

# Assessment and Attainment of Course Outcomes and Program Outcomes

C Lavanya<sup>1</sup>, Jandhyala N Murthy<sup>2</sup>

<sup>1</sup>Professor, Department of Civil Engineering, GRIET, Hyderabad, India

<sup>2</sup> Professor, Department of Mechanical Engineering, GRIET, Hyderabad, India

<sup>1</sup>lavanya.cc@gmail.com

<sup>2</sup>nm.jandhyala@gmail.com

**Abstract:** Outcome Based Education (OBE) is an approach in the field of engineering education, accepted in recent years all over the world. Output in terms of Cumulative Grade Points Average (CGPA), pass percentage, etc. has been the traditional measurement in education whereas outcome focuses on the level of transformation and achievement in the student. Every institution endeavours to fulfil its mission through its programs which constitute courses and learning activities. The program objectives guide to form the program outcomes, which need to align with universally accepted graduate attributes. These are mapped to the course outcomes whose knowledge levels can be guided by Blooms Taxonomy. Achievement of program objectives can be judged only through the attainment of program outcomes which are indicated by the attainment of the outcomes of the courses which constitute the program. Therefore, assessment tools and attainment methods for the course outcomes and program outcomes are required to indicate the level of transformation at each level. This paper presents a methodology to calculate the attainment of course

outcomes and program outcomes and provides the recommended threshold values to identify the extent of desired transformation in a student after a teaching learning process. Awareness and implementation of these assessment methods with systematic review of thresholds and consequent course correction measures can have a profound impact on student success and mission accomplishments of institutions.

**Keywords:** Assessment, Attainment, Course Outcomes, Program Outcomes, Outcome Based Education, Blooms Taxonomy

## 1. Introduction

'Assessment drives learning' is an accepted statement across all the domains. Assessment along with the educational objectives and pedagogy is an essential mantra for learning achievement in any teaching-learning process. With time, the educational philosophies have been changing with new definitions. The new paradigm of Outcome Based Education (OBE) has been evolved in the last few decades and is being accepted all over the world. With the change from the traditional teacher centric environment to the transformation teaching, OBE shifts focus to become a learner centric exercise, where outcome is described by what a student is expected to know and can do at the end of the course or program through transformation in attitude, skills and knowledge. The role of instructor thus becomes a

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C Lavanya

Professor, Department of Civil Engineering,  
GRIET, Hyderabad, India  
lavanya.cc@gmail.com

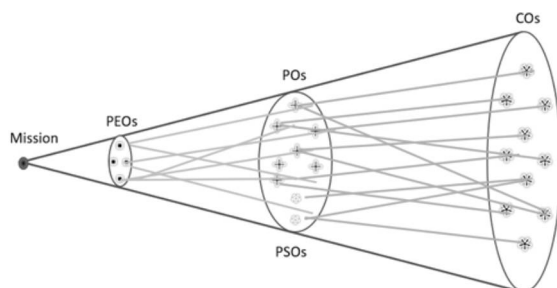
facilitator rather than a teacher. While what to learn and how to learn are given by program and course outcomes and teaching methods respectively, how much is learnt is brought out by assessment which provides timely course corrections for the learner and the faculty. This aids in the fulfilment of learning objectives leading to the accomplishment of mission of the institute.

Learning is a lifelong activity, starting with K-12 education which may lead to graduation and beyond. Learner can exit at any stage to follow a career of his choice (Jandhyala N Murthy, 2012). Well-developed critical thinking skills are important for dealing with the multi-dimensional nature of engineering problems which are structured on complex thought processes that require evaluation (Aoife Ahern et al, 2019). But each program has predefined objectives and OBE defines the path to fulfill them.

Success for each student is the only goal and it is measured by the student ability to meet the pre-defined outcomes (William G Spady, 1994). The key components of OBE are Vision, Mission, Program Educational Objectives (PEOs), Graduate Attributes (GAs), Program Outcomes (POs), Course Outcomes (COs), Mapping, Assessment, Attainments.

The vision and mission, identified as the direction, destination and the path for an institution in a long term prospective, are evolved by involving all the stakeholders or constituents like students, alumni, parents, professional bodies, faculty, industry, management, etc. considering the scope for its growth and future societal requirements.

