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Systematic Approach in Assessment of Course Outcomes / Program Outcomes for Undergraduate Engineering Programs – A Case Study

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Abstract: The accreditation bodies like NBA and NAAC instructs all Institutes to define Course Outcomes (COs) and Program Outcomes (POs) and their assessment methodology for the effective implementation of Outcome Based Education (OBE). Due to lack of experience and maturity in this domain, most of the Institutes struggle in defining these methodologies and procedures. The curriculum design, the teaching learning processes and the assessment procedures have to be well defined so that OBE can be implemented effectively across the Institute for all programs. This research article presents some of the best practices adopted at our Institute for institutionalizing the OBE processes. A systematic and scientific approach for fixing the CO/PO targets and CO/PO attainment calculation have been evolved and discussed with samples in this paper. The case study has been presented to provide guidelines and better insights to the readers for the effective implementation of OBE.

Keywords: Course Outcomes, Program Outcomes, Assessment of Course Outcomes, Assessment of Program Outcomes, Continuous Improvement

1. Introduction

Outcome Based Education (OBE) is an educational theory which primarily focuses on achievement of well-defined outcomes or goals. OBE emphasizes the orientation of teaching learning and other academic processes to help students in achieving their goals. Many of the accreditation and regulatory agencies like NAAC, NBA and AICTE have insisted on continuous improvement in the quality of OBE. However, there is no single style of assessment procedure recommended for the implementation of OBE.

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The curriculum, content delivery and assessment must be aligned and refined in such a way that the learners are able to achieve the intended learning outcomes. The customization of the academic process can be done based on the nature of the learners and the learning environment. This research article presents some of the best practices adopted at our Institute for the effective implementation of OBE.

A systematic and scientific approach for fixing the target for the attainment of course outcomes / program outcomes has been evolved. The procedure for mapping of course outcomes with the program outcomes has been standardized across the Institute. Exclusive parameters have been identified for the indirect assessment of program outcomes. And targets have been set based on the performance of the previous batches of graduates. The attainment of course outcomes and program outcomes are analysed in the Program Performance Assessment Committee (PPAC) constituted at the Department level. In case of deviations from the target, an action plan for improvement has been devised. The targets are revised if the attainment exceeds the target for more than two consecutive years. An exclusive web application has been developed for automation of assessment of course outcomes and program outcomes.

All these tasks have significantly enhanced the effectiveness of implementation of OBE at our Institute. Based on the analysis of attainment of program outcomes, actions for improvement were taken in all the domains of curriculum design, content delivery, assessment, co-curricular and extracurricular activities. The case study has been presented to provide guidelines and better insights to the readers on the effective implementation of OBE. The paper is organized as follows: section 2 explains the related work and the motivation behind this work, sections 3 and 4 describe the proposed methodology with case study, section 5 discusses the results and section 6 concludes the paper.

2. Related Works

Jayashri et. al (2019) used case study approach and explored the CO/PO attainment of the batch of Tier II institutions and demonstrated the calculations for the course *'Analog Electronics'*. Pradhan (2021) proposed Engineering Pedagogy Outcome Based Education (EPOBE) which includes graduate attributes, OBE framework and training framework to strengthen the Engineering Pedagogy. Zamri et. al. (2010) discussed in detail about the mapping of Course Outcomes to Program Outcomes and their assessment methodology. Rajagopal Reddy et. al. (2021) calculated CO-PO attainment levels for the batch of Engineering students and exhibited the calculations using the first semester course *'Basic Electrical Engineering'*.

Balasubramani et. al. (2017) used a sample course *'Building Enterprise Applications'* and demonstrated the CO and PO attainment calculation process. Significant amount of research works have been carried out in the assessment of course outcomes and program outcomes during the last decade. Kavitha et. al. (2018) demonstrated CO-PO attainment calculations of UG engineering programs of Tier II Institutions. Pravin et. al. (2019) used different weights based on the evaluation scheme of the courses such as theory, practical, oral and term work. Shivakumar et. al. (2014) used CO-PO mapping at the question level for CO/PO attainment calculation. Shrivastava et. al. (2018) explored the study of CO, PO and PEO attainment calculation for various engineering programs.

