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A preliminary study on Attainment of course outcomes for outcome based education in mechanical engineering using a case study of material science and metallurgy

Dr. Drakshayani D N
Professor, Department of Mechanical Engineering, Sir.M.VIT, Bengalure, India.,

Abstract: *In the Outcome-Based Education (OBE) the assessment of the course outcomes is the most prominent aspect required to the improve the quality of education. The Course Outcomes (COs) for each course are based on the Program Outcomes (POs), Program Specific Outcomes (PSOs) and other requirements. COs are the attributes, that the student is expected to have obtained at the time of completing the course. A method to evaluate the attainment of the COs is given. The paper describes the Attainment of CO for Material science and Metallurgy and its analysis, which is offered to 3rd Semester students of Mechanical Engineering Department. The method utilises both direct and indirect assessments. The results can be utilised for improving the teaching learning process which is an important component of OBE.*

Keywords: *Course Outcome, Outcome Based Education, Program Outcome, Program Specific Outcome*

I. Introduction

Education plays a vital role in the development of any nation. Therefore, there is premium on both quantity and quality (relevance and excellence of academic programmes offered) of higher education. Like in any other domain, the method to improve quality remains the same that is, finding and recognising new needs and satisfying them with products and services of international standards. There are two central bodies involved in accreditation in India: the National Accreditation and Assessment Council (NAAC) and the National Board of Accreditation (NBA)[1]. The NBA was originally constituted in September 1994 to assess the qualitative competence of the educational institutions from the diploma to the postgraduate level in the fields of engineering and technology, management, pharmacy, architecture, and related disciplines. The implementation of Outcome Based Education has been among the main focus of academic institutions in India.

Accreditation is a process of quality assurance and improvement, whereby a programme in an institution is critically appraised to verify that the institution or the programme continues to meet and exceed the norms and standards prescribed by the appropriate designated authorities. NBA accreditation is a quality assurance scheme for higher technical education.

The significance and role of Accreditation

- To stimulate the academic environment and quality of teaching and research in these institutions and contribute to the sphere of knowledge in its discipline,
- To motivate colleges and/or institutions of technical and professional education for research, and adopt teaching practices that groom their students for the innovation and development of leadership qualities,
- To encourage innovation, self-evaluation and accountability in higher education.
- To promote necessary changes, innovation and reforms in all aspects of technical and professional education and help institutions to realise their academic objectives.
- To provide graduates with quality education which lead to a wide range of job opportunities globally and entrepreneurship abilities.

Course Outcomes (COs) -- Course Outcomes are statements that describe what students are expected to know, and be able to do at the completion of the course [2,3]. They relate to the skills, knowledge, and behaviour that students acquire on completion of the course. The course outcomes of all the courses in a four year engineering course are mapped to Program outcomes to obtain the graduate attributes of NBA. The course outcomes for material science and metallurgy offered in third semester of mechanical engineering are given in Table 1.

Table 1: Course Outcomes of material science and metallurgy with subject code ME32A

COs	Course outcomes
CO32A.1	To understand the basic concepts of crystal structure, concepts of diffusion and solidification.
CO32A.2	An ability to apply knowledge of mathematics, science and engineering to solve problems.
CO32A.3	To analyze and solve problems on mechanical behaviour of materials and understand the properties of ferrous and nonferrous alloys and composites.

CO32A.4	To construct phase diagrams and analyze different heat treatment processes of ferrous alloys and nonferrous alloys.
CO32A.5	To understand the various processes for manufacturing of composites and obtain a knowledge of contemporary issues and an ability to use the skills and techniques in engineering practice
CO32A.6	An ability to use the techniques, skills and modern engineering tools necessary for engineering practice and lifelong learning.

Program Outcome's (PO's)

According to NBA [1] there are 12 program outcomes which are the graduate attributes and are listed below.

