Outcome Based Assessment of Engineering Programs for Achieving the Quality Assurance – A Case Study

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Abstract: In the dynamic world knowledge without skills is worthless. In earlier times the education program focused on imparting knowledge alone. But presently along with knowledge transfer, skills should be developed in graduates to meet the demands of technical profession and emerging job markets across the world. As a result the engineering education system was transformed from input - output model to outcome based education model. ABET, NBA, ENQA, and AAAC etc were some of the accreditation agencies established to monitor and implement quality in professional education. This paper outlined the procedure for the assessment and attainment of outcomes defined by National Board of Accreditation (NBA), the accreditation body of India. A case study of attainment of program outcome (PO) and program specific outcome (PSO) process was discussed for tier II under graduate engineering program in the country. A comparison of PO & PSO attainments among different programs in an institute was also presented in the paper. From the study it had seen that only few courses in an engineering program contributed in accomplishing professional competencies defined by NBA. Also, various engineering programs exhibited medium level of correlation with program outcomes and program specific outcomes.

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1. Introduction

The rapid advancement of technology and globalization had made both developed and developing countries to think about an efficient and effective strategy to improve the quality of education. Outcome based education was one of the strategy followed to assess and implement quality of education all over the world. Accreditation Board for Engineering and Technology, (ABET) was established worldwide, which is a non profit, non – governmental agency that provided assurance that the colleges or university program met the quality standards of the profession for which the program prepares the graduates. In India the quality assurance and improvement of a program in an approved institution was monitored and certified by national board of accreditation (NBA) which ensured a kind of recognition which indicated that a program fulfilled certain standards. NBA had given guideline to measure the competencies of engineering graduates in terms of graduate attributes. There were 12 graduate attributes defined by NBA which measured the knowledge, skills and attributes necessary for a competent engineering graduate. They were 1 Engineering Knowledge 2 Problem analysis 3 Design and development of solution 4 Investigation of complex problem 5 Modern Tool Usage 6 Engineering and Society 7 Environment and

Sustainability 8 Ethics 9 Individual and Team Work 10 Communication skills 11 Project management and finance and 12 Lifelong learning. Among the 12 graduate attributes, the first five attributes addressed discipline based competencies and remaining seven addressed professional competencies of a graduate. The parameters used to measure these attributes were program outcomes (PO) defined by NBA and program specific outcome (PSO) developed by the institution for each program.

It was the responsibility of the institute to ensure that the students graduating from it possessed skills needed for a competent professional. National Board of Accreditation suggested ten criteria to measure these skills of an engineering graduate by investigating the vision and mission of the institute, program educational objectives, curriculum, teaching learning process, student performance, faculty contribution, support facilities from institution etc. In which one of the criteria measured the attainment of program outcomes and program specific outcomes recommended by NBA. The steps involved in the evaluation and attainment of PO & PSO of a program, as well as its comparison of attainment levels among different programs in an institute was discussed in the paper. A tier II engineering institute in Kerala, Federal Institute of Science and Technology (FISAT) was chosen for the study. FISAT is a self financing engineering college established in the year 2002 affiliated to APJ Abdul Kalam Technological University and approved by All India Council for Technical Education (AICTE), New Delhi. The vision of the institution is to become a world class professional institute with focus on excellence, moulding committed global professionals and technocrats who can meet the demands of business, industry and research. FISAT aimed to bring out professionals with superior skills and social commitment and nurture brilliant young talents, enabling them to take up challenging assignments in the highly competitive global scenario.