It could be inferred from the literature that there is no statistical approach used in fixing the target for the attainment of course outcomes and program outcomes. Also, the mapping between course outcomes and program outcomes is purely subjective. No scientific approach has been adopted in the mapping of course outcomes and program outcomes.

3. Research Objectives

The motivation for research is supported by the following research objectives:

A. To develop a scientific method for fixing the targets of course outcomes and program outcomes
B. To standardize the procedure for the indirect assessment of Program Outcomes.

4. Materials and Methods

A. Design of Course Outcomes

Course Outcomes are measurable, observable, and specific statements that clearly indicate what a student should know and be able to do as a result of learning. The Course Outcomes generally include an action verb, subject content, level of achievement and condition of performance. Course Outcomes are framed by the course designers or course handling faculty. The course outcome statements are written in accordance with Bloom's taxonomy and are mapped to twelve POs. The syllabus is reviewed by a Special Interest Group (SIG) constituted at the Department level.

B. Assessment of Course Outcomes

(1) Continuous Assessment Tests (CAT) and Terminal Examinations - the question papers are set in accordance with the Revised Bloom's cognitive levels and assessment pattern as specified in the syllabus book.
(2) Assignments - address Higher Order Thinking Skills (HOTS) which includes worksheets, mini-projects, case studies, seminar presentation, review of journal papers, online certification and tutorials. The type of assignment is decided by the course faculty based on the nature of the course.
(3) Projects - rubrics designed in accordance with program outcomes are used for the assessment of course outcomes of project.
(4) Course End Surveys - feedback for course content, content delivery and assessment are collected through course end surveys for every course during the end of the semester. It is used as an indirect assessment tool for assessment of course outcomes.

C. Fixing the targets for Course Outcomes

Each course has two targets, namely Expected Proficiency (EP) and Expected Level of Attainment (ELA). These targets are fixed based on the average performance in the end semester examinations for the respective set of students graduated in the previous academic years. For fixing the expected level of attainment in the current academic year, 30% improvement is considered from the current level of achievement. The process for fixing the targets for the course outcome is demonstrated in Fig. 1. A sample calculation for fixing the target is shown in Table 1 for the course on Data Structures and algorithms.

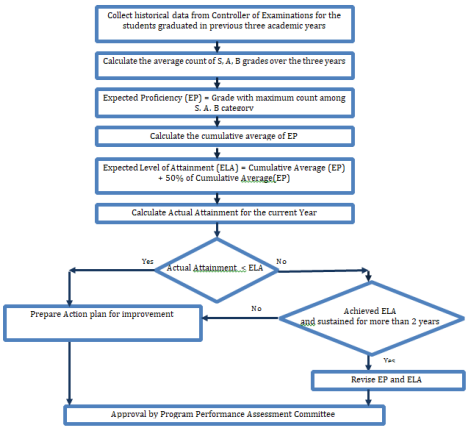

Fig 1. Process for Fixing the Targets

Table 1 shows the end semester results of three different batches of students, where the grades 'S' (90-100%), 'A' (80-89%), 'B' (70-79%), 'C' (60-69%) and 'D' (50-59%) refer to *'pass'* and 'U' (<50%) refers to *'fail'*.

Table 1. Target fixing for Course

Batch	S	A	B	C	D	U	Total
2011-15	8	31	36	35	20	7	137
2012-16	8	37	32	32	19	10	138
2013-17	3	33	42	30	20	11	139
Count	19	101	110	97	59	28	414
Average (in %)	5	24	27	23	15	6	
Cumulative Average (in %)	5	29	**56**	79	100		

It could be inferred from the Table 1, that the Expected Proficiency (EP) is set as B and the Expected Level of Attainment (ELA) is 70% *(30% improvement on cumulative average of 56%)* for this course for the next batch of students.