1. Engineering Knowledge: Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems.
2. Problem Analysis: Identify, formulate, research literature and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.
3. Design/ Development of Solutions: Design solutions for complex engineering problems and design system components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal and environmental considerations.
4. Conduct investigations of complex problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data and synthesis of information to provide valid conclusions.
5. Modern Tool Usage: Create, select and apply appropriate techniques, resources and modern engineering and IT tools including prediction and modelling to complex engineering activities with an under- standing of the limitations.
6. The Engineer and Society: Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice.
7. Environment and Sustainability: Understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development.
8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.
9. Individual and Team Work: Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.
10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations and give and receive clear instructions.
11. Project Management and Finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to owners own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. Life-long Learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Mapping of COs to POs

The mapping of COs to POs is given in Table 2 and COs to PSOs in Table 3.

Table 2. Mapping of COs to POs

COs	**POs**											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO32A.1	3	2	3	2								3
CO32A. 2	3	2		3	2							3
CO32A. 3	3	2	3	2	1							3
CO32A.4	3	3	3	2								3
CO32A.5	3	2	3		3							3
CO32A.6	3				3							3
CO32A	**3**	**2.2**	**3**	**2.25**	**2.25**							**3**

Programme Specific Outcomes of the Mechanical Engineering Programme

The Programme Specific Outcomes (PSOs) of the Mechanical Engineering Programme of our institution is given below.

1. An understanding of fundamentals, analysis and design procedures, material aspects, manufacturing methods, management of resources of various kinds, and application of various modern tools / techniques to develop products/components related to mechanical engineering and allied fields.

2. An ability to solve engineering problems and work in industry, R&D organizations and institutions of higher learning in mechanical engineering and related areas.

Mapping of COs to PSOs

Table 3. Mapping of COs to PSOs

COs	**PSOs**	
	PSO1	PSO2
CO32A. 1	3	2
CO32A. 2	3	2
CO32A. 3	3	2
CO32A. 4	3	3
CO32A. 5	3	3
CO32A. 6	3	2
CO32A	**3**	**2.33**

Attainment of course outcomes

Course outcomes are statements that describe significant and essential learning that students have achieved, and can reliably demonstrate at the end of a course. In other words, course outcomes identify what the student will know and be able to do by the end of a course. Course outcomes should be stated in clear, specific, and measurable terms, describe what the student can accomplish as a result of completing a course. The main focus is on what the student will be able to do as a result of taking the course and describe what the learner can draw from the knowledge, skills, and experiences acquired in a course. In addition, they should be aligned with the program outcomes and represent the minimum requirements to complete a course. This assessment can be done directly or indirectly [1,2,3,4].

According to Palomba and Banta [5] assessment involves the systematic collection, review, and use of evidence or information related to student learning. Assessment helps faculty to know how well their students understand the various topics present in the course. Assessment exercises are often anonymous. This anonymity allows students to respond freely, rather than trying to get the "right" answer or look good. It can be either online or offline. Assessment helps to gauge students' understanding and knowledge in order to see what areas need to be addressed more effectively to increase the students' learning. In other words, assessment is the process of determining what students are learning during the course and also know how well they are learning with respect to the stated expectations for the course. It provides a feedback to the faculty and helps in improving the teaching –learning process. This process also involves providing feedback to the students about their learning and providing new learning opportunities/strategies to increase their learning.

Direct and Indirect Assessment of Student Learning

It is important to understand the distinction between direct and indirect evidence of student learning. Direct evidence of student learning is tangible, visible, and measureable and tends to be more compelling evidence of exactly what students have and have not learned. This is because you can directly look at students' work or performances to determine what they have learned.

Indirect evidence tends to be composed of proxy signs that students are probably learning. An example of indirect evidence is a survey asking students to self-report what they have learned. This is evidence that students probably are learning what they report to have learned, but is not as compelling as a faculty member actually looking at students' work. It is not uncommon in students' self-reports to either inflate or undervalue what they have actually learned.

