

Outcome Based Approach Applied to a Mechanical Engineering Course to Advance the Teaching-Learning Processes*

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Increasing significance of OBE has made the faculty of engineering programs to move towards preparing course outcomes. Also, they are expected to see how they are attained at the end of the course. Only few works have attempted the aspect of outcomes of a course and its use in the improvement of the program. In this work, an undergraduate course like 'Applied Thermodynamics' related to Mechanical Engineering program is considered, which is similar to any other course taught across India or elsewhere. Suitable action verbs are recommended, based on the topics associated with different modules of the course. These are then compared with the reference bloom's taxonomy table to ascertain their suitability according to the abilities acquainted. Using the appropriate assessment methods, the coverage of COs is presented in a comprehensive way. It is identified that action verbs like understand, estimate, know, analyze and discover are appropriate as per the syllabus. Later, these verbs are compared with the reference taxonomy table, while determining the type of knowledge gained. It is observed that cognitive levels like understand, apply and analyze are covered by the course. The correctness and coverage of respective course outcomes in the assessment processes adapted are also deliberated. Again, CO attainment is calculated, which is based on both internal and external examinations. Results show that the average grade mark for the last two years is same. Also, the CO attainment for the latest year is good. Thus, the present work provides the teaching community, a best way to adapt the OBE approach appropriately, in order to ensure that the overall outcomes of the program are achieved through the course outcomes.

Keywords: outcome based approach; course outcomes; applied thermodynamics; CO attainment

1. Introduction

Engineering institutes across India are facing problems in getting proper admissions, both in terms of quantity and quality. Same is applicable to any program like Mechanical Engineering. In this scenario, getting the approval from authorities like All India Council for Technical Education (AICTE) or University Grants Commission (UGC) of India for running the program itself is not sufficient to attract top rank holders to join their institute or program. It is required for them to adapt Outcome Based Education (OBE) approach and move towards National Board of Accreditation (NBA) or National Institute Ranking Framework (NIRF) as the next step to have long life of the institute or the program concerned. Faculty and students are the main stake holders of any engineering program as far as the teaching-learning processes are considered. In such a scenario, the Faculty must understand this aspect and make the students understand better by implementing appropriate OBE approach. Then only, there is a chance of providing the best teaching-learning processes. Of late, the class-room instruction has been more teachers oriented with the main objective being delivery of lectures as per the timetable and more towards completing the syllabus. Increasing demand for

quality input and output, in view of growing number of institutes, the managements of the institutes are making the faculty understand the aspects of OBE and how to implement it. This approach is outcome oriented, dealing with what exactly the students gain at the end of a lecture or a course or a program. In this context, the faculty are in the process of understanding the abilities expected at the end of the specific period, which would refine their way of teaching.

In order to make this happen, there should be proper lecture plan, instructional materials and assessment procedures, to be followed by the faculty. Lecture plan gives clear idea about what will be taught in the class and what will be the expected outcomes. Preparation of lecture plan or lesson plan is linked to the preparation of intended learning outcomes for each lecture and all such lectures cumulatively lead to the accomplishment of the course in any semester. This would in turn lead to the attainment of definite Course Outcomes (COs). Outcomes are nothing but the abilities expected from the students or learner at the end of the course or a program. The outcomes of any given program are achieved through the coverage of all the COs of the courses as per the curriculum designed. As per the norms of the regulating authority in India, the maximum number of COs

can be 6 and elsewhere also the number will be alike. Earlier, Bloom [1] has recommended the categorization of educational goals. The mentioned objectives provided a better way of writing the outcomes based on the plan made for class room teaching. Later, the set was reviewed slightly as per the changing scenario of teaching-learning process [2]. In the improved one, the significance of measurability was deliberated and re-framing was done accordingly. Appropriate action verbs can be chosen as per the syllabus and like that any undergraduate program in mechanical engineering may have 45-55 courses, spread in four years or eight semesters of the study. Faculty are expected to prepare the COs for the courses, irrespective of the levels of taxonomy. The levels required are chosen by the curriculum designing authorities, according to the type of program. Similarly, the outcomes expected at the end of such type of programs are framed by the respective boards or governing bodies for maintaining uniformity of the relevant programs in the territory under consideration.

