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Towards assessment and attainment of Engineering Graduate Attributes in Outcome Based Education (OBE)

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***Abstract*—Outcome-Based Education (OBE) has been practised for over a century, as educationalists have highlighted the need to understand learners' characteristics during the learning process. This educational framework aims to ensure that learners possess the necessary attributes to become successful not only in their education but in their lives as well. Graduate attributes are pre-defined high-level skills students should acquire due to their learning and experiences while pursuing a degree. These attributes are indicators of a graduate's future capabilities and have a many-to-many relationship between the courses. The measure of these attributes is called attainment. Concrete assessment methods lay the groundwork for precise attainment to acquire one or more graduate attributes.**

This paper aims to provide a mathematical assessment formulation for attaining engineering graduate attributes based on course outcomes. The research also highlights the understanding of the outcome-based education concept in higher education institutions in India.

***Index Terms*—Assessment methods, Attainment, Course Outcomes, Graduate Attributes, Higher Education Institutions (HEIs), Outcome-based Education, Program Outcomes**

I. Introduction

The importance of education in national development is critical. Thus, there is a concern about higher education's quantity and quality. It is well-known that no matter what domain you are in, quality is improved by discovering and meeting new requirements and fulfilling them with worldwide standards-level products and services.

Technology, which had always been supported in classroom teaching, has suddenly become the centre stage for learning in the last few years. The quintessence of technology empowers us with predictive analysis of the outcomes based on our actions and better feedback to reflect on ourselves as teachers. The learning outcomes could be more precise if personalized for an individual learner. Personalized learning meets learners' characteristics by tailoring course material and assessment methods pertinent to individual needs and interests. Research suggests that personalization can contribute to improving learning outcomes through enhancing motivation and attitudes [1] and supporting the development of meta-cognitive skills and self-reflection [2] [3]. Higher levels of personalization have been associated with better academic achievement, improved school culture, and greater learner engagement [4].

A transparent and fair relationship is developed with stakeholders (universities, industry, regulators, government, and colleges/employers) to ensure that the programmes teach graduates practical skills and build competency in essential areas of national and international global professional benchmarks. [5]. Graduate attributes (GAs) include these outcome-based characteristics that indicate a graduate's future capabilities. There is a many-to-many relationship between the courses and graduate attributes. One course can be mapped to many graduate attributes, and one graduate attribute can be aligned with many courses. The measure of these attributes is called attainment.

This paper aims to quantify the attainment of these attributes based on some pre-defined levels.

II. Motivation and Contributions

Evaluation, grading, and certification in the Indian education system still rely on examinations, but the academic quality of these examinations has always been

a matter of concern.

To overcome this challenge, the All India Council for Technical Education (AICTE) launched the exam reform policy [6] in the year 2018, which was a stage set-up for the new education policy "2020." Higher-order cognitive skills like critical thinking, creativity, and problem-solving are essential for any technical professional, so this policy aims to raise the bar on evaluation according to Bloom's taxonomy. It is hoped that this will also force necessary alignment in the teaching-learning processes on the one hand and the bridging of the gap between theory and practicals, and prepare students for innovation and creativity while keeping the assessment methods at the centre of the paradigm.

Though most Indian universities and colleges have started implementing the OBE framework [7], the innovation is limited to curriculum design and the mapping of components with the appropriate graduate attributes of a student. As a result, the primary motivation for this article is to benchmark the correlation matrix between course outcomes and program outcomes so that, when appropriate assessment methods and rubrics are used, an accurate measure of programme outcomes can be attained, resulting in clarity about a student's attainment of an individual graduate attribute.
The major contributions of this research are to:

- Present the outlook of outcome-based education systems globally.
- Furnishing the major amendments and reforms in the outcome-based teaching-learning process on the grounds of the Examination Reform Policy.
- Proposing a mathematical assessment method for course outcome and program outcome mapping with attainment.

III. Literature Review

A lot of literature can be cited now regarding research in outcome-based education from India and other member countries of the Washington Accord [8]. The framework is quite mature and has accelerated with the advent of education technology as a specialization.