2. Course Articulation and Program Articulation Matrix

The attainment of PO & PSO was achieved by executing the following procedure including the definition of course outcomes, development of course articulation matrix and program articulation matrix, executing direct and indirect assessment of CO, PO and PSO, computation of CO, PO and PSO attainment etc. The course outcomes (CO) for all the courses

should be in adherence with the course curriculum given by the university. A sample course outcome was presented in Table1. For the presented course there were five course outcomes within the scope of the curriculum. Once the course outcomes of all the courses were defined it should be mapped with the program outcomes and program specific outcomes. The mapping strength of course outcomes with program outcomes was represented in a scale of 1 to 3, in which 1, 2 and 3 stipulated low, medium and high level of correlation respectively. This correlation matrix of each course outcomes of a particular course with the program outcomes and program specific outcomes was called the course articulation matrix. If there was no correlation of CO with PO or PSO that cell was left blank. Justification for the correlation levels of CO - PO and CO - PSO must be provided by the faculty in charge. The overall mapping strength of a course with each PO & PSO was computed from average correlation values of all course outcomes. This overall mapping strength of CO - PO correlation and CO - PSO correlation of each course was the input in the program articulation matrix. It gave the correlation of each course in the program with the NBA graduate attributes. The course articulation matrixes of three sample courses from different department were presented in Fig. 1. For all the courses presented in Fig.1 it was clear that all the courses had good correlation with program outcomes PO1 and PO2. The correlation of these courses with other program outcomes like modern tools usages, societal, environmental, ethical aspects had seen as very low. Majority of courses in different program followed similar pattern of correlation level. The course articulation matrix exhibited the degree of correlation of the course with each PO & PSO.

Program Articulation Matrix and its mapping strength were presented in Fig. 2 for different programs in the institution. From Fig. 2 the percentage

Table 1 : Sample Course Outcomes of a Course

CO #	Course Outcomes
CE403.1	To analyse multi storey structures using suitable approximate methods, given the loading and structural definitions
CE403.2	To analyse trusses, beams and simple frames for a given loading and structural definitions, using matrix flexibility method
CE403.3	To analyse trusses, beams and simple frames for a given loading and structural definitions, using matrix stiffness method
CE403.4	Develop the direct stiffness matrix of trusses, beams and simple frames and analyse it for a given loading
CE403.5	Analyse a single degree of freedom system and explain the basic phenomenon in structural dynamics like different types of vibrations, damping, resonance transient and steady state response etc.