Preparation of COs and the calculation of CO attainment and to see how they improve over the years has been the primary task of the faculty of engineering disciplines. Some of the earlier works dealt the aspect of preparation of ILOs, PEOs and COs. Spady [3] was the first person to discuss about various aspects of outcomes and their relationship with each other. He showcased the hierarchy of how outcomes of the lesson will directly or indirectly fulfil PEOs. Clutter and Arroyo [4] described a set of assessment tools and also elaborated on course objectives and program educational objectives. Shay et al. [5] discussed the approaches to enhance the proficiency of the effective outcomes and assessment processes. Analysis was done for two programs like electrical and computer science programs on the basis of certain indicators and suggested approaches to monitor graduate abilities effectively. Akir et al. [6] compared the aspect of teaching-learning with and without OBE aspect. The students' academic performance was good with regard to OBE approach, when compared to the conventional teaching-learning. Tshai et al. [7] discussed about the assessment of PEOs for an undergraduate engineering program. They used surveys and questionnaire to identify the levels of output achieved by the students. Some of the PEOs were achieved, while some could not be accomplished. The assessment of learning outcomes was discussed by Lile and Bran [8]. Their estimations were very general and not specific to any course or program. Turhan et al. [9] studied about the procedure followed by computer engineering based programs, leading to five years of accreditation. Their

aim was to share the information, which would be useful for the programs that aim accreditation in future. Panter and Williford [10] gave introduction to student learning outcomes assessment, which was implemented for the programs offered in the university. Later, a little was discussed by Bethany et al. [11] about how undergraduate science students use learning objectives in their studies. This aspect is not of that significance in OBE arrangement. Harris and Clayton [12] emphasized on learning outcomes. But, they had not done any case study or conducted investigation on OBE and its application. Thus, earlier works gave only few hints of how OBE can be applied to any course or program. In this context, the present work deals with the outcome based approach applied to a mechanical engineering course in order to advance the teaching-learning processes. The achievement of outcomes is discussed with regard to a course like 'Applied Thermodynamics', offered in an engineering program of UG level. This work deals with the relevance of action verbs chosen, methods of assessment and overall CO attainment, which is not attempted earlier. This work helps the teaching community in implementing the outcome based approach to other engineering and science programs as well.

2. Methodology

In this work, a fourth semester UG Engineering course like 'Applied Thermodynamics' is considered for the analysis. Fig. 1 shows the flow chart of the methodology used in the present work. Initially, effort is made to understand the concepts taught and accordingly action verbs are chosen. The syllabus of the course is spread in five modules and is taken from the model curriculum, which is common to all the mechanical related bachelor engineering programs across India. Then, based on the contents of each module, suitable action verbs are selected. The identified action verbs are then matched with the learning abilities of students, according to the Bloom's taxonomy table. Further, the process of CO assessment is discussed with appropriate weightage given to the internal and external examinations. The actual marks obtained by the students are considered in this work and the present analysis is not based on any assumptions or approximations. Analysis is performed, considering the marks attained by all the students of the program under consideration. Also, COs obtained for the last four years are calculated and compared. It refers to a real time analysis, applying simple methodology, which is useful for any such engineering or science courses. Approach and the implementation aspect discussed surely play crucial role in enhancing the teaching-