Direct assessments (measures) are most familiar to faculty. Direct assessments provide for the direct examination or observation of student knowledge or skills against measurable outcomes. The Faculty conducts direct assessments of student learning throughout a course using such techniques as tests, exams, quizzes, demonstrations, and reports. These techniques provide a sampling of what students know and/or can do and provide strong evidence of student learning. However, not all learning can be measured in a direct way. For example, a desired outcome of a course may be to create more positive student attitudes toward mathematics (or writing, or team work), which are difficult to assess using direct methods. Indirect assessments of student learning assert the perceived extent or value of learning experiences. They assess opinions or thoughts about student knowledge or skills. Indirect measures can provide information about student perception of their learning and how this learning is valued by different constituencies.

The Table 4 below illustrates the direct and indirect assessments considered for a course.

Table 4. Direct and Indirect assessments

Assessment Method	Direct	Indirect
Tests	yes	-
University Exam	Yes	-
Course exit survey	-	yes

Rubrics

A rubric is a scoring tool that explicitly represents the performance expectations for an assignment or piece of work. A rubric divides the assigned work into component parts and provides clear descriptions of the characteristics of the work associated with each component, at varying levels of mastery. Rubrics can be used for a wide array of assignments: papers, projects, oral presentations, artistic performances, group projects, Tests, Exams, etc. Rubrics can be used as scoring or grading guides, to provide formative feedback to support and guide ongoing learning efforts, or both [6].

Advantages of Using Rubrics

Using a rubric provides several advantages to both instructors and students. Grading according to an explicit and descriptive set of criteria that is designed to reflect the weighted importance of the objectives of the assignment helps ensure that the instructor's grading standards don't change over time. Rubrics are invaluable in large courses that have multiple graders (other instructors, teaching assistants, etc.) because they can help ensure consistency across graders and reduce the systematic bias that can be introduced between graders.

Grading rubrics are also valuable to students. A rubric can help faculty communicate to students the specific requirements and acceptable performance standards of an assignment. When rubrics are given to students with description, they can help students monitor and assess their progress as they work toward clearly indicated goals. When assignments are scored and returned with the rubric, students can more easily recognize the strengths and weaknesses of their work and direct their efforts accordingly (Table 5)

Table 5. Grading Rubric for Tests and Exams

Achievement Level (AL-points)	Grading Performance	Based on Marks Obtained	
		Tests(25)	University Exam(100)
High (3)	The student's performance is outstanding in all course outcomes	20-25	70-100
Medium(2)	The student's performance is satisfactory. It largely meets the expected course outcomes.	17-19	51-69
Low(1)	The student's performance is not good. It marginally meets the intended course outcomes.	15-16	41-50
Below(0)	The student's performance is inadequate. It fails to meet many of the intended course learning outcomes.	<15	<=40

Advantages to Students

- The clear expectations that good assessment requires help them understand where they should focus their time and energy.
- Assessment, especially the grading/scoring process, motivates them to do their best.
- Assessment feedback helps them understand their strengths and weaknesses.
- Assessment information documents what they've learned; this documentation is beneficial in applying for jobs, awards and programs of advanced study.

Advantages to Faculty

- Assessment activities bring faculty together to discuss important issues such as what they teach and why as well as their standards and expectations for student learning.
- Assessment activities help faculty see how their courses link together to form a coherent program and how the courses they teach contribute to student success in their subsequent pursuits.
- Assessment creates a common language that engages faculty spanning a variety of specializations and disciplines.

Advantages to Administrators

- Assessment information documenting the success of a program or institution can be used to convince employers, donors, legislators, and other constituents of its quality and worth. This also benefits both faculty and students.
- Assessment can help ensure that institutional resources are being spent in the most effective ways possible - where they'll have the greatest impact on student learning.

Direct attainment

To measure the attainment of Course Outcomes, it is pertinent to decide the threshold value or target value of the marks which will indicate the COs have been achieved. Hence in the present study it is assumed 50% of marks as minimum marks for successful completion of the course for university examination and similarly for internal test it is 15 marks (60%) out of 25. The marks obtained by the students are given in Table

6. If the set targets are attained then all the course outcomes have been achieved for the course and the level of attainment obtained is calculated.