of courses mapped with NBA program outcomes and program specific outcomes and mapping strength for the three programs, Computer Science Engineering (CSE), Electronics and Communication Engineering (ECE) and Mechanical Engineering (ME) at FISAT was portrayed. It had seen that more than 80% courses in each program had good correlation with program outcomes PO1 and PO2. The number of courses mapped with other program outcomes was found declining thereafter, but some courses showed augmented correlation with program outcomes PO9, PO10 and PO12. The program articulation matrix manifested that all the programs had strong correlation with PO1 and moderate or weak correlation with all other program outcomes.
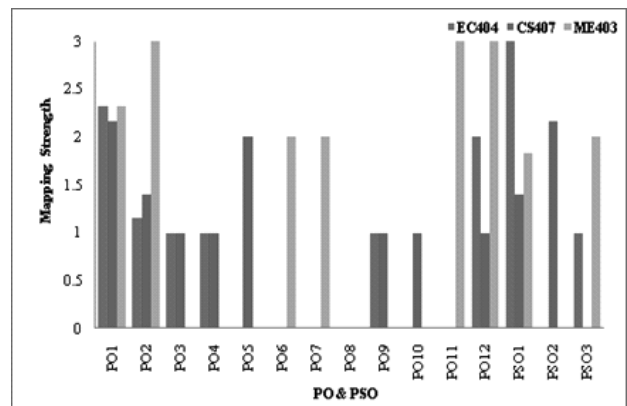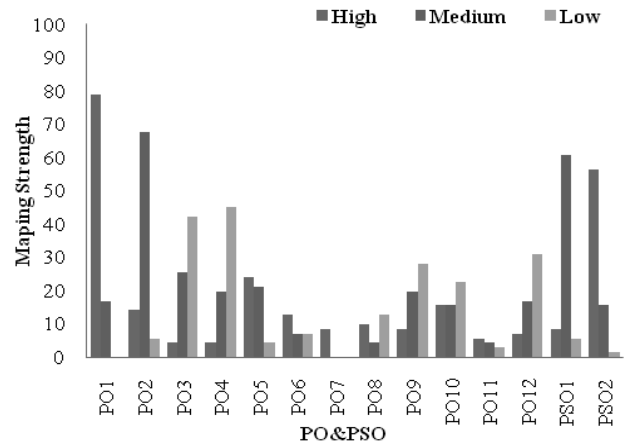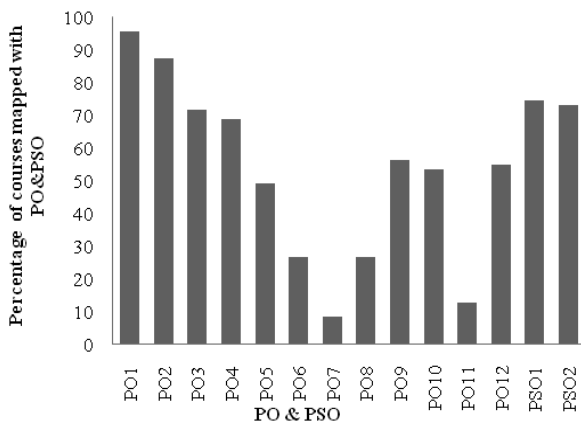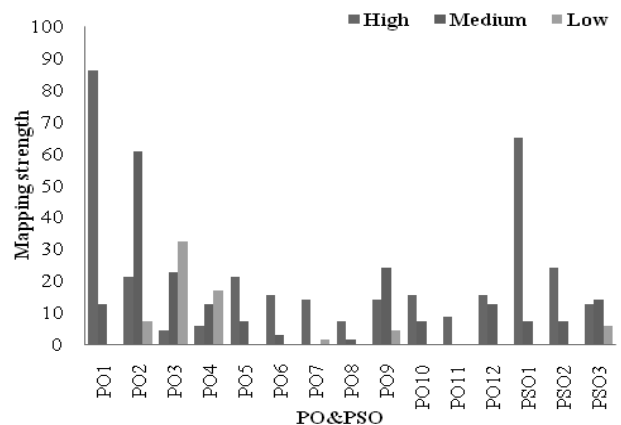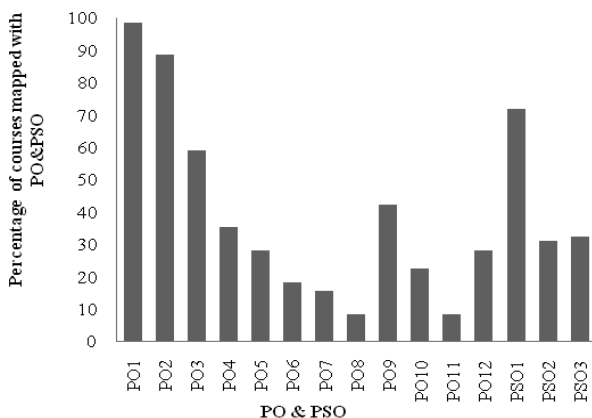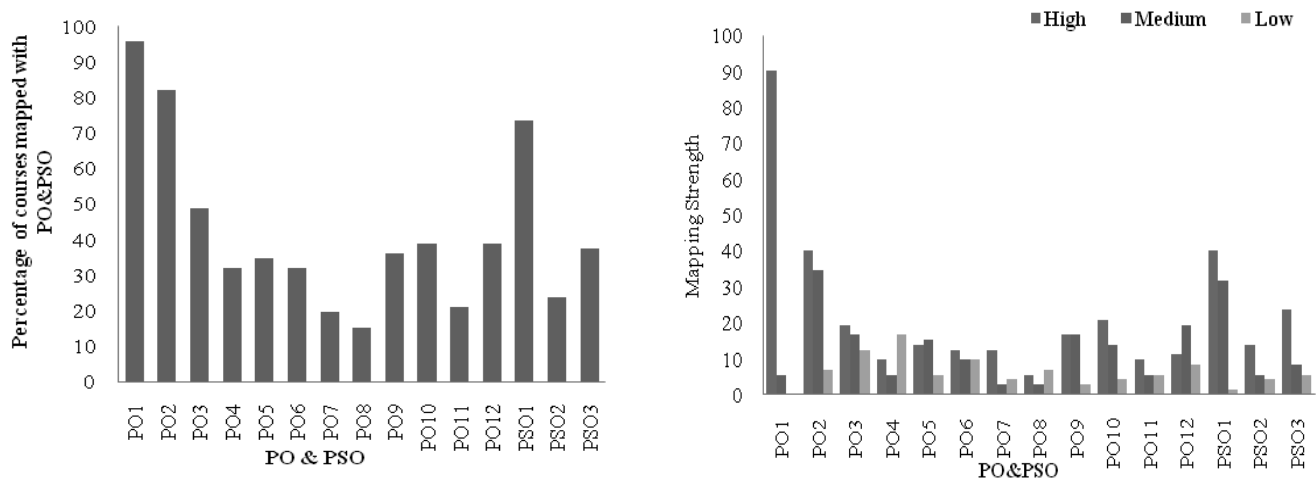