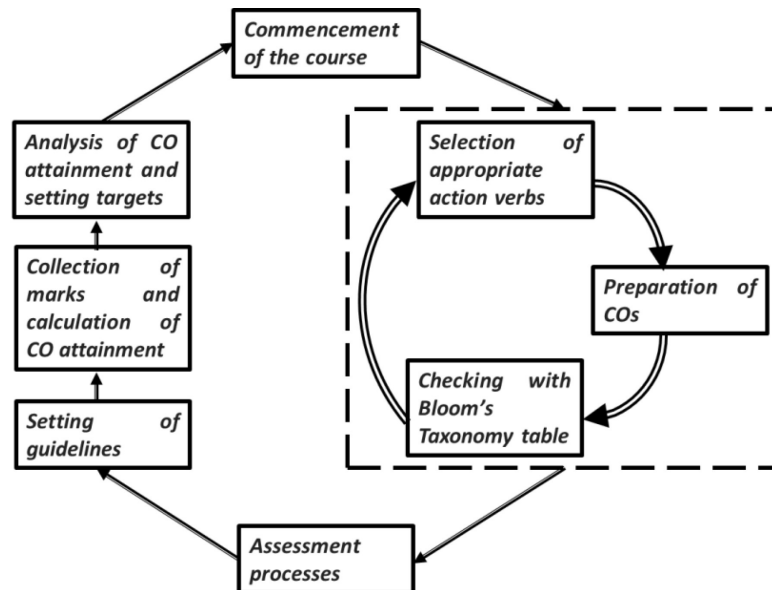


Fig. 1. Methodology adapted in the present work.

learning process as the abilities aspect is clear to both teachers and students.

3. Results and Discussion

In this section, selection of action verbs for the course identified are discussed initially. The verbs are carefully chosen and accordingly courses outcomes are prepared. COs are tabulated along with the syllabus for clarity. Then, comparison of the action verbs with the reference bloom's taxonomy table is done and their relevance is deliberated. Knowledge gained in each module is also analyzed. Later, the processes of CO accomplishment are exemplified. Guidelines framed in order identify the level attained are provided in tables. Calculation of COs for the present semester is presented with the appropriate weightages given for the examinations at university/board level and program level. The process of final CO attainment is presented with all the requisite calculations. In the end, plots are made to compare the achievement of COs for the select course all the four years, i.e. three years apart from the present year.

3.1 Module-Wise Syllabus and Framing of COs and their Relevance

The course chosen has five different modules. In the first module, the fundamental aspects of internal combustion engines are covered. It deliberates the concepts like basics and parts of engines. All these things are about gaining conceptual knowledge related to basics of engineering. Hence 'Understand' is the action verb chosen. The second module deals with CI engines, where the procedural

knowledge is important. Suitable problems based on that make the students estimate the performance of compression ignition engines. Students gain the knowledge by applying the principles of working and related formulae to identify the performance characteristics of the engine. So, 'Estimate' is the suitable verb chosen for this module. Third module covers the principles of compressors and their classification. It is more towards the types of compressors and hence the word 'Classify' is apt for this module. The process of working and analyzing different types of compressors is related to the achievement of conceptual knowledge. Fourth module deals with refrigeration systems. In this, conceptual knowledge is gained by describing the fundamental principles and different methods of refrigeration. Correct action verb suitable in this case is 'Describe'. Fifth module covers the aspect of air conditioning. It is about the concepts of conditioning of air and gaining fundamental knowledge about different systems and their working. This is related to understanding and gaining conceptual knowledge. Accordingly, the action verb is chosen as 'Discuss'. The complete list of course outcomes and details of different modules are shown in Table 1. Based on the CO, appropriate pedagogy approach can be used for further enhancement of the teaching-learning process.

3.2 Comparison with Bloom's Taxonomy Table and Coverage of COs

Bloom [1] formed the grouping of measurable verbs to assist the faculty to outline and classify the abilities that can be obtained. These levels are established on the deeds relating to the intellectual

