed decisions on curriculum design, teaching strategies, and continuous improvement processes. Ultimately, it contributes to producing engineering graduates who are better equipped with the professional skills and critical thinking abilities demanded by today's global and dynamic work environment.

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