Program educational objectives are defined based on the vision and mission of department and the institute. Mapping must be aligned between mission and the PEOs, similarly, between PEOs, POs, PSOs and COs as shown in Fig. 1.



**Fig. 1: Mapping of PEOs, POs, PSOs and COs**

PEOs are the expected achievements of graduated students in their career, during the first few years after graduation. These must be realistic and attainable which address needs of all the stakeholders.

These objectives are deemed to be attained if the student attains or displays desired transformations at the end of the programme. These expected attributes or transformations are known as Program Outcomes (POs). Thus, extent of attainment of PEOs can be gauged through the measurable POs. For universality and standardization, POs are defined based on attributes, which are commonly known as Graduate Attributes (GAs). They are common standard attributes / qualities expected from any graduate from a recognized program from any corner of the world (Washington Accord, 2012). They are as follows.

1. Engineering Knowledge
2. Problem Analysis
3. Design of Solutions
4. Conduct Investigations of Complex Problems
5. Modern Tool Usage
6. Engineer and Society
7. Environment and Sustainability
8. Ethics
9. Individual and Team Work
10. Communication
11. Project Management
12. Life-long Learning

POs are prescribed with the objectives of assurance of quality and relevance to technical education. Generally, a program has 12 POs signifying the 12 GAs. In addition, two to four Program Specific Outcomes (PSOs), may also be needed to signify outcomes which are needed for areas/ domains which are specific or peculiar to a program. PSOs are also evaluated in the same manner as POs. The expected transformations, as signified by the POs and PSOs are delivered through various courses. The number of courses and duration needed

depends on the breadth and depth of the domains needed for the specific programme. Each course shall in turn have 5 to 8 pre-defined Course Outcomes (COs) which describe what students are expected to know and be able to display at the end of the course. These relate to transformations expected in terms of attitude, skills and knowledge that the student acquires as they progress through the course. These must be specific, measurable and student-centred. One of the most important and valuable measurement to identify the outcome level is Blooms Taxonomy.

Course outcomes are articulated as per Revised Blooms Taxonomy from knowledge levels 1 to 6 as shown in Fig. 2. The endeavour is to reach the higher order thinking skills. (Anderson Lorin & Krathwohl David, 2001).

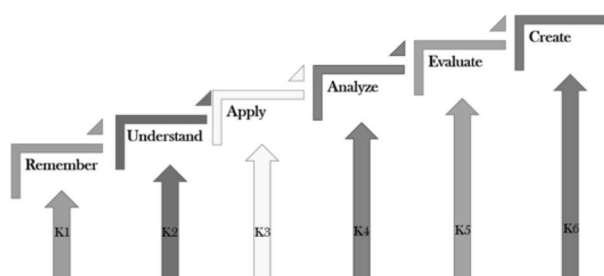


Fig. 2: Revised Blooms Taxonomy

Course outcomes must be written by the course coordinator or module coordinator who is the subject expert and can identify the relevance and importance in terms of knowledge levels by using the appropriate action verbs. Also, they should reflect from both higher order (K4 to K6) and lower order (K1 to K3) as shown in Fig. 3. Five to seven COs can be written for each course. Care should be taken to see that assessment aligns course objectives, by ensuring the knowledge levels being questioned should be of the same level as per the objectives and pedagogical methods.

CO	Course Outcomes	Knowledge Level
1	Explain basic Engineering properties of ....	K2
2	Evaluate various experiments to ....	K5
3	Recognize the shear parameters of ....	K2
4	Analyse the mechanism and ....	K4
5	Distinguish field equipment used in ....	K4
6	Illustrate the importance of ....	K3
7	Assess the mechanism of....	K3

Fig. 3: Sample Course Outcomes

Examinations play a vital role to assess the extent

of learning by the student and also to classify them as per grades. Examination method and the questions are crucial to highlight the level of learning in a course in particular and hence in a program. Since assessment drives learning, the design of questions needs to cover all levels of learning preferably going beyond simple memory recall. They should also identify suitable PO competencies and performance indicators and test for higher-order abilities and skills. This will help to understand the competencies of students to achieve and forms the basis for the creation of measurable indicators. (Examination Reform Policy, Nov 2018).