Table 1. Course Outcomes

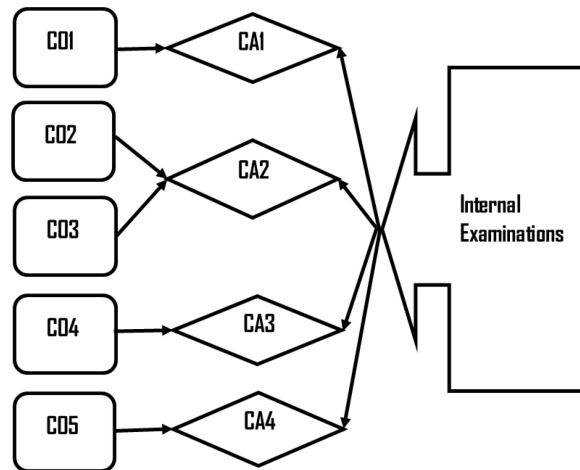
Modules	On successful completion of the course, the students will be able to:
Module 1: Internal Combustion Engines	CO1: Understand the fundamentals of internal combustion engines.
Module 2: CI Engines	CO2: Estimate the performance of CI and SI engines.
Module 3: Compressors	CO3: Classify compressors.
Module 4: Refrigeration system	CO4: Describe the fundamental principles and different methods of refrigeration.
Module 5: Air Conditioning	CO5: Discuss the basics and working of air conditioning systems.

Table 2. Comparison of the selected verbs

Modules	Knowledge aspect	Appropriate ability from Bloom's Taxonomy table	Selected verb
Module 1	Conceptual knowledge	Understand	Understand
Module 2	Procedural knowledge	Apply	Estimate
Module 3	Procedural knowledge	Analyze	Classify
Module 4	Conceptual knowledge	Understand	Describe
Module 5	Conceptual knowledge	Understand	Discuss

activity. Purely, these are the various levels of gaining knowledge, exhibited by students, when a faculty teaches something in the class. The levels are ranging from remember to create something novel, relating to the branch of engineering considered here. Comparison of the selected action verbs for 'Applied Thermodynamics' course is done with that of taxonomy table as shown in Table 2. Learning levels covered in this course are understanding, applying and analyzing, as per the Bloom's taxonomy table. Table 2 shows the exact mapping of the levels and action verbs chosen and their similarity. Knowledge domains like conceptual and procedural aspects are taken care in modules 1 to 5 of the course.

For the teaching-learning processes to be at their level best, outcomes aspect is dealt, not only in class room, but also, in assessment. If the assessment is continuous, it will be still better. Hence, few universities and boards in India are adapting to continuous assessment tests rather than just one or two class tests. The way of conducting the internal examinations may vary from institute to institute or university to university. But they will be similar. For the present course, CO1 is taken care in CA1, i.e. Continuous Assessment 1. Questions asked will rely on testing student's abilities with regard to the first outcome, i.e. CO1. CO2 and CO3 are taken care in CA2 as shown in Fig. 2. It can be an

**Fig. 2.** Coverage of COs in the internal examinations.

assignment based on the topics related to the modules 2 and 3. It can be a take home assignment or a presentation based on the ability gained in classifying compressors and estimating the performance of CI engines. Similarly, the last two internal examinations CA3 and CA4 would cover CO4 and CO5 respectively. Once the skeleton is formed for the course, it can be used for the future semesters as well with few modifications, however, subjected to the condition that the syllabus is same. If the curriculum is being changed, the pattern of outcomes may slightly change as per the course intended. Questions asked in these examinations may be of equal weightage with regard to COs or as per the number of lectures as per the curriculum. In the course under consideration, equal weightage could be possible, because of the equal distribution of the syllabus. Whatever may be the course, it should be made sure that all COs are covered in the in-house assessments, while setting the questions and by these means, the related capabilities from the students of the course are achieved. Same way, it is expected that the question papers of the external examination take care of all the COs. Accordingly, instructions are given to the question paper setters. Both these assessments are direct and are powerful in gauging the student's abilities.

3.3 Assessment Processes Adapted

Continuous assessment of the course involves class work, internal and external examinations as shown in Fig. 3. Before the commencement of the classes, targets are set in the faculty meeting held, just prior to the starting of the semester. The internal examinations are conducted by the faculty associated with the course at the institute or program level, as per the academic calendar. Here, four internal examinations are considered and are referred to as

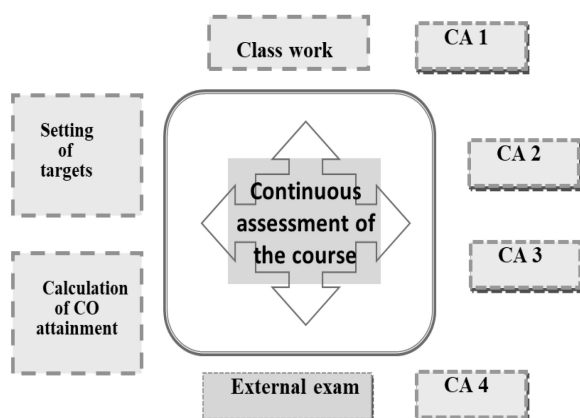


Fig. 3. Direct assessment adapted in the select course.