The same target level is fixed for all COs. For example, if the course has 6 COs and all of them are at 'Apply' level, then the targets EP-'B' and ELA-70% can be fixed for all COs. Otherwise, the target may be reduced to 5 – 10% for higher levels of Bloom's category. For example, if CO1 is at 'Understand' level, its target may be set to EP-'B' and ELA-70%; if CO2 is at 'Apply' level, its target may be set to EP-'B' and ELA-65%; if CO3 is at 'Analyze' level, its target may be set to EP-'B' and ELA-60%. In order to maintain the quality, lower limit for the targets may be set such that no course would have the EP level below 'B' and ELA below 60%.

D. Course Outcome Attainment

The complete process of attainment of course outcomes along with the weightages for continuous assessment, terminal examinations and course end survey is presented in Fig. 2.

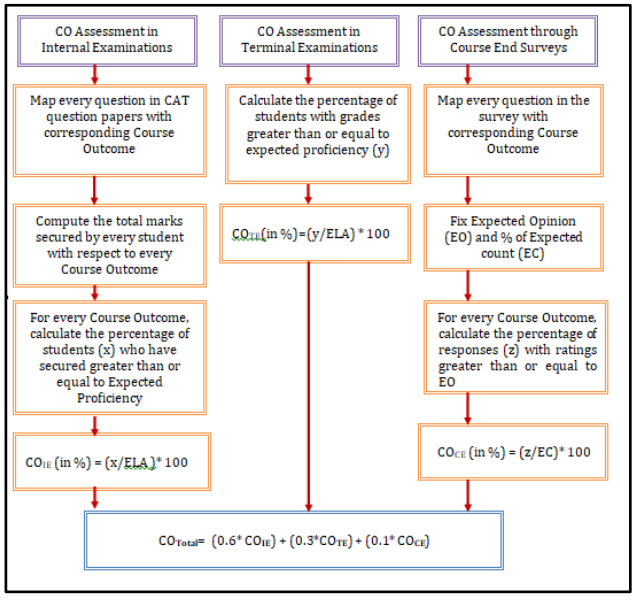

Fig 2. Process of Course Outcome Attainment Calculation

An in-house web application has been developed for automation of the attainment process. The course outcome attainment for the course on Computer Networks from the web application is shown in Fig. 3 and Fig. 4. The course outcomes are Describe various Network components, topologies, reference models and technologies

- Experiment Flow control, Error control and Access control techniques at Data link layer
- Apply Subnetting and routing mechanisms for a given network
- Explain the working principle of End-to-End and application layer protocols
- Compare the needs and implementation architectures of peer to peer, Client server and Cloud Networks
- Examine the Performance metrics of a specific Network traffic using tools such as Wire shark

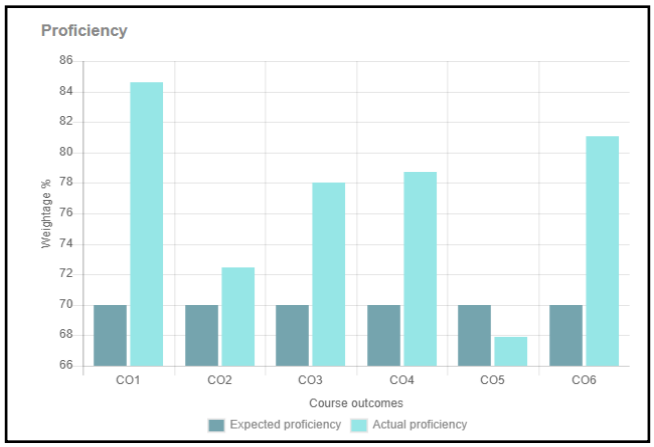

Fig 3. Sample Course Outcome Attainment (EP)

Fig. 3 shows that there are 6 Course Outcomes and EP is set to B (70) for all of them. It is inferred that CO1, CO2, CO3, CO4 and CO6 are above the target; and CO5 needs to be improved.