A. The Peer perception: OBE around the world

OBE has been practised for over a century, as educationalists highlighted the need to understand learners' characteristics during the learning process. The goal of OBE is to ensure that learners are prepared with the information, competencies, and attitudes necessary to become successful. All these characteristics are defined in the Graduate attributes suggested by Washington Accord. The research of Bloom [9], and his colleagues had a critical role in developing taxonomies for educational aims in the 1950s. Eventually, taxonomies were established as benchmarks for development. Then they were utilized to set particular targets and formulate focused criteria to demonstrate the learners' achievement of accepted norms. Bloom's work is still a vital tool in assessing OBE. He prioritised connecting assessment results to long-term and substantial outcomes that learners can expect. In addition, he placed importance on relating assessment results to short-term enabling outcomes generated from these long-term outcomes. This follows the 'clarity of focus' and 'designing back' ideas.
Primarily conceptualized for HEIs for technical education, the concept is so evolved that researchers are trying to introduce it in other education domains, including distance learning and Business Education [10] [11]. Raof et al. [12] suggested that OBE is changing the landscape of the vocational education system in Malaysia. Even the awareness of the framework amongst the students and faculties varies from moderate to high. Medical Education in Pakistan is looking forward to implementing OBE, which opens influential horizons for educational transformation and organization. [13].
The impact of outcome-based education can be further enhanced by using visible learning claimed [14]. The article suggested that the ten mind frames of visible learning can make the learning and assessment visible, which eases the process and encourages learners to strive for better achievement. [15] developed a web-based information system for implementing OBE at Sebelas Maret University, Indonesia. The application is designed using rapid application development methods. It uses the Yii2 Framework with the concept of MVC (Model, View, Controller), where system programming is separated based on application components, such as manipulating data, controllers, and user interfaces. [16] ensured that the universities in Hong Kong have undergone a facelift in implementing outcome-based teaching-learning (OBTLP). A "fitness for purpose" approach has been adopted. Each institution sets its own visions and missions, goals and directions, intended learning outcomes, and indicators of measurement of program accomplishment. [17] investigated the attitudes of Afghan students towards the outcome-based education paradigm. Both quantitative and qualitative data are shared with the Ministry of Higher Education and the Higher Education Development Program to develop applicable policies while addressing the existing challenges. [18] compared the new accreditation process of the International Engineering Alliance (IEA) in Nigeria. The country is observing a complete paradigm shift in terms of the OBTLP. Therefore the paper also highlighted the readiness of staffing, equipment, programme educational objectives, learning outcomes, industrial training, curriculum development, and continuous quality improvement for the Council for the Regulation of Engineering in Nigeria (COREN).
[19] proposed implementing various components of OBE

through Blockchain technology, including open framework design, network node construction and student evaluation record data. The case study comprises students of Computer Science from an HEI in Myanmar. [20] presented two learning process models for OBE implementation in e-learning. Furthermore, the paper also compared the extent to which OBE optimization occurs in students upon implementing the aforesaid models. [21] suggested authentic assessment methods in the OBTL process to examine the learners' performance critically. Similarly, [22] used a reverse engineering method to identify the flaws in the conventional OBE framework and suggested a dynamic model by explicitly introducing the marks of learner assessment and then verifying it qualitatively and quantitatively.
As Killen [23] describes two broad forms of OBEs, the two types fall into two categories:

- The first emphasises curriculum and examination results being measured and the duration of programmes and graduates finding employment after school
- the second performance indicator is more nebulous, which might be considered less quantifiable and rely on learners conveying what they have learned and implementing it in their learning process.

B. OBE in India

The National Assessment and Accreditation Council (NAAC) and the National Board of Accreditation (NBA) are two central entities in India's accreditation process.

The University Grants Commission (UGC) created the National Accreditation Agency (NAAC) in 1994 so that institutions could get and keep their accreditation based on internal and external evaluations.

In September 1994, the NBA was formed to assess the degree of qualitative competency of post-secondary institutions in engineering and technology, management, pharmacy, architecture, and related subjects. While existing in its present form, the NBA came into being on January 7, 2010, to ensure the quality and relevance of technical education through the accreditation of educational programmes. A transparent and equitable relationship is developed with stakeholders (universities, industry, regulators, government, and colleges/employers) to ensure that the programmes teach graduates practical skills and build competency in essential areas such as general technical competency and national and global professional competence. The NBA is dedicated to finding out if the programmes given by technical institutions at various levels meet the NBA's standards [24].