Table 3. Specimen regulations for external examinations

Attainment levels	Indices
Level 1	30% students of the students scoring more than the university or board average.
Level 2	50% students of the students scoring more than the university or board average.
Level 3	70% students of the students scoring more than the university or board average.

Table 4. Specimen regulations for internal examinations

Attainment levels	Indices
Level 1	30% students of the students scoring more than the class average.
Level 2	50% students of the students scoring more than the class average.
Level 3	70% students of the students scoring more than the class average.

Table 5. Calculation of CO attainment for 2020–21

S. No	Marks obtained	Overall CO attainment
Student 1	8	Board/University average = 7.714 Based on the grades, they are at level $(5/7) = 71.42\%$ Attainment = $100\% \times 3 = 3$
Student 2	7	
Student 3	8	
Student 4	8	
Student 5	8	
Student 6	7	
Student 7	8	

CA 1 to CA 4. These can be based on assignments, class test, quizzes or presentations, as per the interest or convenience of the faculty. But, in this course, all the four are conducted as simple class tests that test their abilities at prescribed intervals, enforced by the university. Such tests can be simple at times, just to see, whether they are following the class work or not. In the present case, the marks are entered in the university web portal, once the tests are over. This would avoid any undesirable mod-

eration afterwards. At the end of the semester, external examinations are conducted as per the university academic calendar. The weightage of the marks in class tests is taken as 30% and the weightage of the external marks or grades is taken as 70%. Combined, the grades are declared by the university, confirming the weightage of 100%. Overall CO attainment is calculated at the end of the semester, once the results are declared.

3.4 Attainment of COs

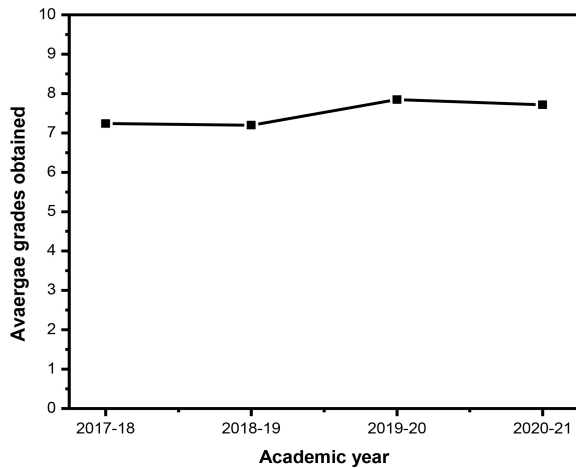
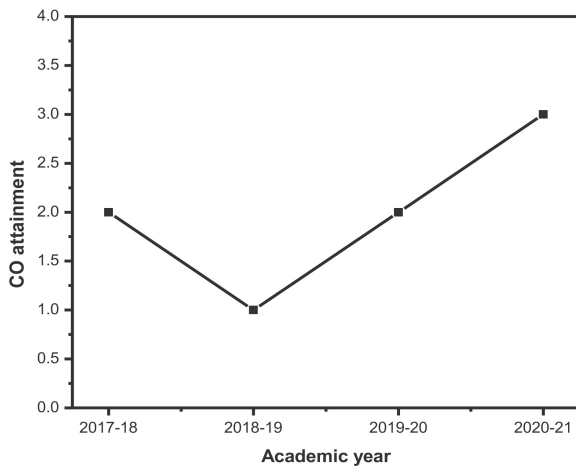
CO attainment is very important in the present day scenario as OBE approach is gaining prominence and is seen as a tool for comparing the present scenario with earlier instances of taking the same course. This is a vital task and is mainly required for getting accreditation in India or elsewhere. It is based on internal and external examinations. Usually, the weightage is 70% and 30%, with regard to external and internal examinations. So, the overall CO attainment of a course is $0.7 * L_e + 0.3 * L_i$. Where, L_e is the level acquired, based on the performance of the students in external assessments. L_i is the level attained, based on the performance of the students in internal assessments. The levels obtained by the total number of students with regard to a particular exam is based on the regulations framed at the program level. For example, the regulations for external examinations is as shown in Table 3 and for internal examinations, they are given in Table 4. These guidelines or indices for the confirmation of levels for all the courses of a program are finalized by the uppermost academic authority, i.e. academic council or board of studies. For the present course and program, the highest academic authority is academic council. It meets either once or twice in any given year and finalizes such regulations and processes in all the academic aspects. In the present study, the grades are declared by the university affiliated, considering both internal and external marks. They are as shown in Table 5. Correspondingly, the attainment levels are calculated and tabulated. In this case, the weightage of these final grades will be 100%. The attainment will be $1 * L_{\text{based on grades}}$. For the year 2020–21, the total number of students is 7. The board/university average grade mark is 7.714, as the course is offered in the select institute only. Applying similar set of regulations, it is clear that they are at level 3. Hence, the overall CO attainment for Applied Thermodynamics in the recent year is $100\% * 3 = 3$.