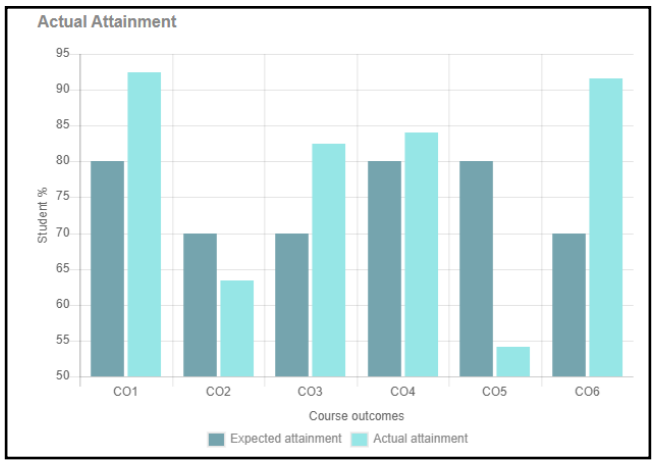

Fig 4. Sample Course Outcome Attainment (ELA)

Fig. 4 shows the CO attainment for the course Computer Networks. The ELA targets are at 80% for CO1, CO4 and

CO5; and 70% for CO2, CO3 and CO6. More than 90% of students attained CO1 whereas less than 55% students attained CO5 which needs to be improved.

E. Program Outcomes Attainment

The program outcomes are based on the twelve graduate attributes as prescribed by the National Board of Accreditation (NBA). Program Outcomes (POs) are assessed through

Direct Assessment

- Curricular Component

Indirect Assessment

- Co-curricular and Extracurricular Activities
- Program End Survey
- Employer Survey

The process of calculating PO attainment is shown in Fig. 5.

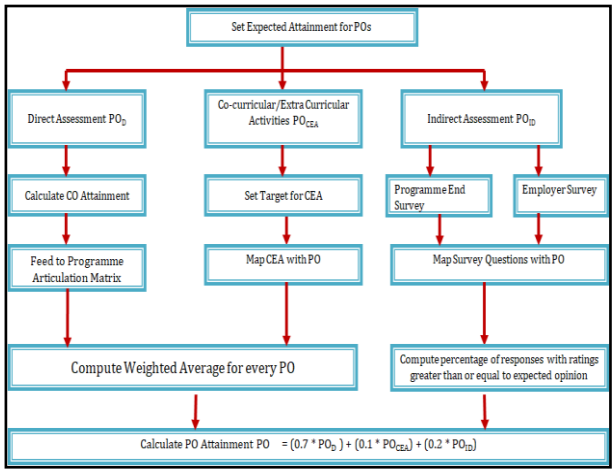

Fig 5. Process for Program Outcome Attainment Calculation

The mapping of Course Outcomes with Program Outcomes play a vital role in the direct assessment of POs. Guidelines for mapping of COs and POs in the knowledge level have been evolved based on the revised Bloom's taxonomy. The program outcomes on Engineering knowledge, Problem analysis, Design/Development of solutions, Conduct investigation of complex problems, Modern tool usage are mapped to the Blooms cognitive levels Apply, Analyse, Evaluate, Evaluate/Create, Apply/Analyse depending on the nature of the courses respectively. The guidelines for mapping is shown in Table 2.

Table 2. Guidelines for CO-PO Mapping

Criteria	Mapping Guidelines
Bloom's Level of CO ≥ Bloom's level of PO	Strong
Bloom's Level of CO is one level less Bloom's level of PO	Medium
Bloom's Level of CO is two levels less Bloom's level of PO	Low
Bloom's Level of CO is less than the Bloom's level of PO by 3 or more	No correlation

These guidelines have contributed significantly in ensuring the uniformity in mapping across all courses in the Institute. The parameters of indirect survey are identified by the Program Performance Assessment Committee (PPAC) and the standard operating procedure for data collection is defined, as shown in the Table 3.

