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Effectiveness of CO-PSO Formulation and Attainment with T-shape Engineer for Aligning Students Learning Outcomes with Alumni Profiles

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***Abstract*—** Program Specific Outcomes (PSOs) are required to be formulated and then mapped, attained for dissemination of skills and competency in students. PSOs should not be derived from POs and should be beyond POs as per National Board of Accreditation norms. PSOs are formulated as per outcomes (placement/higher education/entrepreneurship) through course outcomes. CO-PSO model is attempted as CO (knowledge) – PSO (Application). Blooms Taxonomy Action verb are practiced as outcomes are rewarded monetarily for doing and not just having capability. During this study was observed that more than 95% of alumni are working in Higher Order Thinking Skills (HOTs) in Industry 4.0 era. PSOs are therefore required to be framed essentially in HOTs.
T shaped engineer is plotted to easily segregate core and broad statements to integrate core statements for formulation of program specific outcomes.

In this paper, a root to fruit model is presented for mapping and attainment by considering alumni profiles to align students learning outcomes with alumni relevant skills and competencies. Students' responses during indirect survey validates the interests created in students for learning through the root to fruit model.
This Model integrated with T shaped Engineer; Discrimination Index ensures that students have learned through questions as indicated in Direct Attainment. Survey questions in Indirect Attainment reveals learning levels of satisfaction of students reaching to 82%.

***Keywords*—**T-Shaped Engineer, Discrimination Index, Program Specific Outcomes, Course Outcomes, Direct and Indirect Attainment

I. INTRODUCTION

Outcome based education (OBE), concentrates on making students employable. Dictionary meaning of outcome is end-result or net-result. End-result or net result of outcome for any professional degree education is either Placement [on campus (OC), off campus (OFC)] or Higher Education [HE] or Entrepreneurship [EN] (Business). These outcomes are reflected through achievement of POs (Program Outcomes) by students [1,2]. POs are the subjectwise knowledge gained by students during the program. Knowledge, skills, and competencies are the reflections in POs [3]. Fig 1 illustrates the timeline of outcome-based education.

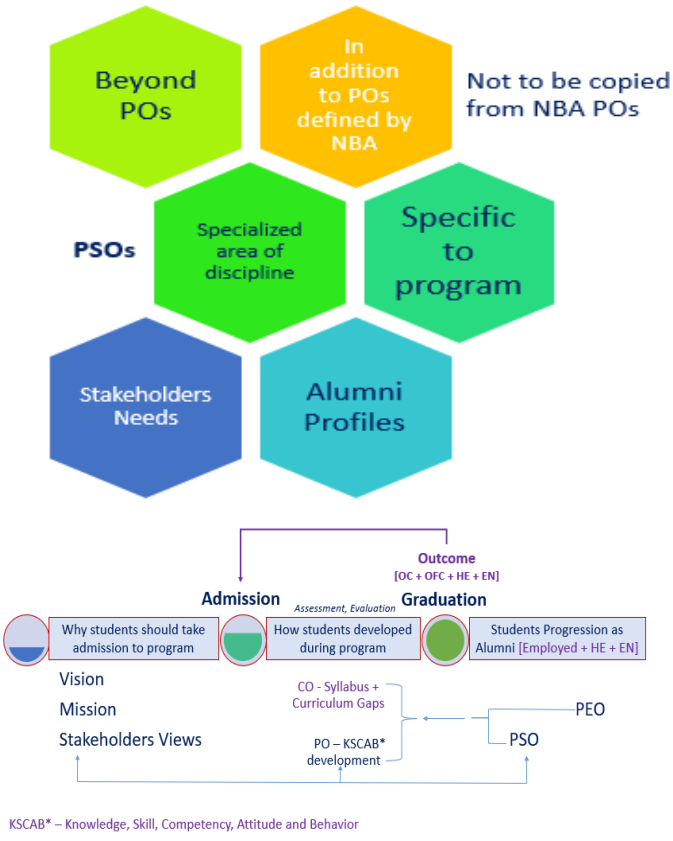

Fig. 1: Outcome Based Education Time-Line

NBA has not defined PSOs like POs. Therefore, a mechanism

needs to be devised for formulation of PSOs.

