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Engineering Course Development Process to meet Outcome Based Education

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Abstract—**The major components of Outcome Based Education (OBE) are an outcome-based curriculum, outcome-based teaching & learning, and outcome-based assessment. Courses in Outcome based curriculum are designed with a goal of what a student will be able to do at the end of the course. In this paper, the course development process is covered in detail to meet the OBE. The Course development process comprises of four distinct stages. These are course planning, course designing and developing, course implementation, and course evaluation. The output of the course planning and course designing phases leads to the emergence of well-defined course topics that are to be implemented. Writing Course objectives and outcomes play a vital role in OBE. Various levels of engineering course development are also presented. While developing the new course, Bloom's levels and engineering knowledge categories are used. Two methods are presented to map the course outcomes with program outcomes. In method 1, the number of classroom sessions planned are used for mapping. In the second method, matching components are used for mapping. The course evaluation process is also discussed in this paper to meet student-centric learning. Experiments indicate that engineering course development using all three Bloom's domains with engineering knowledge categories addresses the maximum number of graduate attributes.**

***Keywords*—Course Outcomes; Graduate Attributes; Outcome Based Education; Program Outcomes.**

***JEET Category*—Research**

I. INTRODUCTION

COURSE content varies with the desired course outcomes. A course might be comprised of more than one approach and vary with the desired learning outcomes. "Analysis, Design, Development, Implementation, and Evaluation (ADDIE)" is a popular design process model. Ed Forest (1975) presented ADDIE model. One should understand Bloom's domains and taxonomy to develop a good course. To inculcate higher order thinking, Bloom, Furst, et al. (1956) created Bloom's Taxonomy. Bloom's proposed three domains. The first one is cognitive domain. It is further divided into cognitive processes and knowledge categories. The second one is the psychomotor domain. It is on action (skill) based. The third one is the affective domain. It is on an emotion-based level. In each domain, Bloom defined several levels. Levels used in cognitive domain are remember, understand, apply, analyze, evaluate, and create. Levels used in psychomotor domain are imitation, manipulation, precision, articulation, and naturalization. Levels used in affective domain are receive, respond, value, organize, and characterize. All three dimensions are involved to varying degrees in all intended learning experiences and activities. A well-designed course addresses Graduate Attributes (GAs) or Program Outcomes (POs) properly. Well-aligned course can meet a greater number of GAs (Veeraswamy, 2021) in turn meeting Bloom's three domains. Anderson& Krathwohl, et al. (2001) four knowledge categories are important in engineering education. These are factual, conceptual, procedural, and metacognitive knowledge categories. A useful taxonomy table is prepared by combining Knowledge and Cognitive Process. The learner may not be directly dealing with metacognitive elements. The instructor must deal with metacognitive elements in organizing and designing learning events.

Vincenti, Walter G (1990) attempted to identify the nature of engineering knowledge. Categories of Knowledge specific to Engineering considered are Fundamental Design Concepts (FDC), Criteria and Specifications (CS), Practical Constraints (PC), Design Instrumentalities (DI). Taxonomy Table plays a vital role in the course design. It can facilitate achieving a specified alignment among the elements of course. It helps to design well-structured test item banks. Consequently, validity and reliability, two important properties of assessment, can be achieved. It further serves as an effective tool for organizing direct or automatic intelligent tutoring. Outcome based teaching and learning; teacher develops a concrete action plan which directly encourages students to achieve learning outcomes. Teacher performs assessment tasks to assess the performance and to ensure the learning in the students. Teacher encourages students to participate actively in the class sessions, labs, co-curricular, and extra-curricular activities. It is a student centric approach, which delivers course topics of a course to the students for achieving intended learning outcomes. Spady (1993) elaborated Outcome-based education: Reform and the curriculum process in detail. Krathwohl (2002) discussed on the revision of Bloom's taxonomy. Veeraswamy and Bindu (2018) discussed various Teaching Learning Processes (TLP) suitable to meet OBE. Syeed et al. (2022) defined the Process and Practice for Engineering Education.