Table 3. Parameters of Indirect Survey

Data	Responsibility	Frequency
CO Attainment	Course Faculty	Every Semester
Publications	Proctors	Every Semester
Product Design	Coordinator for Association activities	Every Semester
Software Contests	Coordinator for Association activities	Every Semester
Certifications	Course Faculty/ Proctors	Every Semester
Professional Society	Professional Society coordinators	Every Semester
Industrial Visit	Coordinator for Industry Institute Interaction	Every Semester
In-plant Training	Coordinator for Industry Institute Interaction	Every Semester
Guest Lecture/ Seminar/ Workshop	Tutors	Every Semester
Sports/ NSS/ NCC/ Cultural Activities	Sports/NSS/NCC /Cultural coordinator	Every Year
Programme End Survey	Alumni coordinator	Every Year
Employer Survey	Coordinator for Industry Institute Interaction	Every Year
Employer Survey	Placement Coordinator	Every Year

Target values for POs is calculated by calculating the average of actual values of POs of previous three years and then increased with 10%. The mapping of parameters for indirect assessment has been done at the Department level and is shown in Appendix Table A1. The attainment of POs is calculated by the weighted average of participation in co-curricular and extracurricular activities.

The questions in the employer survey and program end survey are also mapped with the respective POs. The attainment of POs is calculated by the average of responses with ratings greater than or equal to Expected Opinion (EO) for the questions mapped with every PO, in Program End Survey and Employer Survey.

Attainment of PO through Programme End surveys / Employer surveys =
(Count of responses for corresponding questions with ratings greater than or equal to EO /Total Responses) ∗ 100

The templates used for Program End Survey and Employer Survey and the mapping of questions with appropriate POs are presented in Appendix Tables A2 and A3.

5. Results and Discussion

The attainment of Program Outcomes for the graduates of B.Tech Information Technology using direct and indirect mode of assessment is presented in Table 4 for the batch 2014-18.

Table 4. PO Attainment – Direct and Indirect Modes

2014-18	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
	68.78	61.36	57.13	56.45	70.29	59.02
	PO7	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
	60.21	70.68	69.03	66.86	64	60.35

The areas of weaknesses in the program based on the analysis of evaluation of COs and POs attainment levels are identified in the PPAC meeting. Action plan were designed and implemented to improve the attainment levels of POs. Some of the initiatives on curriculum design, pedagogy for content delivery and support system improvements are highlighted in this section.

Curriculum intervention:

The Institute has adopted Conceive Design Implement Operate (CDIO) framework for curricular planning and outcome-based assessment. The framework provides students with an education stressing engineering fundamentals set for real-world systems and products. The product, process, or system lifecycle have been more emphasized in the CDIO curriculum. In alignment with CDIO syllabus goals and mission of the institute, new courses namely Engineering Exploration, Lateral Thinking, Design Thinking, Project Management, System Thinking, Engineering Design Project, and Capstone Project are introduced in the CDIO curriculum. The objectives of these courses are to improve creativity, critical thinking, collaboration and communication among the millennial learners. Theory cum Practical courses have been strengthened to promote synchronous learning on both theoretical concepts with hands on training through industry supported laboratories and courses. More program specific elective courses with expanded scope like Virtual Reality, Assistive Technologies, Time Series Analysis have been introduced to promote learning on the recent state of the art technologies. Skill/Proficiency based courses include Personality Development/Employability Enhancement courses, internship/training at industry/ research organizations, MOOCs such as Coursera, edX, SWYAM and Spoken Tutorial have become part of curriculum.

Pedagogical initiatives:

Faculty members are exclusively trained in series of pedagogical programmes like FDP101x, 201x and 301x of IIT Bombay and International Engineering Educator Certification Program (IIEECP) of IUCEE. Many of the active learning strategies such as Think Pair Share, Flipped Class Room, Peer Instruction, Problem Based Learning and Collaborative Learning are being practiced in many of the courses. Learning Management Systems such as MOODLE and Canvas are used widely for sharing of resources, online quizzes, online assignments and discussion forums. Exclusive ICT tools like SafeApp, Clickers, Plickers and Padlets are used to enhance learning experience. Exclusive rubrics are used for assessments of laboratory exercises, assignments and project reviews. The experience in using active learning strategies, ICT Tools and rubric based assessments have resulted in more than 60 publications in Engineering Education Journals and Conferences in the past three academic years.

The students are motivated for increased participation in community based projects under IUCEE-EPICS programme. Special camps are being organized to the nearby villages to understand the lifestyle of the local community partners and to identify their potential problems. Interdisciplinary teams are formed to develop solutions: The Institute organizes a series of events related to socially relevant activities mapped with United Nations Sustainable Development Goals (UN-SDG). Encouraging student participation in United Nations Sustainable Development Goals UN-SDG projects provide them with an experiential learning to understand the societal needs.