Fig. 2: Program Specific Outcomes salient features

Fig 2 indicates salient features of PSOs, and key points are highlighted before formulation of PSOs. It indicates that PSOs are beyond POs and should not be derived from POs. These are program specific statements (technical in engineering) indicating core skills and developments in program domain[1]. This needs to be developed from stakeholders' point of view. Question no. 3.3.2 of National Board of Accreditation [NBA] Self-Appraisal Report [SAR] Tier-II indicates two major stakeholders to be considered as students and employers [1].

II. Formulation of PSOs

Alumni are ambassadors of the program, and their progression indicates opportunities available in job market for graduated students [4]. The alumni may take up a job in the core area or non-core area. Core area is specific to a program. For example, in Mechanical Engineering core area is Thermal, Design, Manufacturing. In Electronics it is Sensors and Embedded systems, and in Civil engineering it is construction and alike [5], [6]. Broad areas include core and other areas of working, as indicated from alumni profile. For example, for Computer engineering core area is Software and Web Development, Programming, Communication Networking, Coding, while broader areas in Electronics can be attributed as Embedded Systems, VLSI Design, High Performance Computation, Signal Processing, and allied domains. Non-core areas will be marketing, finance/ valuation, agri-business etc.

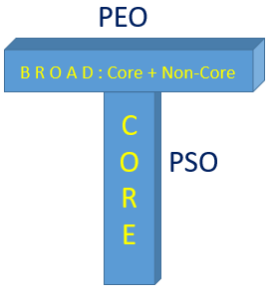

Fig. 3:T Shape Engineer

As shown in fig 3, T shaped Engineer is plotted for understanding percentage alumni in broad and core areas. Referring Fig 3.Depth of T = Alumni's working in Core area / Total No. of alumni. Percentage depth will indicate degree of curriculum gaps required for attainment of POs and PSOs [6].

If core areas are deeper than broad areas, opportunities in program are growing, else it can be concluded as diminishing.

After examining PO statements and for effective participation of alumni profiles in OBE, PSOs formulation from alumni profiles point of view is recommended.

Table I indicates the strategy for integrating alumni profiles in PSO formulation.

TABLE I
PSO STATEMENTS FORMULATION

Sr. No.	PSO Statement No.	Collective Skills from Alumni Profiles (<5 Years after Graduation)
1	PSO 1	Working in Jobs and Placements
2	PSO 2	Skills required for higher education
3	PSO 3	Alumni profiles having startups, setup business and entrepreneurship in core areas

In post Covid situation with amalgamation of work from home and online systems, opportunity segments have changed drastically. Therefore, study of alumni profiles of recent two years are more indicative to be studied for the benefit of students.

Advantages of framing PSOs as per alumni profiles are:

1] Trend line of alumni progression can be inculcated in OBE

2] Help teachers in knowing the shocks faced by alumni's due to change of skills and competency, technological upgradations in outside world

3] Mapping of CO-PSO will ensure that, present students' skills and competency will developed are aligned with alumni profiles.

4] Help teachers to design and development of pedagogy to attain skills and competencies earned by alumni in students.

5] Attainment of CO-PSO will indicate, Students
   i) Readiness as per skills of alumni.
   ii) Employability in alumni profile domain

6] Depth of T = Alumni's working in Core area / Total No. of alumni will help in quantification of alumni data [6].

Table II, rubrics will guide formulation of PSOs for effectiveness of OBE.

TABLE II
RUBRICS FOR PSO STATEMENTS FORMULATION

Parameters	**Average**	**Good**	**Best**
No. of PSO statements	1	2	3-4
Is it Specific	Generalized Terms	Program Specific terms are used	Program specific terms are used depicting alumni profile, professional and employability opportunities
Stakeholders' views	Teachers Perception	Inputs are taken from field experts, employers	Apart from stakeholders' inputs, job market trends, alumni profiles, inputs from job advertisements are considered
Blooms Taxonomy Action Verbs	Not present	HOTs Action Verbs are present	HOTs Action Verbs are present with purpose and readers can visualize employable requirements from it
Is it Outcome Based (SCPAMHE) Approach	Generalized approach	Specific approach	SCPAMHE is visible Specific Condition Purpose Attainable Measurable Higher Order Thinking Skills (HOTs) Employable

A Google form is created to get the profiles from alumni (As given in Annexure 1). This is further segregated into alumni profiles as per PSO1, PSO 2 and PSO 3 as shown in Table 1.
Collective core domains from alumni profile are created.
If is found that, additional following data also can be generated from formulation.