Fig.1: Course Articulation Matrix

(a) Program Articulation Matrix and mapping strength for CSE program

(b) Program Articulation Matrix and mapping strength for ECE program

(c)Program Articulation Matrix and mapping strength for ME program

Fig. 2 : Program Articulation Matrix and mapping strength

Table 2 : Expected Proficiency and expected attainment calculation

Grades	>=90%	85 - 89	80-85	70-80	**60-70**	50-60	45-50	<45%			No. of Students
	O	A+	A	B+	**B**	C	P	F	FE	I	
2015	0	11		31	38	34		7	0	0	121
2016	0	5	11	38	30	22	4	6	2	0	118
2017	1	2	7	22	34	35	7	16	3	0	127
No: of students obtained the grade	1	18	18	91	102	91	11	29	5	0	366
Average	0.33	6	6	30.33	34	30.33	3.67	9.67	1.67	0	122
Average %	0.27	4.92	4.92	24.86	27.87	24.86	3.01	7.93	1.37	0	
Cumulative percentage	0.27	5.19	10.11	34.97	**62.84**	87.7	90.71	98.64	100	100	

3. CO attainment calculation

In order to evaluate the CO attainment level of each course, the first target level of attainment was specified. The institutions had the freedom to choose the target level based on the previous experiences in the academic performance of students. Table 2 showed a sample of target setting procedure of different courses considering university results of three consecutive years. In this table the average percentage of no of students secured a particular grade as well as its cumulative average was calculated. From these values the expected proficiency as well as its corresponding base attainment level was computed. Expected Proficiency /Knowledge (EP) is defined as the average grade secured by at least 50% of the total number of students in the previous three

years and the corresponding percentage of students was chosen as the base attainment level. The expected attainment level was obtained from base attainment level by assuming 5% rise in academic performance of students in every successive year. For the presented course the expected proficiency was B grade and the base attainment level was 62.84%. The expected attainment (EA) for the course in the first year was $65.98\% (1.05 \times 62.84)$.

Next step in the attainment process was the fixing of attainment level. Normally attainment levels were set in a scale of 0 to 3, indicating not attained (0), low (1), medium (2) and high (3) level of attainment. Some examples of each attainment levels were; Attainment Level 1: 60% students scoring more than 60% percentage marks in the final examination.

Attainment Level 2: 70% students scoring more than 60% percentage marks in the final examination. Attainment Level 3: 80% students scoring more than 60% percentage marks in the final examination. Another example is Attainment Level 1: 60% students scoring more than 60% percentage marks in the final examination. Attainment Level 2: 65% students scoring more than 70% percentage marks in the final examination. Attainment Level 3: 75% students scoring more than 80% percentage marks in the final examination. The attainment levels were selected based on the previous academic performance of students in the institution. The attainment level target for FISAT was presented in the Table 3.