Assessment measures effective involvement of the student during learning and also reflects on the effective teaching methodologies. The selection of appropriate assessment method, stage of the course at which the assessment is done and frequency play a key role in the attainment of course outcomes. An assessment can be of two types - formative or summative.

Formative assessment (Assessment for learning) aims to provide feedback and guidance to help students to improve while the course is being carried out on a continuous basis. Whereas Summative Assessment (Assessment of learning) focuses on evaluation of a student's performance, often at the end of a course and provides useful feedback for subsequent assessments (Lorna M. Earl, 2003).

Formative assessment provides insights to both teacher and student on the teaching and learning effectiveness and performance of both. It enables to observe students transformation during the learning process (Huhta Ari, 2010). This helps to measure outcome attainments after each class or session or at any convenient mid-course stage and assists in focussing on knowledge gaps and fine-tuning teaching methodology for maximising teaching-learning effectiveness as the course progresses. Hence, it is also known as continuous assessment.

Summative assessment, as the name suggests, is done after finishing the entire teaching learning process for the whole course assessing the outcome of the completed course. Questions are so designed to cover the essence of the whole course and hence the durations could be longer than the formative assessments. (Lavanya C et al. 2020).

Quantitative measurement of the performance is universally done relying on direct tools like written

tests, quizzes, etc. These direct tools may be inadequate for some academic activities like projects, seminars, presentations, etc, because the number of indicators to judge the level of performance could be varying as per the activity leading to subjectivity. For such cases, a suitable assessment tool is rubric. Rubric tool is ideal to make performance measurements as objective and consistent as possible by defining the criteria (Susan Brookhart, 2013).

## 2. CO-PO Mapping

Program, depending on its duration, may contain one or several courses. Courses are mapped judiciously to ensure progress and to achieve mastery of the learning outcomes given by POs and PSOs. Each course outcome may have varying impact on the program outcome, which is highlighted through CO-PO mapping.

CO-PO mapping is done based on the relevancy or influence of CO on the POs and PSOs. It is represented as high (H) or moderate (M) or low (L) as shown in Fig. 4. This mapping must be done by the subject expert based on the content of the syllabus and its importance as given by knowledge levels, in relation to the program outcomes. Each CO may not

have influence on all the POs, but may have varying relevance on one or more.

During the planning stage, well before the commencement of the course the degree of relevance between CO and PO is rated accordingly. It is customary to give a numerical value of 3, 2 and 1 for high, moderate and low relevancies respectively as shown in Fig. 5. Average can be calculated which suggests the expected value for each PO.

## 3. Attainment of CO

Performance of the student can be reviewed through the attainment process where the student acquires knowledge as they progress through the course. CO attainment is calculated through internal examinations, external or semester end examinations, assignments for both theory and laboratory courses by using direct and indirect methods. Direct methods are used where examinations are conducted and indirect assessment is done through surveys to understand the perception of the stakeholders.

So far overall marks or grades are used to signify the achievement of the student. Higher it is greater is the level of achievement for all the outcomes as a whole. But OBE brings out the importance of GA through POs and COs and allows to review attainment of each outcome through individual questions. Each question is expected to be worded to an appropriate knowledge level thus comprehensively covering all the outcomes of the course.

100% students getting 100% marks is ideal for the achievement. But practically, achieving both is rare though not impossible. So, a pragmatic view is taken through appropriate thresholds. For reasonable achievement for a certain number of students crossing a certain performance is termed as threshold, which if achieved, can periodically be reviewed to raise the level of achievement.