Regarding "technical institutions," colleges and university departments providing engineering programmes are called "technical institutions."

NBA joined the Washington Accord (WA) in 2007 as a provisional member, an international agreement between authorities overseeing engineering degree programmes to establish their credibility. This initiative advises that the other signatory bodies should recognise graduates of accredited engineering programmes across the world. With the backing of the stakeholders, the NBA is using a rigorous accreditation system developed by the Washington Accord, which is currently being implemented by the Indian education system.

The accreditation procedure for engineering programmes is based on ten criteria defined by experts from prestigious national-level technical institutions, industries, R& D organisations, and professional bodies who conducted a participatory process with subjects. Accreditation requirements approved by the Washington Accord signatories are also referenced. All of these criteria focus on identifying an institutional element that influences the overall level of effectiveness. These are defined using quantitative measures, including parameters, which were crafted for maximising objectivity when evaluating each aspect.

1) **Graduate Attributes (GAs)** comprise an outcomes-based set of characteristics that indicate a graduate's future capability to practise. The GAs are excellent examples of the characteristics often expected of someone who has graduated from a recognised institution.
2) **Programme Outcomes (POs)** are the Students' expected outcomes, in very general terms, will say what they will know and be able to do following graduation. The skills, knowledge, and behaviour that students learn and gain during matriculation through the programme are the factors these variables measure.
3) **Programme Educational Objectives (PEOs)** - The statements that describe what graduates of an engineering degree programme can expect to accomplish in their careers and the first few years after graduation are called educational objectives.
4) **Course Outcomes (COs)**- At the end of each course, students should be able to establish clear objectives or results that explain what they've learned. These attributes relate to students' academic and occupational skills, knowledge, and behaviour during matriculation.
5) **Assessment** - Students are assessed on their achievement in implementing programme goals and programme results.
6) **Evaluation** - Evaluation is a process of data interpretation that the evaluation team undertakes. Evaluation gauges whether the program's educational aims or outcomes are being
7) **Mapping**- is the process of portraying relationships

among parameters in matrix form. In contrast, the matrix cells contain the weightage of the mapped two parameters. Institutions should clearly demonstrate how course outcomes, modalities of delivery of the courses, assessment techniques, and laboratory and project coursework are used to gauge the programme's success.

8) **Attainment**- The attainment of goals can be assessed using both direct and indirect approaches. Direct assessment approaches essentially focus on students' ability to demonstrate knowledge or skills using trackable numerical indicators. Indirect evaluation techniques include questionnaires, interviews, and observation to determine people's thoughts and feelings.
9) **Rubric**- A rubric is an excellent tool for indirectly assessing program outcomes. An evaluation rubric spells out the goals and expectations for student achievements, which helps instructors determine student success or achievement. Program outcomes that are complex or cannot be easily quantified or evaluated using standardised tests or surveys are ideal for using rubrics. For example, written assessment, oral communication assessment, and critical thinking evaluation are typically conducted using rubrics.

NBA has left the formula open-ended, so different ways to reach course and/or programme outcomes have already been suggested.

[7] proposed a soft computing approach for deriving a quantitative assessment of the scoring grade of students based on rubrics-based assessment. The study concluded that the open right sigmoidal fuzzifier outperformed other fuzzified and was versatile enough to be adopted for every course. Sinha et al. [25] recommended an approach for accessing students' learning outcomes (SLOs). The research demonstrated the matrices, measures, and policies that can transform the educational sector.

IV. PO Attainment Framework

A. Formulation of Course Outcomes

The proper definition and attainment of course outcomes contribute to the attainment of program outcomes, which will help the graduate perform his or her duties, professional responsibilities, design and development, production and testing of novel products, and ability to deal with finances and project management during his or her engineering program. Further, these POs contribute to attaining PEOs during their early professional career.

After developing CO statements, they are mapped with any possible POs based on their relationship. However, the POs are not always associated with CO and may be left blank. In any case, it is required that all POs be mapped to one of the PEOs specified by the programme.