Table 3 : Levels of Attainment

Attainment levels	Target setting
Level 0	Not attained
Level 1 (Low)	50% students scoring more than **EP** out of the relevant maximum marks.
Level 2 (Medium)	60% students scoring more than **EP** out of the relevant maximum marks.
Level 3 (High)	70% students scoring more than **EP** out of the relevant maximum marks.

4. Course Evaluation Procedure

Course Outcomes were evaluated by direct and indirect assessment methods. Direct assessment tools evaluated student's knowledge and ability to apply their knowledge and skills in continuous assessments like mid semester examinations, assignments, class test, seminar/quiz, end semester examinations, project work, seminar, design project, viva-voce , laboratory course evaluation and viva-voce, etc. The direct assessment gave an outlook regarding familiarity of students with the basics of course offered, presentation skills and ethics and acquaintance with research activities. At FISAT the direct assessment was done by internal assessments out of 50 marks (40 for mid semester exams, 10 for assignments, class test/quiz/seminar etc) for theory courses. For laboratory courses, the regular assessment and viva voce was done for 70 marks and internal practical exam was done for 30 marks. All these internal assessment processes questions were mapped with relevant course outcomes satisfying Bloom's Taxonomy of cognitive level. For engineering programs higher order cognitive levels were measured through these various evaluation methods. The entire course outcomes should be addressed by at least one of the course evaluation methods. From various evaluation methods, course outcome wise

marks of each student was assessed and tabulated. Seminars, design project and main projects were evaluated in 50, 100 and 150 marks respectively. University had give guidelines for the rubrics for assessment for these courses.

For theory courses external assessment was done by end semester exams, which were evaluated out of 100marks. But course outcome wise split up marks were not available for end semester exams. Hence the attainment level was assessed from the percentage of students achieving the grade (expected proficiency). It was distributed evenly among all the course outcomes in a course. Indirect assessment was done by course exit survey. At the end of a particular course self evaluation of course outcomes was done by all students on a five point scale. The percentage of students achieving expected proficiency level was computed. This gave the attainment level by indirect method. The weightage of internal evaluation, end semester exam and course exit survey was 70%, 20% and 10% respectively for computing the course outcome attainment.

An example of course outcome attainment computation was presented in Table 4. The contribution of each course outcome as well as method of evaluation for a particular course was designed by the faculty in charge prior to the start of the course. The percentage of student achieved expected proficiency was counted. This value gave the attainment level. From the table it was seen that for the first course outcome C205.1, 52 % of students attained expected proficiency by internal assessment and the attainment level was 1, 91.2% students achieved expected proficiency for indirect assessment and attainment level was 3. For end semester exam 76% student attained expected proficiency and it was distributed among all course outcomes evenly. The overall CO attainment was calculated from the weighted average of each category of attainment method. For the course outcome, C205.1 the overall attainment = $(70 \times 52/100) + (10 \times 91.2/100) + (20 \times 76/100) = 60.8\%$. Similarly for all the courses, the overall CO attainment level was calculated.

5. PO & PSO attainment calculation

The PO and PSO attainment was computed by direct method and indirect method. In direct method the overall course outcome attainment value and course articulation matrix was used to calculate attainment calculation. For example from the overall CO attainment level and CO - PO mapping strength