3.5 Analysis of CO Attainment

All the details of marks and the scenario of finalizing the level are shown in Table 6. The average reference mark or university average is plotted as shown in Fig. 4. For the earlier batches of 2017–18

Table 6. Details of marks and finalizing the level

Particulars	2017–18	2018–19	2019–20	2020–21
Average marks	7.235	7.2	7.846	7.714
% of students scoring above university average	52.9%	40%	61.53%	71.42%
CO attainment = 100% * (Level achieved)	2	1	2	3

**Fig. 4.** Average grades obtained for all the four years.**Fig. 5.** Comparison of CO attainment.

and 2018–19, the average grade mark achieved was low. For the last two years, it has been good. This may be due to the changed examination pattern because of the pandemic situation. Short and long answer questions were removed and the question papers were confined to multiple choice questions of 1 or 2 marks. May be due to this, the students' performance has been good for the last two years. Further, as discussed in the previous section, the CO attainment for the last four years is calculated

and plot is made for comparison as shown in Fig. 5. Interestingly, the CO attainment has been good in the last two years as well. In the last academic year (2020–21), the attainment has been the highest. This shows that both teaching and learning have been at their level best. As mentioned earlier, the reason could be the changed exam pattern. However, if the same scenario stands even with the same question paper pattern as before, then the results are really appreciable.

4. Conclusions

Outcome based scenario is applied to a course related to an undergraduate mechanical engineering program. Initially, the outcomes of the selected 'Applied Thermodynamics' course are prepared and their relevance is checked with the bloom's taxonomy table. COs for the select course are covering the domains of conceptual and procedural knowledge. The learning levels are of understanding, applying and analyzing. It is clear that the levels in the lower half of the reference bloom's taxonomy table are covered in this course. Also, the selection of the verbs is justified in the present context. Appropriate assessment processes are deliberated and guidelines for deciding the levels are thoroughly discussed. The grades of the select students are compared to university average grade mark to decide the level of attainment in the course. For the previous year 2020–21, model calculation of CO attainment is presented. Similarly, the grades are taken and analyzed for all the four years of the course under consideration. Average mark obtained by the students and the attainment of COs for the academic years under consideration are plotted and examined. It is seen that the CO attainment is good in the recent years. Thus, the present work studies the aspects of outcomes, ways of assessment and calculation of CO attainment in case of thermodynamics based course, which is similar to any other course. This work tries to clear the confusion and gives better idea to the teaching fraternity about outcomes and their attainment, applicable to any engineering program.

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