The information, abilities, and/or attitudes that students will acquire in a course are explicitly described in the course outcomes. Well-written course outcomes involve the following parts: action verb, subject content, level of achievement, and condition of performance (if applicable). One example is represented below table I:

TABLE I
Sample Course Outcomes: Course Name Course Code: Signal and System (301)

COs	Statement of Course Outcomes
CO1	Understand the basics of continuous and discrete-time signals and systems.
CO2	Explain state space analysis of the LTI system.
CO3	Comprehend the effects of sampling on a continuous-time signal.
CO4	Calculate Fourier series and Fourier transform of continuous and discrete time signals.
CO5	Analyze signal and system properties like stability and causality using Laplace and Z transforms.

The action verbs in the above table are mapped to Bloom's learning level [9].

B. Course-Outcome & Program-Outcome Mapping

The next step is CO-PO mapping, which represents a link between the course and program outcomes. This mapping is one of the most important aspects because it is required for the OBE to be implemented.

Until now, the CO-PO mapping was based on the keywords mapped and weighted by the instructor's perception. Since the PO statements are fairly high-level statements and define the characteristics of an engineering graduate, the observability and measurability of the POs at the course level are inappropriate.

Therefore, To connect high-level program outcomes (POs) with course content, course outcomes and assessment methods, the exam reform policy document [6] introduced the concept of competencies and performance indicators. (Exam Reform Policy). The relation between PO, competency, and performance indicators is shown in figure 1. Whereas competency clarifies what

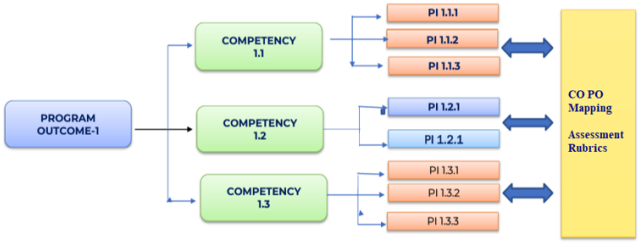

Fig. 1. Relationship: Program Outcomes, Competencies and Performance Indicators

the programme expects a student to achieve, indicators serve as measuring tools in assessment to determine the extent to which outcomes are attained.

Referring to the exam reform policy document, this research suggests a mathematical formulation to correlate COs with POs based on assessing performance

indicators. The COs are mapped to PIs, which results in a stronger CO-PO mapping. Further, this strong mapping results in a stronger and more accurate PO attainment.

C. Mapping Formulation

The final CO-PO mapping is identified by observing the following steps:

- Identification of Competencies to be attained corresponding to each relevant PO for a course.
- Defining Performance Indicators (PI) corresponding to each competency defined in step-1.
- Establishing mapping or correlation of COs with POs using PIs.

The correlation is calculated as the number of correlated indicators of a PO mapped with CO divided by the total indicators of a PO. The calculated value represents the correlation level between a CO & PO as shown in equation 1. *W* represents the weighted average of program outcome indicators, as shown in equation 2. Finally, the value of *alpha* represents the mapping between a course outcome and a programme outcome. This value will always have a domain of [1, 2, 3], with 1 representing the weakest correlation and 3 representing the strongest.

$$CO_i - \ i^{th}\ Course\ Outcome$$

$$PO_l - \ l^{th}\ Program\ Outcome$$

$$I_{kjl} - \ K^{th}\ indicator\ of\ j^{th}\ Competency\ Level\ of$$

$$l^{th}\ Program\ Outcome$$

$$C_{jl} - \ j^{th}\ Competency\ Level\ of\ l^{th}\ Program\ Outcome$$

$$\Lambda\left(I_{jkl}, C_{jl}\right) - \ Measure\ of\ Competency\ and\ Indicators$$

$$W_{jl}^{c} - \ Weightage\ of\ j^{th}\ Competency\ Level\ of$$

$$l^{th}\ Program\ Outcome$$

$$\lambda - \ Degree\ of\ Correlation$$

$$\Lambda(I_{jkl}, C_{jl}) = \frac{\sum_j [\ \lambda(I_{jkl}, CO_{i})]}{CountI_k, C_{jl}} \tag{1}$$

$$W_{jl}^{c} = \frac{Count\ I_{jkl}}{Count\ I_k} \tag{2}$$

$$\alpha(CO_i, PO_l) = \sum_j [W_{jl}^{c} \ * \ \Gamma(I_{jkl}, C_{jl})] * 100 \tag{3}$$

$$\alpha < 50 : \quad 1$$

$$50 \leq \alpha < 70 \ : 2$$

$$\alpha > 70 \ : \quad 3$$

Table II represents a sample CO-PO correlation table after implementing the above mathematical formulation. The mapping markers are on a scale of 1,2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