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Harden (2002) presented Developments in outcome-based education. Program Outcomes (POs) considered in this work are Engineering Knowledge (PO1), Problem Analysis (PO2), Design/Development of solutions (PO3), Conduct Investigation of Complex Engineering Problems (PO4), Use of Modern Engineering Tools (PO5), Engineer and Society (PO6), Environment and Sustainability (PO7), Ethics (PO8), Individual /Teamwork (PO9), Communications Skills (PO10), Project management and Finance (PO11) and Lifelong Learning (PO12). Program Specific Outcomes (PSOs) are not considered for simplicity. Further, Program Specific Outcomes varies program to program in a drastic way.

II. Proposed Methodologies

Systematically design and develop outcome-based course is very important phenomena in professional education. Success in the course depends on course learning outcomes. The sum of the course learning outcomes of constituent courses should be mapped to the program learning outcomes. Typically,4 to 6 Course Outcomes (COs) are identified per course. Action verbs are used to write COs. These are specific, measurable and can be demonstrated by students on completion of the course. COs should aim to develop higher order skills in each Domain of Learning. Courses in Outcome based curriculum are designed with a goal of what a student able to do at the end of the course. New course development process considered in this work is shown in Fig.1

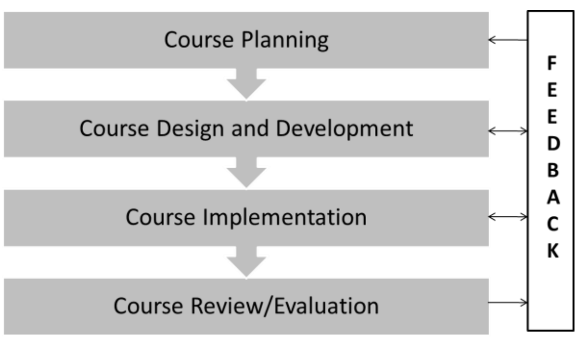

Fig.1. New course development process.

A. Course Plan

Course planning is a complex process. In the planning phase, the important components are who will take the course, what does the learner already know and attitude of the learners towards this course. Course mapping to POs is to be considered to plan course structure. Accordingly, Bloom's domains and taxonomies are to be identified. Anderson knowledge categories are also considered to design Sciences and humanities course. Engineering courses are designed with Bloom-Anderson-Vincenti models. Accordingly, items required in course are to be finalized in this phase. Course structure contains the items like, course objectives, course learning outcomes, topics, sequence of course content, CO-PO mapping, teaching and learning methods, assessment plans, and references. Further, course planning also considers prerequisite, number of hours needed, and depth of the course.

B. Course Design and Development

Design: Course design involves systematic procedures of analysing the needs from various sources, formulating course objectives, course learning outcomes, and selecting & organizing content. The system then brings out a course content document which may be considered as some kind of proposal which when implemented in right spirit, will result in achieving the intended program outcomes and program educational objectives. Course design is a macro level activity.

Development: Course development is a micro level activity. Examine the previous course contents. Consider the knowledge, skill, and attitude levels that the students are expected to have in this course. Determine the topics in the course which meet the various Bloom's domains, taxonomies, knowledge categories, and POs. Feedback from stakeholders plays an important role here. Finally, the development process is going to address the following:

i. Topics selection based on COs and POs mapping
ii. Content organization
iii. Selection of teaching methods
iv. Selection of learning methods
v. Determination of what to evaluate and how to evaluate
vi. Finalization of the reference materials

Course Outcomes (COs) are what the student should be able to do at the end of the course. Anderson& Krathwohl, et al. (2001) presented taxonomies, teaching, and assessment processes. It includes attitude, skills, and knowledge. The structure of a CO statement contains actions, knowledge, condition, and criteria. Mager (1962) explains the importance of the Learning Outcomes. Learning Outcomes should include three elements. These are given below:

Performance: An outcome statement should always say what the learner should be able to do.

Condition: The outcome always describes the important conditions, if any, under which the performance is to occur.

Criterion: It is the acceptable performance by describing how well the leaner must perform to be considered acceptable.