Students are expected to attempt and answer questions and as each question is mapped to one or more COs, students performance is key to extent of attainment of that CO. CO attainment is based on attempt and performance of the students appeared for the examination at a question level. Percentage attempt is the ratio of number of students attempted the question to that of number of students appeared for the examination. If the percentage attempt is less than a threshold value, then attainment is also zero, as less

Course Code	Program Outcomes											
Course Outcomes	a	b	c	d	e	f	g	h	i	j	k	l
CO1	H	M	M							M		
CO2	M	H					M					M
CO3	M	H		H								
CO4		H	M				M	L				M
CO5		M	H				M					M
CO6	M			M		M		L			M	H
CO7			H	M		M	M			M		

Fig. 4: CO-PO Mapping

Course Code	Program Outcomes											
Course Outcomes	a	b	c	d	e	f	g	h	i	j	k	l
CO1	3	2	2							2		
CO2	2	3					2					2
CO3	2	3		3								
CO4		3	2				2	1				2
CO5		2	3				2					2
CO6	2			2		2		1			2	3
CO7			3	2		2	2			2		
PO (Planning)	2.25	2.6	2.5	2.33		2	2	1		2	2	2.25

Fig. 5: CO-PO (Planning)

attempt is an indication that the students are not up to that knowledge level. Threshold for attempt percentage can be taken from average attempt percentage for the last three academic years. If it is more than threshold value, then accordingly CO attainment is calculated as per the following procedure.

One reasonable threshold for the level of marks attained is 60% as it signifies first class. Thus, CO attainment is calculated based on the number of students who got more than 60% of marks out of number of students attempted the question. CO attainment percentage is the ratio of number of students who got more than threshold for marks to that of number of students attempted the question. Accordingly, the relevant score for the attainment value is given, taking threshold for number of people attaining as 60%. Therefore, if 60% or more students attain threshold marks then score is 3. If the number of students attaining threshold marks is between 50-59% then the score is 2, if it is between 30-49% the score is 1 and for less than 30%, score is 0. For this example, 30% is taken as the threshold for minimum attempt percentage. Attainment is calculated as per the weightage for formative and summative examination marks which is a direct method.

Also, as part of indirect method, CO attainment is calculated based on the feedback given in the course end survey which is relevant to the course outcomes with the same procedure where total number of students who rate 3 or more on a scale of 1-5, 5 being the high value. Final CO attainment weightage for direct and indirect can be consolidated as below.

$$\text{Final CO} = 90\% \text{ Total CO} + 10\% \text{ Course End survey}$$

This CO attainment procedure as shown in Fig. 6 can be carried for all the courses of the program. Program in its duration may involve curricular activities and beyond also. POs 1 to 5 cover adequately knowledge and skills but POs 6 to 12 indicate the character, attitude, self vs others, self vs society, etc. They are imbibed through beyond curricular activities such as industrial visits, guest lectures, seminars, projects, workshops, hackathons, competitions, etc. All have profound impact and lead to desired transformations in students broadly covered under POs, like teamwork, communication, ethics, finance, life-long learning, etc. Suitable weightage can be provided accordingly for all the activities.