TABLE II
SAMPLE CO-PO MAPPING: SIGNAL AND SYSTEM (301)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	1	1	-	-	-	-	-	1	-	3
CO2	3	3	1	1	-	-	-	-	-	1	-	3
CO3	3	3	1	1	-	-	-	-	-	1	-	3
CO4	3	3	1	2	-	-	-	-	-	1	-	3
CO5	3	3	1	2	-	-	-	-	-	1	-	3

This mapping is done for all courses, and a weighted average of all COs w.r.t. a single PO is calculated to generate the Course-PO mapping as shown in Table III

TABLE III
COURSE-PO MAPPING

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
101	-	-	-	-	-	2	2	3	-	-	-	1
102	3	2	-	-	-	-	-	-	-	-	-	1
-												
-												
201	-	-	-	1	1	-	-	-	2	2	-	2
202	-	-	-	-	1	-	-	-	3	1	-	2
-										-		
-												
301	3	3	1	2	-	-	-	-	-	1	-	3
302	3	3	-	-	-	-	-	-	-	-	-	-
-												
-												
401	-	-	-	3	-	-	-	-	3	2	3	3
402	3	3	2	2	2	-	-	-	-	-	2	-
-												
-						-						3
501	2	2	2	2	3	-	3	2	3	2	2	2
502	2	3	2	3	2	-	-	-	-	-	-	3
-												
601	3	2	2	3	3	3	3	-	-	-	-	3
602	3	3	3	3	-	2	-	3	-	-	3	3
-												
-												
701	1	2	-	3	3	3	3	3	2	-	3	3
702	2	-	1	2	3	-	-	-	-	-	-	-
-												
-											-	
801	2	3	3	2	3	-	2	3	-	3	-	3
802	3	3	2	2	-	-	-	-	2	-	2	3
-												
-												

D. PO Attainment

The role of CO-PO mapping, followed by CO attainment based on pre-defined rubrics, leads to programme outcomes and, ultimately, the level of individual graduate attributes attained. And hence, it is justified to say that the assessment of courses actually lays the foundation for an outcome-based teaching and learning process.

The program uses direct and indirect measurement methods to calculate the total PO attainment. The following are a few assessment tools used to determine a PO's attainment level, but they are not exhaustive.

Probable direct attainment tools:

- Examinations
- Seminars
- Project Evaluation & Internships
- Students' portfolio

Probable indirect attainment tools:

- Surveys from alumni and industry stakeholders
- MOOCs
- Rubrics developed for various program-level events organized for students