Table 6. Test and university marks obtained in Material science and metallurgy.

Sl.No.	Students Name	Exam Marks	TEST Marks	Sl.No.	Students Name	Exam Marks	TEST Marks
1	ABHIJEET SINGH	66	22	22	ASHWIN. S. T.	57	25
2	ABHINANDAN PRABHU. D	50	15	23	BALAMURUGAN. R	61	15
3	ABHIRATH ANAND	73	24	24	BHARGAV VIJAY KUMAR	50	19
4	ABHISHEK NAIK. K	55	20	25	B. P. DHYAN DEVAIAH	62	19
5	ACHARYA SRINIDHI SRINIVASA	71	22	26	CHAITANYA RAMA PUJAR	74	20
6	ADITYA KATARIA	71	19	27	CHANDRAPRAKASH SHANKAR KAKADE	57	16
7	ADITYA KUMAR	54	19	28	CHETHAN. H. G	62	17
8	AKARSH. R	55	15	29	DEEPAK KUMAR JHA	61	15
9	AKASH. V. VARIER	53	19	30	DEVYANSHU RAJ	75	21
10	AMAN KUMAR	70	20	31	DHANANJAY MAHERE	41	15
11	AMAN KUMAR ISHU	63	19	32	GAURAV KUMAR	59	22
12	AMIT TAVVA	64	18	33	HARSHA WALVEKAR	65	21
13	AMOGHVARSH. A. KULKARNI	63	18	34	HARSHITH. P. RAJU	50	18
14	ANAND BARDHAN	61	20	35	ASIF HUJARE	58	16
15	ANIKET RAJ	46	17	36	ARUN BASAVARAJ BILEYALI	62	16
16	ANUPNATH SHETTY	56	23	37	MANU N.	68	21
17	ARAVIND. N. V	54	22	38	GIRISHA L	45	15
18	ARBAN BAIG	49	22	39	NITHIN KUMAR	43	15
19	ARTHIK ALEXANDER	40	21	40	SACHIN	40	16
20	ARUN BABURAJ. C	63	21	41	JAGADESH	45	17
21	ASHWIN. S. N.	46	15				

The performance of students based on grading rubric for tests and university examination is given in Table 7 and Figure 1 and 2.

Table 7. The Performance of students in percentage based on grading rubric.

Sl.No.	Test Marks				University Examination Marks			
		No.	%	AL		No.	%	AL
1.	No. Of students<15	0	0	0	No. Of students<= 40	2	4.9	0
2.	No. Of students 15to16	12	29.3	1	No. Of students between 41 to 50	10	24.4	1
3.	No. Of students 17 to 19	12	29.3	2	No. Of students between 51 to 69	23	56.1	2
4.	No. Of students 20-25	17	41.4	3	No. Of students between > =70	6	14.6	3