C. Course implementation

Course implementation is 'putting into action' the various course components stipulated in course design. For this to happen, some of the course stakeholders have a major role to play. The first step is to create a battery of 'master trainers' who will have to be trained about the various aspects of revised/changed course. Therefore, such course-design workshops also serve as training workshops for creating 'master-trainers' of the changed course. Often these chosen faculty members for these workshops are drawn from the far flung geographically separated affiliated colleges of the university which is a good and common phenomenon in India. The primary responsibility for the successful implementation of any course is the teacher, more so, if it is a new or revised course. One of the effective ways of course implementation is the 'shake hand' practice that should take place with the student in the first contact hour of the semester itself. This guides the student the direction in which he/she must go. During this first contact hour, the teacher should hold an interactive session wherein the curriculum philosophy and other course components are read out to the whole class. Each matter with their implications is discussed and explained to them. This activity will make every student aware of the destination (expected behaviours) he/she must reach at the end of course. This will accelerate the self-learning habit in the students using not only the prescribed books in print, but also the non-print and other electronic media. The teaching learning should be so oriented, that students are encouraged to make maximum use of the laboratory, library, and other resources. The teachers then organise the relevant co-curricular and learning activities in the classroom, laboratory, workshop, library, and other places. At regular intervals, they should monitor the progress of the students and solve learning problems using various strategies such as remedial treatment, guidance, counselling, and tutorials. To develop the cognitive domain related outcomes in the students judiciously, various types of teaching strategies and methods should be adapted inside the classroom, as well as for activities outside the classroom. As today's students are more electronic savvy, teachers will have to be trained and encouraged to use the electronic media to teach, and administer group and individual assignments, which will make the students to use various types of electronic media and encourage online submissions. To make the teaching-learning more effective, the teacher should also wisely offer different types of educational projects to students encouraging them to use electronic resources such as MOOCs, freely available websites, 'YouTube' videos, 'WhatsApp' applications and such others. Similarly, for developing the skills related to the Psychomotor Domain is essential. Design the laboratory/workshop assignments not to verify the theory taught in the class but facilitate the gradual development of the practical skills required by the industry.

D. Course review and evaluation

Periodical course review is an important aspect in engineering education. The review and evaluation of the course in its life cycle is highly desirable to respond to the market changes in terms of technology, relevance, and employment opportunities. Course end survey plays an important role to take feedback from the students. It provides reflections and provide feedback on their own learning. Alumni and industry experts feedback also plays a vital role here. During try out and implementation stages the feedback mechanism shall provide enough data and information for corrective measures and continuous improvements. A committee composition consisting of course coordinator, expert from premier educational institute, expert from industry, alumni, and employer is important aspect.

E. Basic level course

Locating COs in cognitive Bloom's TABLE: Here, COs are mapped with cognitive bloom's taxonomy (Krathwohl,2002), POs/PSOs, and actual class sessions needed. The author treated this as Level 1 course. Bloom's cognitive domain is considered in these courses. It is the cognitive level to be learned. Accordingly, content, Teaching Learning Processes, and assessment pattern will change. Keeping COs and cognitive levels are presented in TABLE I. These type of courses gives a little understanding on OBE. It affects the learning outcomes of the students.

TABLE I
COURSE MAPPED WITH COGNITIVE LEVEL

CO No.	Cognitive BTL Level	PO	Class Sessions
1	3	2	10

F. Medium level course

Locating COs in Cognitive Bloom-Anderson TABLE: The course belongs to Sciences, Humanities and Social Sciences keeping COs in Bloom-Anderson taxonomy table is sufficient. Anderson considered two dimensions. One is the kind of knowledge to be learned. Second one is the cognitive processes used to acquire the knowledge. The knowledge dimension consists of factual, conceptual, procedural, and meta cognitive knowledge. Cognitive dimension consists of remember, understand, apply, analyse, evaluate, and create. Second one is nothing but Bloom's taxonomy. Hence, this method is considered as Anderson-Bloom taxonomy. The author treated this as Medium level course. Accordingly, content, Teaching Learning Processes, and assessment pattern will change. Keeping COs and cognitive levels along with knowledge categories are presented in TABLE II.

- Factual Knowledge (FN)
- Conceptual Knowledge (CN)
- Procedural Knowledge (PN)
- Metacognitive Knowledge (MN)

TABLE II
COGNITIVE BLOOM-ANDERSON

CO No.	Cognitive BTL Level	Knowledge Categories (4)	PO	Class Sessions
1	3	CN, FN	2	10

Details of Cognitive processes and Knowledge categories are presented in TABLE III. Consider CO1 as "Design of Local Area Networks for educational institutes". This is meeting Application level as per cognitive process. Conceptual and Procedural knowledge categories are needed here. Hence, CO1 is placed in two locations. Details are presented in TABLE III.