1. Percentage of Alumni Profile covered in Curriculum.
2. Percentage of Alumni in Core Area.
3. Percentage of Profiles needing Curriculum Gaps to be worked upon.

Table III demonstrates how alumni profiles can be segregated into core and broad areas for further assessment of finding out curriculum gaps as per Blooms Taxonomy (BT) [2].
Actual percentage of alumni working in curriculum gaps can be computed out of this exercise, which will be helpful in deciding the percentage of indirect attainment in computing program specific outcomes (PSO). Alumni whose profiles are institute specific and program specific, reflects fruitful case study for assessment and further enhancement to fulfil gaps.

TABLE III
SEGREGATION OF ALUMNI FOR FORMULATION OF PSOS

Sr. No.	Name of company	Profile	Broad	Core	Curriculum	BT curriculum	BT Required
1	X	Associate Consultant	Yes	-	Yes	2	4
2	Y	System Engineer	-	Yes	No (Gaps)	2	5
Average			1 Alumni	1 Alumni	50% Gaps	2	4

Case study conducted from Electronics alumni helped in framing the following PSO statements

1. PSO1 (Alumni Profiles placed in campus placement during their graduation): Graduates design, test and validate time Switches, Timers, PLC's, GSM Controllers, Protocol & Interface Converters, Signal Transducers, Temperature Controllers, Modular Power Supplies and Instrumentation devices in Electronics industries, embedded Software Engineer/ trainee Software Engineer in transportation along with network Planning an Engineer for all National long-distance routes.
2. PSO2 (Alumni Profiles pursued their higher education after their immediate graduation): Graduates develop problem solving skills like data interpretation, numerical Computation, and analysis, in areas of Communication, Control System, Signal Processing and Electronic Circuits
3. PSO3 (Alumni Profiles started their business in core areas): Graduates start their business in areas like Renewable Energy, Digital Branding, Website Development.

Above 3 statements fulfil points mentioned in Fig. 2 and indicates core and program specific domains.

III. MAPPING AND ATTAINMENT OF PSOS

Elements in PSO statements needs to check for extent of compliance in curriculum for mapping and attainment. Table IV is devised and found useful for disseminating PSOs in students (Attainment). PSO1 and PSO2 statements are indicated in table IV.

TABLE IV
PSO MAPPING AND ATTAINMENT

Sr. No.	(I) PSO Statement No.	(II) Elements in PSO Statement	(III) Is it in curriculum	(IV) Gaps with respect to column I	(V) Mapping Strategy
1	1	Test and Validate Time Switch	Time Swtich is in curriculum but testing and validation is not included	Testing and validate	Creation of extra self-module for column IV/Open book self-learning test
2	2	Numerical Computation	Yes, but in LOT, BT 2 (Lower Order Thinking Skills)	Reaching to BT 4 is required (Gap BT 2)	Creating open book test with BT 4 for practice