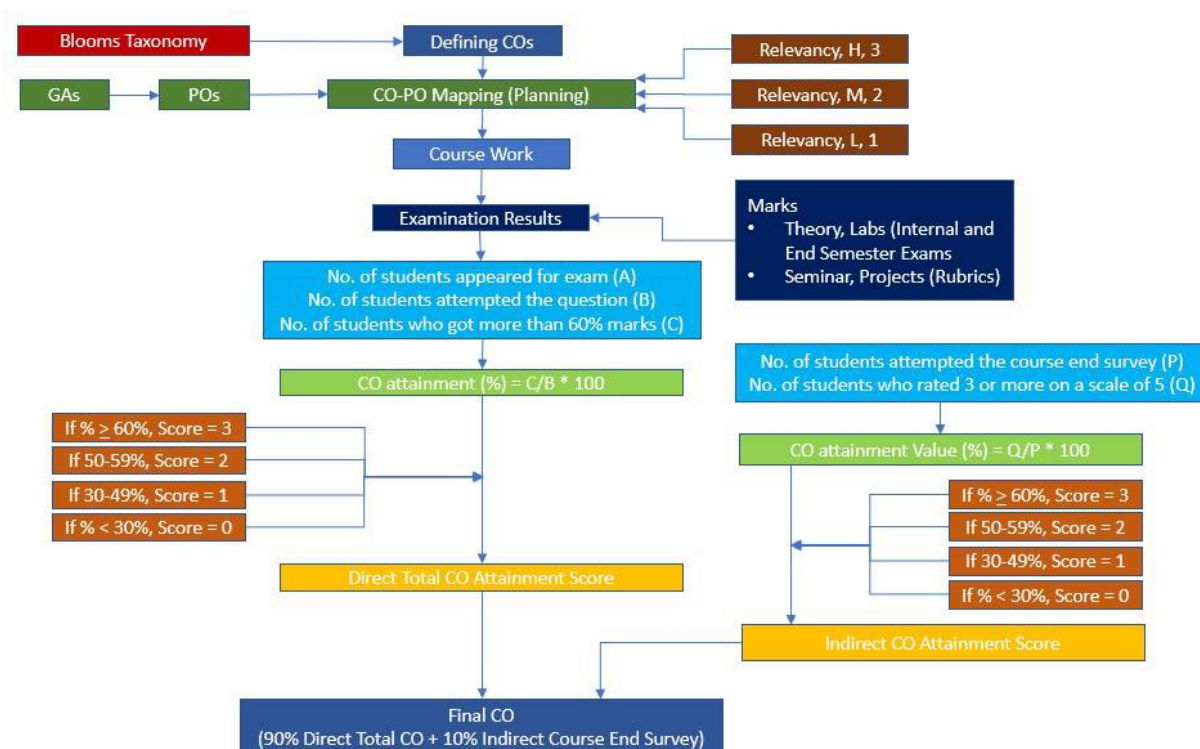


Fig. 6: Flow chart to calculate CO

#### 4. Attainment of PO

A program will have multiple courses for which attainment will be calculated. Combining all of them through CO-PO mapping, attainment for the program is evaluated to identify the level of transformation of the student at the end of the program in terms of the attitude, skills and knowledge.

To illustrate the process of PO attainment, the following arbitrary values are taken as an example as shown in Fig. 7 which consists of percentage of students who crossed threshold value and the relevant score values. With the final CO attainments of all the outcomes calculate the sum. For each course multiply the final CO attainment value with CO-PO mapping relevance value of 3, 2 or 1 and divide with total number of relevant COs normalized on a scale of 3. Fig. 8 shows the PO attainment for a course obtained from the CO-PO mapping and the relevant CO attainment values.

PO attainment is calculated as shown in Fig. 9 for all the courses and added together to obtain the final PO. As in case of CO attainments, PO attainments also consider the weightage for direct and indirect methods. Indirect assessment relies on the program exit feedback taken from the outgoing students for each program provided on all the aspects of attitude, skill and knowledge. Final PO attainment can be consolidated as 90% of direct and 10% of indirect.

Course Outcomes	% of students crossed threshold value	Score
CO1	55.83	2
CO2	74.56	3
CO3	58.23	2
CO4	69.89	3
CO5	81.21	3
CO6	50.67	2
CO7	82.45	3

Fig. 7: Percentage of students crossed threshold value

Couse Code	Program Outcomes											
Course Outcomes	a	b	c	d	e	f	g	h	i	j	k	L
CO1	2	1.33	1.33							1.33		
CO2	2	3					2					2
CO3	1.33	2		2								
CO4		3	2				2	1				2
CO5		2	3				2					2
CO6	1.33			1.33	1.33	0.67				1.33		2
CO7			3	2		2	2		2.00			
<b>PO (Execution)</b>	<b>1.67</b>	<b>2.27</b>	<b>2.33</b>	<b>1.78</b>	<b>1.67</b>	<b>2</b>	<b>0.83</b>	<b>1.67</b>	<b>1.33</b>	<b>2</b>		

Fig. 8: CO-PO (Execution)