Figure 1. Plot of number of students with respect to test marks

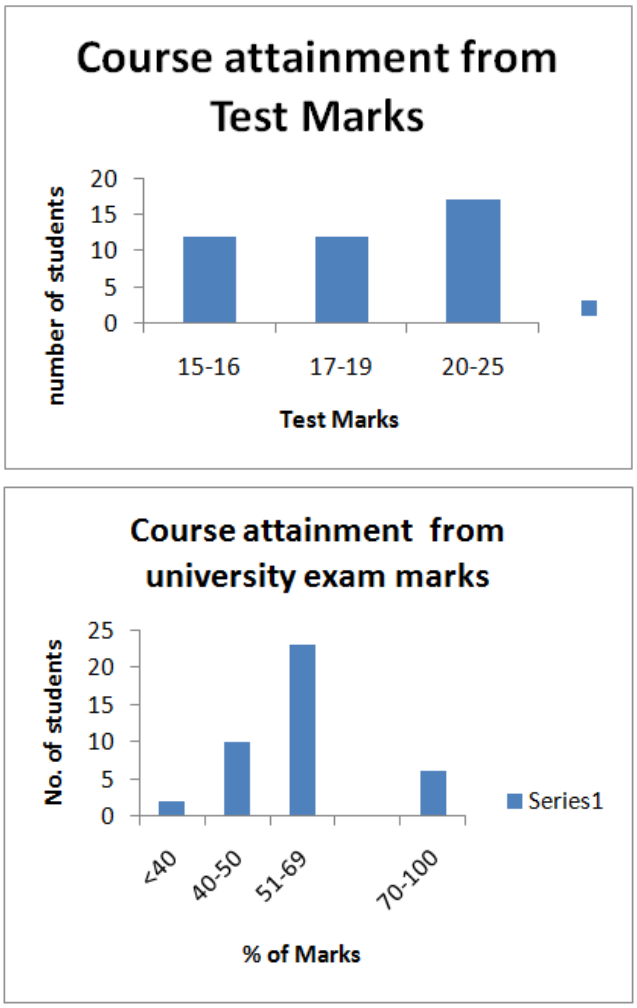


Figure 2. The plot of number of students with respect to university marks

The course attainment level obtained from tests using Table 3 and 5 is sum of the product of % of students and AL. That is 0%*0 + (29.3%)*1+(29.3%)*2+(41.4%)*3.
The normalized equation to obtain the attainment level is 0+(.293*1)+(.293*2)+(.414*3)= 2.121
Similarly the course attainment level obtained from university exam is 0+(.244*1)+(.561*2)+(.146*3)= 1.804
The final course attainment from tests and university examination by giving equal weightage to tests and university examination is 1.963.

According to NBA manual June 2015 [1] format if one considers the target level of marks to be obtained and the percentage of students who score the set level, then the following attainment level is obtained. For tests the target set is 80% of the students should have scored above 60% marks (greater or equal to 15). From Table 5 it is seen that 100% of the students have achieved the set target. Therefore from tests the course attainment level is 3. Similarly for university examination the target set is 70% of the students should have scored above 50% marks. From Table 7 it is seen that 71% of the students have achieved the set target. Therefore from university examination, the course attainment level is 2. Hence the final course attainment level obtained using target levels set is 2.5 (average of 3&2)

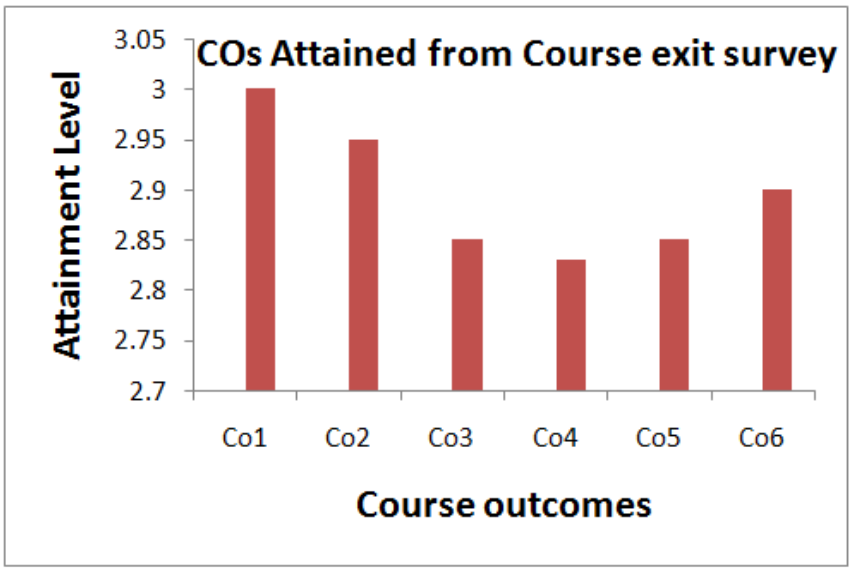
Indirect Attainment: Indirect attainment of COs can be determined from the course exit surveys. The course exit survey is given in Table 8 and Figure 3. The students were asked to rate learning outcomes as high(3), medium(2) and low (1). The attainment level for the six course outcomes from the exit survey is given in Figure 3. The average attainment level of course outcomes is 2.898.