Table 4 : Course outcome attainment calculation of a sample course

			C205.1	C205.2	C205.3	C205.4	C205.5	C205.6
Internal assessment		Course Outcomes	C205.1	C205.2	C205.3	C205.4	C205.5	C205.6
		Maximum CO marks	12	6	16	10	6	10
		Expected Proficiency (60%)	7.2	3.6	9.6	6	3.6	6
		No. of students Scored ≥ EP (N)	65	107	96	73	62	123
		Attainment (N/125)%	**52**	**86**	**77**	**59**	**50**	**99**
		Attainment Level	1	3	3	1	1	3
Indirect assessment		Course Outcomes	C205.1	C205.2	C205.3	C205.4	C205.5	C205.6
		Maximum CO marks	10	10	10	10	10	10
		Expected Proficiency	6	6	6	6	6	6
		No. of students Scored ≥ EP (N)	114	109	113	115	115	113
		Attainment (N/125)%	**91.2**	**87.2**	**90.4**	**92**	**92**	**90.4**
		Attainment Level	3	3	3	3	3	3
End Semester exam		No. of students Scored ≥ EP (N)	95					
		Attainment (N/125)%	**76**					
		Attainment Level	3					
Course Outcome Assessments		Course Outcomes	C205.1	C205.2	C205.3	C205.4	C205.5	C205.6
		Direct Assessment (%)	52	86	77	59	50	99
		Indirect Assessment (%)	91.2	87.2	90.4	92	92	90.4
		University Assessment (%)	76	76	76	76	76	76
		CO Attainment (%)	60.8	84.2	78.2	65.7	59.4	93.6
		Attainment Level	2	3	3	2	1	3
		Overall CO Attainment (%)	0.7365					
		Overall CO Attainment Level	3					
		Expected Attainment	0.6598					

presented in Table 5, PO1 attainment procedure was described for a sample course C205. The attainment of all program outcomes by direct assessment was obtained from the weighted average as $\sum Ai \, Pi / \sum Pi$, where, Ai is the attainment level of each course outcome and Pi is the degree of CO PO mapping strength. The direct attainment level of PO1of the sample course was 2.36 [$(2 \times 1 + 3 \times 2 + 3 \times 3 + 2 \times 2 + 1 \times 3 + 3 \times 3)/(1+2+3+2+3+3)$].

Table 5. CO Attainment level and CO PO mapping strength of a sample course CS205

Course Outcomes	C205.1	C205.2	C205.3	C205.4	C205.5	C205.6
Attainment level (A$_i$)	2	3	3	2	1	3
Mapping strength PO1 (P$_i$)	1	2	3	2	3	3

Similarly for all POs and PSOs, direct attainment level for each course was computed and tabulated. The average value gave the attainment of each PO by direct assessment method. Indirect assessment of POs & PSOs was evaluated by the following assessment tools; graduated exit survey (10%) and alumni feedback (10%). Graduate Exit Survey was carried out for all the students in the final semester at the end of the program to evaluate how far POs and PSOs were met with. Relevant questionnaire was prepared and rated on a 5 point scale for the exit survey. The number of responses satisfying the expected proficiency was calculated. Alumni feedback was also collected on a 3 point scale survey. The attainments was evaluated as weighted sum of scale value, attainment level $= \sum Ni \, Si / \sum Ni$ where Ni is the no of responses for a particular scale value Si. The overall attainment for each PO/PSO was determined by adding the respective attainment from direct and