To enhance the level of attainment of Program Outcome on ethics, plagiarism check with tools like Urkund has been mandated in project reports. Licensed software and open source software are strongly recommended for laboratory works and mini project works. Individual assignments in core courses and individual application development in laboratory courses have been enforced to prevent copying of assignments and program codes.

To enhance the level of attainment of program outcome on communication, exclusive English club and Tamil Literary club are functioning at the Department level to promote communication skills. Contests such as debate, creative writing, vocabulary cards and extempore speech are conducted regularly to enhance communication skills. Remedial classes are conducted in bilingual mode to support students with schooling in vernacular medium of instruction. Students are motivated to acquire certifications like Business English Certification. The “Language Studies Club” under Career Guidance Cell of the Institute organizes foreign language programs on German, French, Japanese and Coaching Classes for Hindi & English Communication for the needy students through qualified faculty, after regular class hours. Students were encouraged to write both technical and non-technical blogs in order to improve the communication skills.

To promote self-learning, enrolments for Guided Study Courses are being encouraged, wherein learners are not insisted to attend regular classes. However, assessments and periodic discussion with the faculty are encouraged. Certifications for online courses offered by Swayam/ NPTEL are recognized for academic credits. Assignments are created to explore the contents beyond the curriculum. Courses like Problem Solving using Computers and Computer Networks are integrated with corresponding NPTEL, Spoken Tutorial classes from IIT Bombay, eDx

and Udemy. Hackathons, Department Association activities, Professional society events like Tool Demo contests create opportunities for self-learning. Internships at industries, higher learning institutes like IITs, NITs have created interest among learners for higher studies. Contests in Association Events and Mini projects involving use of libraries, Application Programming Interfaces, software frameworks have motivated the students to do self-learning.

Support system improvements:

Quality Circle activities are being encouraged to improve the effectiveness of the teaching learning process. The academic process is automated by the web application for administering course registrations, student attendance, computation of attainment of Course Outcomes and analyses of course exit surveys. Lecture Capturing System has been enabled in classrooms to enable students to watch lectures outside the classrooms in self-paced mode. Smart Boards have been installed in all classrooms to promote student interaction and engagement.

The action plan was successfully implemented for the subsequent batches and the PO attainment result is shown in Fig. 6.

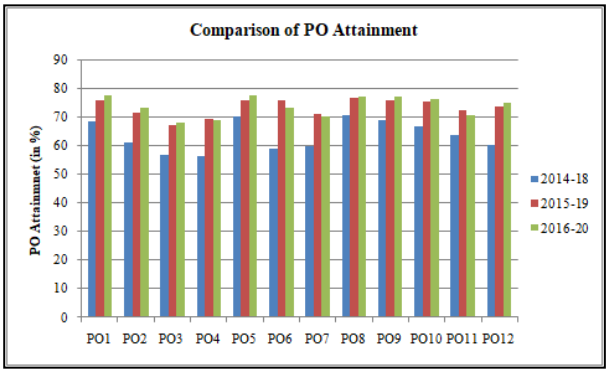

Fig 6. Program Outcome Attainment

It could be observed from the figure that there is a significant improvement in the attainment of program outcomes for the batch 2016-20, when compared with the previous batches.

6. Conclusion

The effective implementation of Outcome Based Education is governed by the curriculum design, teaching learning processes and the assessment procedure. The case study discussed in this paper used samples for calculating PO attainment using direct and indirect mode. The curricular component of PO assessment was detailed by discussing different procedures like CO/PO targets fixing, CO-PO mapping and CO/PO assessment methods. Co-curricular and extra-curricular activities of students were also considered for their PO attainment with suitable PO mappings. The indirect mode of PO assessment was also discussed by the use of survey questions.

Future work includes by setting the Proficiency Scale (PS) for each CO assessment which would support in the measurement of CO attainment in knowledge, skill and affective domains. The targets for attainment of individual course outcomes are to be varied in accordance with the Bloom's taxonomy. The quantitative analysis for the

Acknowledgement

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National Board of Accreditation Training Material for Evaluators / Stakeholders on Outcome Based Accreditation Process & Parameters.