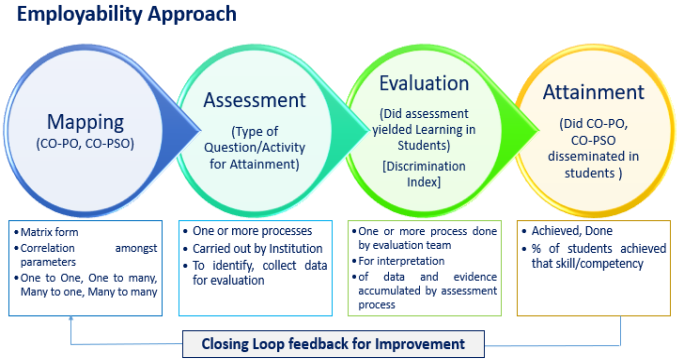

Fig. 4: CO-PSO mapping and attainment

Fig. 4. demonstrates steps to be taken up from mapping till attainment. For example, the teacher is explaining the topic of Time switch to the students.CO is relevant to knowledge of Time Switch. POs in this case will be application of time switch. For example, safety of time switch will be CO-PO6. PSO's will indicate alumni working in the field of time switch. The teacher will classify alumni into placement, higher education, and entrepreneurship, in the field of time switch and study their profiles. If alumni are working in company like Havells it is aligned to PSO1. Similarly, if alumni have taken up higher education or established a business in the field of time switch it can be attributed to PSO2 and PSO3 respectively. It is observed that the students value recruitment

questions, alumni profiles, GATE exam questions as it ensures higher outcomes.

Case study: CO1-PSO1
For assessment MCQ's are formed. These MCQ's are designed for attainment of Testing and Validation skills by using Time Switch.
Question: You are working in Havells company as testing engineer. Multifunction switch suitable for residential and commercial use are operated as per IEC 60730-1/IEC 60730-2-7 standards.
You have come across maintenance requirement of time switch and need to guide your higher-ups for taking appropriate decisions.
Find out correct options [More than one option is correct]
1] Current drawn by every switch is accumulated
2] Protective system is implemented to distribute current across the switches
3] Validation will involve life cycle testing
4] Validation will indicate current distribution diagram as per distribution network
[CO1-PSO1-BT4-Havells]
Advantages of framing this question are:

1. Students can gauge opportunity in Havells company.
2. Question is not copied from internet so students cannot paste answer by Google search and active engagement in learning of student is ensured.
3. Students are made to image the work they will face after joining the company.
4. Scenario Based Learning can make students think from employability point of view.
5. Students' skills gained out of such attempt is proportionate to alumni's performing their work.
6. If answer is not revealed to any students till all students attempt this question, it will lead to active learning by students.
7. All four options are correct, and 0.75 marks are awarded for each option.

However, only marks scored by students will not assure their learning. For that Discrimination Index (DI) needs to be computed for drawing inferences. DI is a measure of the differentiation between two categories of students based on some specific criteria.
Whether this question yielded learning in students?
Ensure by Statistical Analysis of Discrimination Index (DI) [7]
If DI > 40%, It yielded learning, else reframe and reassess (For employability approach)
Discrimination Index is a measure to ensure that, students gained learning from questions. By using, 27% analysis shows maximum difference in normal distribution, making productive item analysis [7].
Direct Attainment – Evaluate marks earned by each student if they get all 3 marks.
Indirect Attainment – Survey question to students and employers, was it helpful to you to learn and make you employable in real life, how this question was helpful to you in learning, how it is benefited your learning process. out of 3 marks [Points/Stars/Ratings] [Average, Good, best]
Case Study for CO-PSO mapping and attainment:
70 students attempted above question and their marks are listed as per Table V.

TABLE V
FREQUENCY DISTRIBUTION OF MARKS OBTAINED BY STUDENTS

Marks	Frequency (Number of students)	Frequency (%)
0	3	4.29
0.75	9	12.86
1.5	23	32.86
2.25	20	28.57
3	15	21.43

Graphical statistical analysis of marks earned by students is indicated in Fig 5. Mean 1.8750 indicates, 62.5% marks central tendency of data.