Final PO =

90% Total PO + 10% Program Exit survey

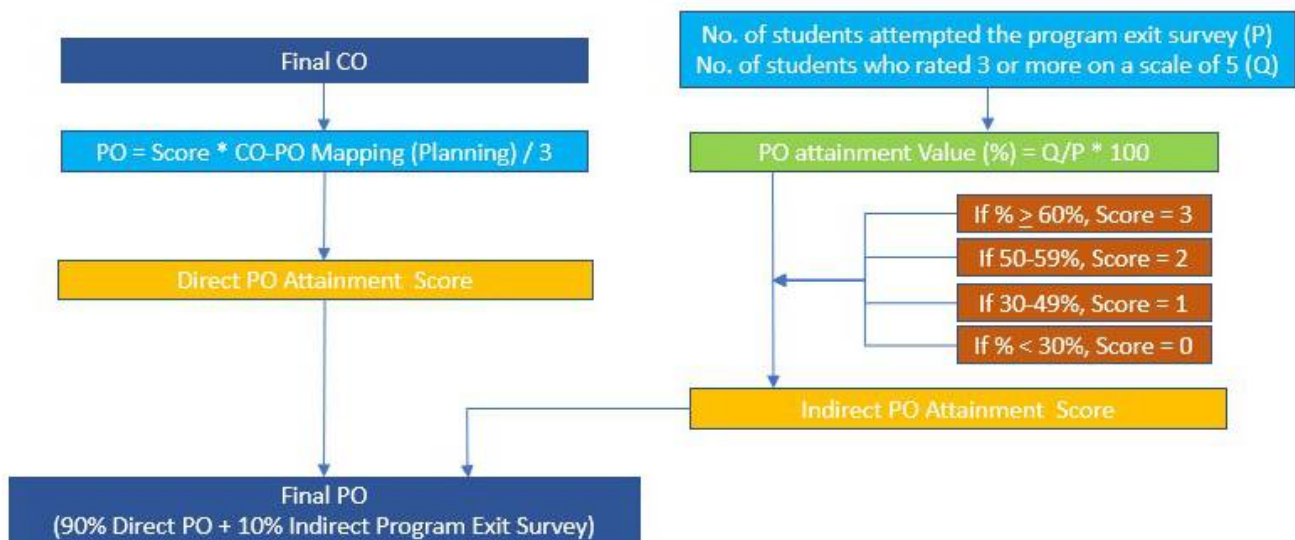


Fig. 9: Flow chart to calculate PO

## 5. Validation of CO and PO Attainment

All the course outcomes must be assessed and the respective CO attainment values are measured. If the attainment of any CO does not satisfy the requirements of threshold value, then suitable remedial actions must be taken so as to improve them through appropriate teaching-learning activities for the ongoing cohort as well as for the future cohorts. Based on the analysis done through various assessments methods, question paper patterns, internal marks, external marks, attainments, attempt percentage, etc., the threshold value for attempt, for the marks, relevance scale bands need to be reviewed and revised periodically so that expectation bars or the targets can be raised, in order to improve quality. PO planning and PO execution is compared as shown in Fig. 10 to analyse the values for a course.

Name of the Course	PO	a	b	c	d	e	f	g	h	i	j	k	l
	Planning	2.25	2.6	2.5	2.33	2	2	1		2	2	2.25	
	Execution	1.67	2.27	2.33	1.78	1.67	2	0.83		1.67	1.33	2	

Fig. 10: PO Actual vs PO Attained

Taking into account all the courses of the program, similar procedure is followed to summarize the final PO attainment. Accordingly, suitable remedial actions such as tutorials, guest lectures, seminars with industry experts and other beyond curricular activities may be planned to enhance and strengthen at program level. Also, if required course outcomes and content can also be revised.

## 6. Conclusions

Mission accomplishment through objective oriented programs consisting of courses and learning activities has been the endeavour of any institution. Program educational objectives can be considered to be wholly achieved only if transformation is evident in all the vital aspects of attitude, skills and knowledge and it is widely accepted that all these aspects can be measured in OBE through the attainment process of course outcomes and program outcomes.

The proposed methodology calculates the attainment at course level and at program level. This also gives an evidence of mapping between course outcomes and program outcomes indicating the significance of program educational objectives. The process of taking first class as threshold value is a reasonable recommended target to measure the attainment of CO and PO for both direct and indirect methods.

The course outcomes could be better achieved with the various teaching methodologies, learning activities and remedial measures. Constant review and revision of assessment methods, threshold values, outcomes and remedial measures boosts the implementation of OBE to improve the quality of learning and student success. Outcome based education thus helps to identify the level of transformation of the student who is intended to be universally acceptable and useful for the society.

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