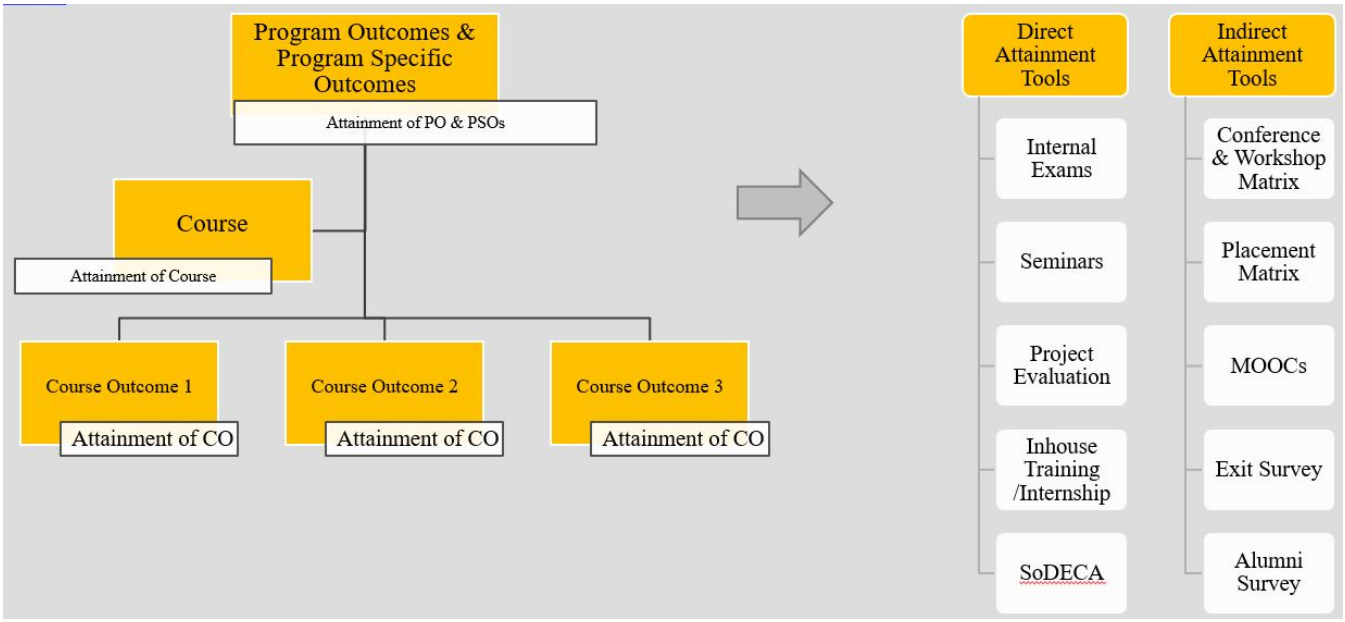

Fig. 2. Outcome Based Education - Assessment and Attainment

The final attainment is calculated as the 80% of direct attainment + 20% of indirect attainment.

Figure 2 depicts the relationships between various components of the outcome-based education along with their assessment and attainment methods. Table IV shows the sample PO attainment that is calculated as per equation 4, which defines that the total PO attainment is the weighted faction of estimated CO attainment and maximum attainment level that can be achieved.

$$POAttainment = \frac{POmappingweightage * ActualCOAttainment}{MaximumAttainmentlevel} \quad (4)$$

TABLE IV
SAMPLE PO ATTAINMENT LEVELS

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
101	-	-	-	-	-	2	2	3	-	-	-	1
102	3	2	-	-	-	-	-	-	-	-	-	1
-												
-												
201	-	-	-	0.67	0.67	-	-	-	1.33	1.33	-	1.33
202	-	-	-	-	0.83	-	-	-	2.50	0.83	-	1.67
-										-		
-												
301	3	3	1	2	-	-	-	-	-	1	-	3
302	2	2	-	-	-	-	-	-	-	-	-	-
-												
-												
401	-	-	-	3	-	-	-	-	3	2	3	3
402	2	2	1.33	1.33	1.33	-	-	-	-	-	1.33	-
-												
-						-						3
501	2	2	2	2	3	-	3	2	3	2	2	2
502	1.67	2.50	1.67	2.50	1.67	-	-	-	-	-	-	2.50
-												
601	3	2	2	3	3	3	3	-	-	-	-	3
602	1	1	1	1	-	0.66	-	1	-	-	1	1
-												
-												
701	1	2	-	3	3	3	3	3	2	-	3	3
702	2	-	1	2	3	-	-	-	-	-	-	-
-												
-											-	
801	2	3	3	2	3	-	2	3	-	3	-	3
802	3	3	2	2	-	-	-	-	2	-	2	3
-												
-												
Direct Attainment	2.14	2.23	1.67	2.04	2.17	2.22	2.75	2.25	2.31	1.69	2.06	2.35
Indirect Attainment	3	2	3	2	2	3	3	3	2	2	3	3
Overall Attainment	2.31	2.18	1.93	2.03	2.13	2.38	2.80	2.40	2.24	1.75	2.24	2.48

V. Conclusion

Outcome-based teaching and learning processes are becoming an integral part of education in India and other Washington Accord signatory countries. Even though the universities and institutions in India are already gearing up for the second phase of the OBTLP, the assessment processes are still obsolete. This paper discussed the complete attainment process of program outcomes while recommending mathematical formulations for assessment, mappings, and eventual attainment. The accurate attainment level will suggest the weaker areas where the program must make efforts. e.g. in the given study, PO10 (Communication) was attained with level 1.75, whereas the highest attainment was 2.80 of PO 7 (Environment and Sustainability). On the basis of that, appropriate actions can be taken, and the target level for the next year can also be divided.

Results of mapping and attainment suggested that the process is transparent and mathematically proven. However, its implementation still needs to be tested for different universities and institutions with varied demographics and students' engineering quotients.

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