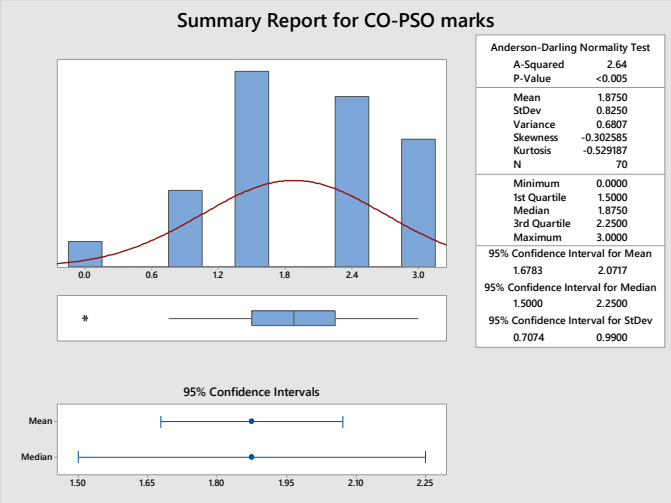

Fig. 5: Frequency Distribution of marks scored by students

Discrimination Index

1. 27% of 70= S = 18.9 = 19 students.
2. Sum of marks in top 19 students (t) = 54
3. No. of students in top 19 scoring full marks
4. (H) = 54/3 (3 is Max Possible Marks for each student) = 18
5. Sum marks of bottom 19 students (B) = 17.25
6. No. of students in top 19 scoring full marks
7. (L) = 17.25/3 (3 is Max Marks for each student) = 5.75
8. Discrimination Index = (H-L)/S = (18-5.75) /19 = 0.644737 = 64.47%

With 64.47% it is assured that, test yielded learning in students
Following Table VI indicates attainment levels decided.

TABLE VI
DIRECT ATTAINMENT CALCULATION TABLE

Marks Range	No. of Students	Attainment
<40% < 1.2	12	0
>=40 and < 60 (1.2 -	23	1

Marks Range	No. of Students	Attainment
1.79)		
>=60 and < 66 (1.8 - 1.98)	0	2
>= 66 (> 1.98)	35	3
Total	70	

Direct Attainment = [(12*0) + (23*1) + (0*2) + (35*3)]/70
= [23+105]/70
= 128/70
= 1.828571

Indirect Attainment is mainly concerned with students learning survey. Format for Indirect Attainment survey is as per following.

Name of Student: Class: Year:

Name of Program:

1] How much percentage, you will rate this question as original and not from open source as it is, like recruitment/competitive examination (GATE/IES/GPAT/UPSC/other Govt. and Private sector examinations)

A] 100% B] 80% to 99% C] 60% to 79% D] Less than 60%

2] Questions should yield learning and not just marks. How much satisfied you are, as a learner, after attempting questions

A] Routine questions and didn't yield new insights, B] Question is relevant to skill/competencies development and yielded new insights C] Any other

3] How helpful this question was for your learning? Write in your own words

4] How was your overall experience out of this examination (1 is lowest, 3 is highest)

- 1
- 2
- 3

Ratings (4 above) are further analyzed for Indirect attainment surveys.

TABLE VII
INDIRECT ATTAINMENT CALCULATION TABLE

Rating	No. of Students	Attainment Level
0	3	0
1	10	1
2	29	2
3	28	3
Total	70	

From Table VII it is evident that total 57 students (29+28, 82%) expressed their satisfaction about learning through this examination.

Indirect Attainment = [(3*0) + (10*1) + (29*2) + (28*3)]/70
= [10+58+84]/70
= 152/70
= 2.171429

Attainment = 70% Direct + 30% Indirect (Considering 30% requirement to students' opinion as per NBA guidelines)
= (0.7 * 1.828571) + (0.3 * 2.171429)
= 1.931429

Considering 30% importance to student's self-evaluation, 70% direct attainment is taken up. It shows that out of 3 level, attainment level is 1.931429 (64.38%).

IV. CLOSING LOOP

Closing loop is required to analyze observations in this process and action to be taken up for improvement in future [8]. Observations and action plan are given in Table VIII.