National Board of Accreditation website: www.nbaind.org

Appendix 1

Table A1. Guidelines for CO-PO Mapping

Co-curricular/Extra-curricular Activities	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	Expected Number of Participation	Expected Level of Attainment (%)
Publications in Conferences / Journals	3	3	2	2	3	2	2	3	3	3	1	3	Once during programme	50
Participation in Product Design Contests/Hackathons	3	3	3	1	3	2	2	3	3	3	3	3		30
Participation in Software Contests	3	2	1	-	3	2	2	3	3	3	3	3		90
Online Certifications	3	2	-	-	2	-	-	3	3	3	-	3		70
Membership in Professional Society	2	1	-	-	1	-	-	3	3	3	2	2		50
Industrial Visit	1	-	-	-		-	3	3	1	1	-	1	Twice during programme	100
In-plant Training	2	-	-	-	1	-	3	3	2	2	-	2	Once during programme	30
Attending Guest Lecture/ Seminar	2	1	-	-	2	-	2	3	2	2	-	2		100
Attending Workshop	2	1	-	-	1	1	2	3	2	2	1	2		100
Participation in Sports/ NSS/ NCC/ Cultural Activities	-	-	-	-	-	-	-	3	3	3	3	1		95

Table A2. Sample Program End Survey

Rate your ability on the parameters mentioned below:		Mapping	4	3	2	1
Q1	Ability in providing engineering solutions to real world problems or issues	PO1				
Q2	Improvement in logical reasoning and problem approaching behavior	PO2				
Q3	Critical thinking behavior and design skills to develop a new product/prototype	PO3				
Q4	Ability in using research knowledge for solving problems	PO2, PO4				
Q5	Ability in investigating complex engineering problems or issues and providing optimal solutions	PO4				
Q6	Ability in identifying and selecting suitable tools and techniques for problem solving	PO5				
Q7	Advancement in technical knowledge and skill through curricular and co-curricular activities	PO1, PO5				
Q8	Confidence level to self learn and use new tools/environment for solving problems	PO5, PO12				
Q9	Ability in providing sustainable solutions to the society by understanding its impact and constraints	PO17, PO6, PO7				
Q10	Industrial exposure and practices gained through industrial visit/ in plant training/ industry internship/one credit courses	PO7				
Q11	Ability in participating as an individual in a project team to accomplish the project requirements and timeliness	PO8, PO9				
Q12	Ability in participating in team activities and societal relevant projects/activities	PO8, PO9				
Q13	Efficiency in communicating your ideas through oral/written presentation	PO10				
Q14	Ability in acquiring inter-personal skills through extra-curricular activities like NCC/NSS/Sports/other non technical events	PO8, PO9, PO10				
Q15	Ability in organizing technical/non-technical events or leading a project team	PO11				
Suggestions/ Comments (If any):			Signature with Date			

Table A3. Sample Employer Survey

Please rate the ability of our student on the following parameters		**Mapping**	**4**	**3**	**2**	**1**
Q1	Exhibit strong foundation of Technical Knowledge	PO1				
Q2	Problem Solving skills and Logical reasoning skills	PO2				
Q3	Ability to analyze and provide systematic solutions to new problems	PO3				
Q4	Ability to contribute effectively to Research and Development activities of your organization	PO4				
Q5	Ability to adapt to usage of new tools	PO5				
Q6	Ability to exhibit ethical conduct in all organizational activities	PO8				
Q7	Ability to consider environmental issues in developing a IT solution	PO7				
Q8	Ability to lead a team efficiently	PO9				
Q9	Ability to contribute effectively as a team member	PO9				
Q10	Ability to participate in social, organizational and societal initiatives	PO6				
Q11	Ability to address audience effectively and keep the session engaged	PO10				
Q12	Ability to create and manage relevant documents	PO11				
Q13	Ability to meet project deadlines	PO11				
Q14	Ability to learn new techniques and get accustomed to new domains	PO12				
	Signature with Date:					