Defining the Performance Indicators: A Framework for Program Outcomes' Attainment

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***Abstract*— The attainment of Program Outcomes (PO) at the time of graduation is a measure of the competence of engineering graduates. The program outcomes are generic and have wide scope for interpretation by the faculty member depending upon his/her experience and judgment. Therefore, the attainment process might end up with either measuring too many things making the entire exercise very hectic or measuring too little that may not be sufficient to capture the intent of the outcome. Nowadays the practice is to expand each of the program outcomes into a set of outcome elements. As a result, the faculty members can use these elements in adapting the outcomes to their courses. Even with the elements being known, many a times it is a difficult proposition especially for the novice and in-experienced faculty members to plan their delivery and assessment mechanism. The reason being each element may involve several attributes or stages before it is fully understood. An attempt has been made to identify those logical stages as performance indicators for each of the outcome elements. Performance indicators provide faculty members with enough resolution for planning effective delivery and assessment modes leading to meaningful attainment of program outcomes.**

Keywords—program outcomes, outcomes elements, performance indicators, course outcomes

I. INTRODUCTION

Program outcomes' attainment is at the top of the agenda of the outcome based education (OBE) philosophy. Program outcomes are the measure of the competence of engineering graduates demonstrated at the time of graduation. To make the measurement possible, the efforts are continuously on to align the teaching-learning process in meeting the challenges of attaining the program outcomes. Consequently, literature is pouring in on how the teachers are attempting to align their teaching-learning process to adapt the program outcomes. Of late, India has become the permanent member of the Washington accord and has adopted OBE framework as backbone of its accreditation process more prominently for autonomous engineering institutes. The OBE approach being relatively new to the Indian engineering institutes, faculty members need to acquaint themselves with the intended expectations of the accreditation requirements. It is therefore necessary to modify/change the curriculum, delivery mechanism and assessment strategies to meet the expectations, mainly program outcomes.

II. PROGRAM OUTCOMES

The POs are observable and measurable manifestations of applied knowledge. According to ABET and NBA, Program Outcomes describe what students are expected to know and be able to do by the time of graduation [1]. Evidently, outcomes relate to the knowledge, skills, and behaviors that students acquire as they progress through the program. Thus the 11 outcomes serve as a foundation for all engineering programs. At BVBCET, each program has defined the outcomes by adding its own specificity. The outcome definitions will continue to be modified and updated as more is learned about their specificity and use.

The Industrial & Production Engineering Program the department objectives are aligned with the POs. The outcomes are as follows.

Graduates of the Industrial & Production Engineering Program are expected to have:

a. Ability to apply knowledge of mathematics, science, and engineering, to model and analyze manufacturing and industrial engineering problems.
b. Ability to design and perform laboratory experiments for manufacturing & allied systems as well as to analyze and interpret data.
c. Ability to Design systems, components, or processes to meet customer needs.
d. Ability to participate effectively in multidisciplinary team.

e. Ability to Identify, formulate and solve manufacturing/industrial engineering problems.
f. Ability to demonstrate his/her understanding of professional and ethical responsibility while assessing a situation.
g. Ability to communicate effectively in both oral and written forms and to become proficient in working with diverse teams.
h. Broad understanding of the impact of engineering in a global, economic, environmental, and societal context.
i. Ability to engage in lifelong learning that will help him/her for growth in professional career.
j. Knowledge about contemporary issues in engineering.
k. Ability to use modern modeling and simulation techniques, and computing tools.

III. Outcome Elements

In addressing the program outcomes, the first step is to dissect the outcomes into smaller elements. For example, the PO c is about the ability of a graduate to design system, component or process to meet the customer needs. Clearly, this PO has three elements contained in it, i.e. design of a system, design of a component and design of a process. These elements are henceforth known as Outcome Elements (OE) [2]. The Table I lists the expanded elements and their definitions along with operational verbs for each particular element.