indirect attainment in the ratio 80%:20 %. Overall attainment PO & PSO was shown in Figure 3. Attainment of PO & PSO was then compared with the target attainment level of each PO & PSO. The target attainment level was decided by course attainment committee in consultation with program attainment committee based on the previous academic performance of the students.
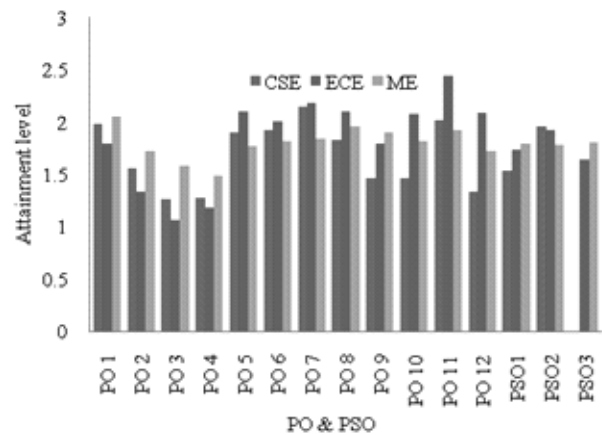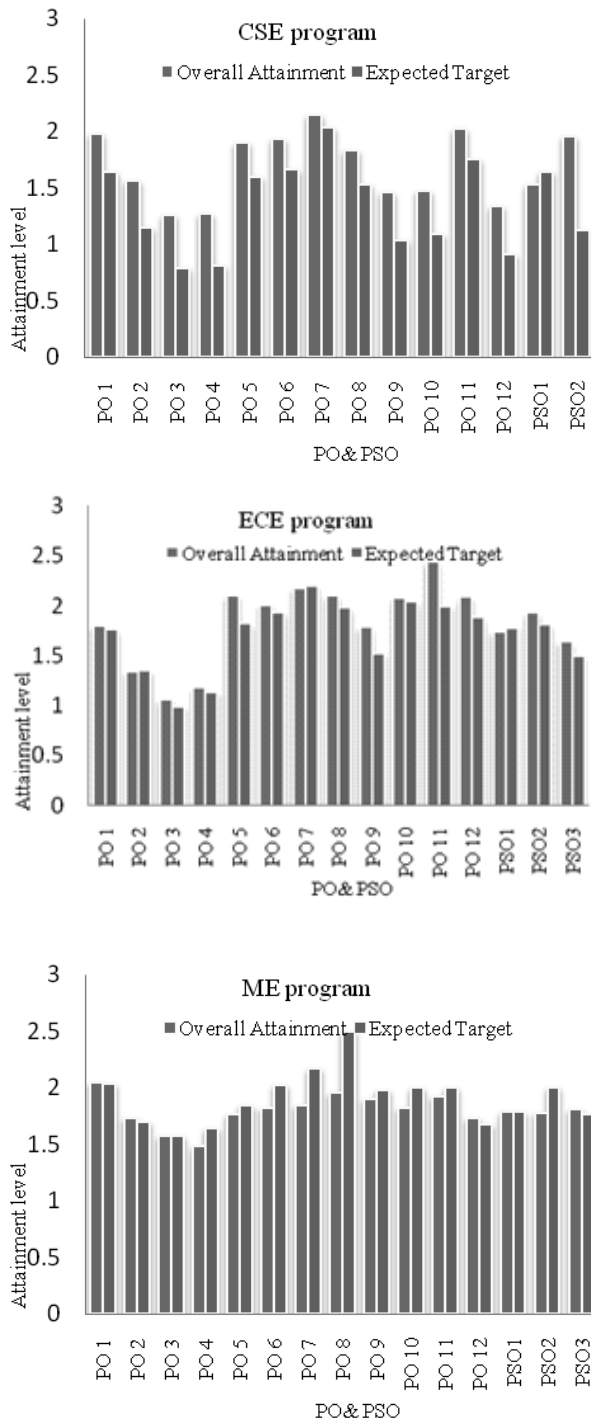

Fig. 3 : PO & PSO Attainment level

The attainment level was medium for all the programs. Even though the numbers of courses mapped with professional competencies were less, the attainment level disguised this fact. The accomplishment of attainment level was compared with the target values given for each PO & PSO. For the CSE program and ECE program the target level was crossed for all PO & PSO. But for ME program, majority of the professional competencies the outcome attainment didn't cross the target attainment. From the program articulation matrix it was clear that only few courses in the programs were mapped to professional competency program outcomes. So reaching the target values with minimum courses was difficult. Also, the quality of students admitting to ME program was lower than that admitted for CSE program as well as ECE program. This fact had also added to the non attainment of PO & PSO. To generalize the observations more studies were required in this area.

6. Conclusions

In the paper the importance of outcome based education was highlighted. The procedure for the evaluation of PO & PSO attainment was discussed based on NBA accreditation guidelines for three programs at FISAT engineering college. The program articulation matrices all the programs showed that a few courses were mapped to professional outcomes of NBA graduate attributes irrespective of the programs in the institution. Attainment of professional competencies with these limited courses in the program was strenuous task. All the programs exhibited medium correlation with PO & PSO statements. Hence it is very essential to think about new strategies to build up professionally competent and technically sound graduates to conquer the fast growing world.

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