Some of the students' responses as per indirect attainment question 3, (How helpful this question was for your learning? Write in your own words)are indicated in Annexure II

TABLE VIII
CLOSING LOOP: OBSERVATIONS AND ACTION PLAN

Targeted Attainment: 3.0	Attained: 1.931429 (64.38%)
Observations: 1] Students who could not apply this question in real life situation and analyze options, could not do better in test. 2] From, Indirect survey responses, it is evident that, students appraised importance of studying real life scenario and they will integrate more case study-oriented learning, in their technical aptitude. 3] Also from students' responses, it can be concluded that, students realized their role in industry relevant to this topic in future as it will be helpful to them for technical interviews.	
Action Plan: 1] 20% Increase in real life, case study-oriented teaching and assignments 2] Questions will be framed by considering, roles and responsibilities spelled from current openings in company websites, advertisements, skills requirements narrated by employers and recruiters for practice	

V. CONCLUSION

Root to Fruit approach is followed. Instead of merely completing procedure of CO-PSO analysis, students' employability is kept at pivotal point during entire formulation, mapping, and attainment. T-shaped engineer depicts alumni profile progression in specific areas and helps to find out elements to be included in formulation of PSO. Curriculum gaps are then framed for achieving these elements. Discrimination Index ensures that students have learned from the question and marks are indicators of yield of learning. Direct Attainment is direct observation of assessment by theory questions/ MCQ's or oral questions while Indirect attainment is contributed by surveys of students to know, how question helped students to disseminate indicated program specific outcomes. Students' self-introspection and thereby deciding their own path to follow, helps teachers to identify advanced learners to facilitate slow learners. Root to fruit model indicated in Fig 6, is therefore found effective as per students' response as given in Annexure II. Fig. 6 indicates graphical conclusion of root to fruit model presented in this paper.

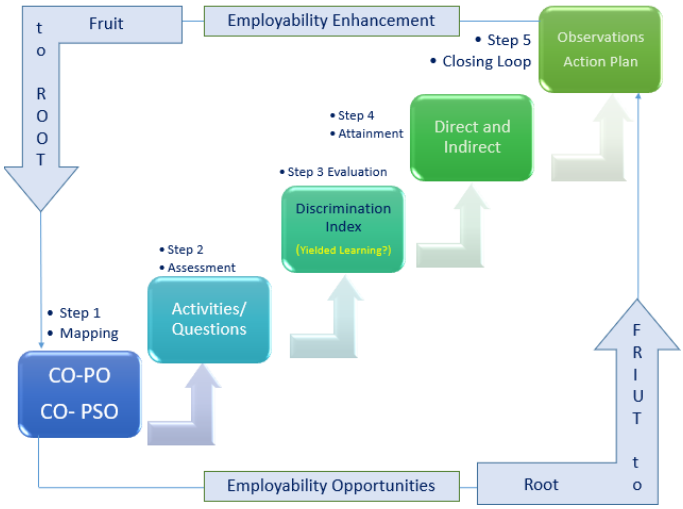

Fig.6: Root to Fruit Model for CO-PSO mapping to attainment

APPENDIX

Annexure – 1: Google Form for assessing alumni profiles

Please fill form carefully for Awards Nomination

Email address *

Valid email address

This form is collecting email addresses. Change settings

Name (First Name, Middle Name and Surname Format) *

Short-answer text

Year of Passing *

Short-answer text

First Job Organization *

Short-answer text

Year of First Job *

Short-answer text

Profile of First Job/Responsibilities Handled *

Long-answer text

Salary of your First Job/Annum *

Short-answer text

Present Job Organization *

Long-answer text

Profile of Present Jobs/Responsibilities Handled *

Long-answer text

Responsibilities handled till date *

Long-answer text

Responsibilities handled till date *

Long-answer text

Salary of Present Job/Annum *

Short-answer text

Awards/Achievements Details if any *

Long-answer text

Annexure – II : Some sample responses from students

Students Responses:

1) It helps me for preparing for future exams...type of questions was totally different due to that I understood how much knowledge is required further
2) Thinking and solving the questions from an engineer's point of view was helpful and will surely help us do better in our coming competitive exams and for future experiences.
3) The problems asked in the test were having real time approach, so that the learner can get to know to about the industry requirements and hence, he / she can work on his / her plan accordingly. As a learner, I am very much satisfied with conduction of such tests as it makes me aware of my level of preparation and helps me in analyzing my subject knowledge.
4) Depth of knowledge prior to the test is very shallow. Test like these can really trigger new thought process and pathway to practical oriented approach. Also realized how originality is imp to than copy pasting, how Basic ideology of study procedure can be harmful for future

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