Table 8. Couse exit survey for Material Science and Metallurgy

Sl.No.	Students Name	CO1	CO2	CO3	CO4	CO5	CO6
1	ABHIJEET SINGH	3	3	3	3	3	3
2	ABHINANDAN PRABHU. D	3	3	3	3	3	3

3	ABHIRATH ANAND	3	3	2	3	3	3
4	ABHISHEK NAIK. K	3	3	3	3	3	3
5	ACHARYA SRINIDHI SRINIVASA	3	3	3	3	3	3
6	ADITYA KATARIA	3	3	3	3	3	3
7	ADITYA KUMAR	3	3	3	3	3	3
8	AKARSH. R	3	3	3	3	3	3
9	AKASH. V. VARIER	3	3	3	3	3	3
10	AMAN KUMAR	3	3	3	2	3	3
11	AMAN KUMAR ISHU	3	3	2	3	3	3
12	AMIT TAVVA	3	2	3	3	3	2
13	AMOGHVARSH. A. KULKARNI	3	3	3	2	3	3
14	ANAND BARDHAN	3	3	3	3	3	3
15	ANIKET RAJ	3	3	3	3	3	3
16	ANUPNATH SHETTY	3	3	2	3	3	3
17	ARAVIND. N. V	3	3	3	3	3	3
18	ARBAN BAIG	3	3	3	3	3	3
19	ARTHIK ALEXANDER	3	3	3	3	2	3
20	ARUN BABURAJ. C	3	3	2	3	2	3
21	ASHWIN. S. N.	3	3	3	2	3	2
22	ASHWIN. S. T.	3	3	3	3	3	3
23	BALAMURUGAN. R	3	3	3	3	3	3
24	BHARGAV VIJAY KUMAR	3	3	2	3	2	3
25	B. P. DHYAN DEVAIAH	3	3	3	3	3	3
26	CHAITANYA RAMA PUJAR	3	3	3	3	3	3
27	CHANDRAPRAKASH SHANKAR KAKADE	3	3	3	3	3	3
28	CHETHAN. H. G	3	3	3	3	3	3
29	DEEPAK KUMAR JHA	3	3	3	3	3	3
30	DEVYANSHU RAJ	3	3	3	3	3	3
31	DHANANJAY MAHERE	3	3	3	3	3	3
32	GAURAV KUMAR	3	3	3	3	3	3
33	HARSHA WALVEKAR	3	2	2	2	3	2
34	HARSHITH. P. RAJU	3	3	3	3	3	3
35	ASIF HUJARE	3	3	3	2	3	3
36	ARUN BASAVARAJ BILEYALI	3	3	3	3	2	3
37	MANU N.	3	3	3	3	3	3
38	GIRISHA L	3	3	3	3	2	2
39	NITHIN KUMAR	3	3	3	2	2	3
40	SACHIN	3	3	3	2	3	3
41	JAGADESH	3	3	3	3	3	3
	Average	**3**	**2.95**	**2.85**	**2.83**	**2.85**	**2.9**
		2.898					

Figure 3 Attainment of Cos from course exit survey



II. Conclusions

The overall course attainment has been obtained by considering the direct and indirect assessments. The direct assessment is done using two simple methods which gives achievement of course outcomes from direct measurements.

Assessment of course outcomes involves the systematic collection of data and use of information about student learning for the purpose of improvement. The above paper explains a method of measuring the Course Outcomes by using Rubrics and also based on percentage of students scoring a set target of marks in tests and university examination based on guide lines given by NBA. Attainment Gap and action proposed to bridge the gap can be discussed by the course coordinator, module coordinator and program assessment committee. From this result, the attainment of course outcome for the course can be further reviewed and analysed. Action plan to improve any weakness can be identified and implemented for the next batch of students.

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