TABLE I. Program Outcomes and Outcome Elements

PO(#)	Outcome Element(s)
a	1. Formulate and solve mathematical models that describe the behavior and performance of physical systems and processes of manufacturing and industrial engineering 2. Use basic scientific and engineering principles to identify applications, explain and analyze the performance of processes and systems of manufacturing and industrial engineering
b	1. Design an experiment to verify the conceptual understanding 2. Conduct (or simulate) an experiment and report the results 3. Analyze a set of experimental data 4. Interpret the results
c	1. Design a system to meet the customer needs 2. Design components of a system 3. Design a process to meet the customer expectations
d	1. Participate in team activities as member(s) in discussions and consolidate the ideas
e	1. Identify gaps in a process or product in the domain 2. Formulate the identified problem 3. Solve the problem
f	1. Assess the situation that requires a decision on ethical implications and professional acumen
g	1. Develop written and graphical communication skills appropriate to the profession of engineering 2. Demonstrate oral and visual communication skills appropriate to the profession of engineering
h	1. Degree of awareness of the global, economic, environmental, and societal impact of engineering solutions
i	1. Find relevant sources of information about a specified topic and meet the challenges for growth in career
j	1. Knowledge of current events, developments and issues in the technical and non-technical space at the regional, national and global level
k	1. Competence to use techniques, skills and modern engineering tools

Though the process of dividing POs into outcome elements allows for sufficient resolution pointing out the prominent requirements of the POs, it is important to note that within each element not all domains are represented. The element may be covered by another element or there may be no attribute identified for the specified domain [3]. For example, when we identify design of a system as one of the elements, several questions arise such as what stages are involved in the design of a system? what attributes to assess in the design? how do we award marks when the design is partially correct? how does the student can know in advance the rationale behind the grade distribution plan is? how can we ensure fair assessment when more than one instructor assesses several group of students? can the same instructor if assesses the same team again ensuring the same grade? The answer for these questions demand increased specificity to the elements. Hence, as a next step, these elements are further sub divided into performance indicators (PI) that describe the attributes or domains or the stages that define elements clearly. The performance indicators for PO a and PO g are listed as examples in Table II.

TABLE II. PERFORMANCE INDICATORS

PO a: Ability to apply knowledge of mathematics, science, and engineering to model and analyze manufacturing and industrial engineering problems.	
OE (1)	Formulate and solve mathematical models that describe the behavior and performance of physical systems and processes of manufacturing and industrial engineering.
Performance Indicators	
A. Identify the variables, objectives and constraints in a problem B. Apply engineering science concepts to a problem C. Derive an engineering formula from mathematical, scientific and/or engineering science principles D. Determine the appropriate formula for a particular engineering problem E. Manipulate formulas to find an appropriate answer F. Solve engineering science problems	
OE (2)	Use basic scientific and engineering principles to identify applications, explain and analyze the performance of processes and systems of manufacturing and industrial engineering.
Performance Indicators	
A. Identify the applications suitable for the process/system B. Explain the underlying concepts C. Verify the output/results D. Analyze the influence of parameters on performance E. Interpret the results	
PO g: Ability to communicate effectively in both oral and written forms and to become proficient in working with diverse teams.	
OE (1)	Develop written and graphical communication skills appropriate to the profession of engineering.
Performance Indicators	
A. Articulate ideas for the assigned task B. Use graphs, tables and diagrams to support points to explain, interpret and assess information C. Conform to the prescribed format and use grammar and spelling correctly D. Critique the written samples and put forward own assessment	
OE (2)	Demonstrate oral and visual communication skills appropriate to the profession of engineering.
Performance Indicators	
A. Plan and deliver an oral presentation for the assigned task B. Reinforce the text and presentation with the visual/graphical aides C. Present detail and appropriate technical content for the time constraint and the audience D. Listen carefully and respond to questions appropriately; is able to explain and interpret results for various audiences and purposes E. Critique the presentation and identify the strengths and weaknesses	

IV. METHODOLOGY

The measurement of program outcomes requires a systematic approach to developing a comprehensive mechanism. The exercise starts with identifying course outcomes for the courses. The course outcomes are attained through attainment of topic outcomes. Here, the topic outcomes are mapped before the delivery plan. Subsequently, the attainment of topic outcomes happens through the appropriate assessment tools after delivery as per plan.

Course Outcomes (CO) - statements of expected student competencies aligned with POs demonstrated at the end of the course for each of the courses offered to students of the IPE program.

The Topic Outcomes (TO) – statements of expected student competencies aligned with COs demonstrated at the end of the topic. TOs for every topic in a course and for every course play a vital role in assessing the student performance and thereby the attainment of POs as direct measures through COs. The topic outcomes are developed with the performance indicators in mind so that an effective delivery and assessment method can be used. The mapping of topic outcomes with performance indicators and the course assessment flow is represented diagrammatically in Figure I.

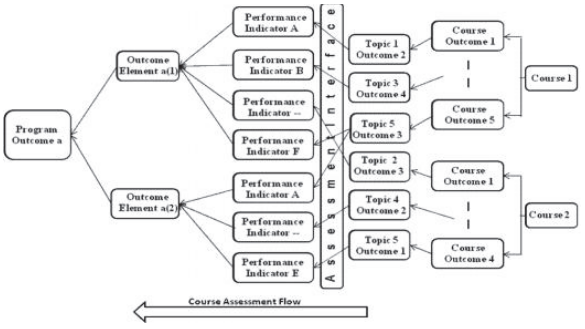

Fig. 1. *Mapping of topic outcomes and performance indicators*

The Table III lists the topic outcomes selected from various courses and their mapping with the associated performance indicator, element and the program outcome. The outcome a is considered here as an example. The three digit PI code against each of the topic outcomes can be deciphered as digit 1 – serial letter of program outcome, digit 2 – serial number of outcome element of the program outcome, digit 3 – serial letter of performance indicator for the corresponding outcome element.

TABLE III. MAPPING OF TOPIC OUTCOMES WITH PERFORMANCE INDICATORS

Topic Outcomes	Code
Identify the need of internal relays in ladder logic programming used in PLC.	a1A
Explain the importance of combinational and sequential logic in digital system.	a1B
Derive relationship between S.F., B.M. and intensity of load at a c/s of a beam.	a1C
Use logic functions to draw ladder diagram in PLC programming	a1D
Find the relative stiffness of a hollow shaft as compared to that of a solid shaft.	a1E
Determine tangential and normal stress on an oblique plane of an element subjected to Uni-axial stress, Bi -axial stress and Bi-axial stress accompanied by shear stress.	a1F
Explain requirements of an ideal control system.	a2A
Explain Principal stresses, principal planes, maximum shear stresses and their planes.	a2B
Verify the initial basic feasible solution of a given transportation problem by using the North-West corner method and VAM.	a2C
Analyze the drawing of tube under plain strain condition.	a2D
Interpret the effect of temperature on the hardness of mild steel.	a2E

Similar exercise has been carried out for the attainment of other program outcomes.

V. PERFORMANCE INDICATORS FOR ASSESSMENT OF OUTCOMES

The student assessment mechanism has been designed to measure the performance indicators. The rubrics have been developed to assess the degree of accomplishment of course outcomes with performance indicators as criteria for assessment. This approach of quantifying the attainment of program outcomes is more precise, unambiguous and easy-to-use for the assessor.

An example on the assessment of program outcome a through corresponding performance indicators and the subsequent attainment calculation is explained in Table IV. The data captured is part of continuous internal evaluation from second year to final year of 70+ students of same admission batch.

The questions were designed to align with the topic outcomes. Each question was to carry 10 marks. The average score attained for every performance indicator i.e. a1A to a1F and a2A to a2E was calculated by considering the total no. of students who attempted that particular question. The average of the scores for the set of performance indicators, a1A to a1F addressing the outcome element 1 was found to be 68%. Similarly, for outcome element 2 was found to be 70%. The average of scores of both outcome element 1 and outcome element 2 gave the attainment of program outcome a as 69%.

TABLE IV. ATTAINMENT OF PROGRAM OUTCOME THROUGH PERFORMANCE INDICATORS

PI	Score, %	OE	Score, %	PO	Score, %
a1A	77	1	68	a	69
a1B	72				
a1C	64				
a1D	69				
a1E	66				
a1F	62				
a2A	79	2	70		
a2B	71				
a2C	70				
a2D	63				
a2E	68				

VI. CONCLUSIONS

The attainment process of program outcomes has now been structured by defining a set of outcome elements and subsequently identifying stage wise performance indicators for each of the elements. Further, the approach has enabled the faculty members in enhanced understanding of the outcomes and better planning of the delivery modes and assessment tools. As a result, one can witness students demonstrating the acquired knowledge and skills during their graduating period and after graduation. The faculty members now enjoy the entire exercise of outcomes' assessment as it has been more specific, unambiguous and measurable than before. It is expected that the process of outcome assessment enhances the proactive involvement of assessors in the teaching-learning process and there by ensures qualitative improvement on a continuous basis in all the three parts – curriculum design, delivery and assessment.

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