TABLE III
COGNITIVE BLOOM-ANDERSON MODEL

Cognitive Processes	Knowledge Categories			
	Factual	Conceptual	Procedural	Metacognitive
Apply	-	CO1	CO1	-

G. High level course

Locating COs in Cognitive Bloom-Anderson-Vincenti TABLE: Anderson-Bloom-Vincenti taxonomy table is needed for engineering courses. The author treated this as Level 3 courses. Accordingly, content, Teaching Learning Processes, and assessment pattern will change. Vincenti and Walter (1990) attempted to identify the nature of engineering knowledge. Categories of Knowledge specific to Engineering are given below:

- Fundamental Design Concepts (FDC)
- Criteria and Specifications (CS)
- Practical Constraints (PC)
- Design Instrumentalities (DI)

Keeping COs and cognitive levels along with knowledge categories are presented in TABLE IV. All engineering courses should have these 8 knowledge categories (general knowledge and knowledge specific to engineering) to meet OBE.

TABLE IV
COGNITIVE BLOOM-ANDERSON-VINCENTI

CO No.	Cognitive BTL Level	Knowledge Categories(8)	PO	Class Sessions
1	3	CN, PN-Anderson FDC-Vincenti	2,3	10

H. Best course

Locating COs in Bloom-Anderson -Vincenti TABLE:
Here, Bloom's three domains are considered. These are Cognitive (Cog), Psychomotor (Psy), and Affective (Aff) domains. The author treated this as Level4 course. Accordingly, content, Teaching Learning Processes, and assessment pattern will change. Keeping COs and Bloom's three domains along with knowledge categories are presented in TABLE V. Bloom's taxonomy levels in cognitive are very popular. Levels used in cognitive domain are remember (Rem), understand (Und), apply (App), analyse (Ana), evaluate (Eva), and create (Cre). Anita (1972) presented taxonomy for the psychomotor domain. In this paper, levels considered in psychomotor domain are imitation (Imi), manipulation (Man), precision (Pre), articulation (Art), and naturalisation (Nat). Psychomotor domain (Elizabeth ,1966) is important in engineering education. Levels used in affective domain are receive (Rec), respond (Res), value (Val), organise (Org), and characterize (Cha).

TABLE V
COGNITIVE BLOOM-ANDERSON-VINCENTI

CO No.	Cognitive/ Psychomotor/ AffectiveBTL Level	Knowledge Categories (8)	PO	Class Sessions
1	Cog-App Psy-Imi	CN, PN-Anderson FDC-Vincenti	2,3,5	10

PO mapping Method1

Rao and Kanth (2019) proposed a simple method to relate the level of PO with the number of hours devoted to the COs which addresses the given PO.

- Level 3: If >40% of classroom sessions/tutorials are planned to a particular PO.
- Level 2: If 20 to 40% of classroom sessions/tutorials are planned to a particular PO.
- Level 1: If 5 to 20% of classroom sessions/tutorials are planned to a particular PO.
- Not addressed: If < 5% of classroom sessions/tutorials are planned to a particular PO.

PO mapping Method2

PO mapping is done based on how well do the CO statements match with the PO statements. Very often a part of a PO is embedded in the CO. This method is based on the degree of the match. Degree of match is considered by the author as: (a) Excellent/ 3 (b) Good / 2 (c) Fair /1.

- Level 3: If >75% of CO components are matching with PO components.
- Level 2: If 50 % to 75% of CO components are matching with PO components.
- Level 1: If 10 % to 50% of CO components are matching with PO component.
- Not addressed: If<10% of CO components are matching PO components.

III. RESULTS AND DISCUSSION

To discuss the various levels of course design and development, author has considered Computer Networks course in undergraduate engineering program. PO mapping method1 is considered to discuss the experimental results. Framing CO is given below with explanation.
CO: Understand the effect of all the devices in Local Area Network through simulation using NS2.
Action: Understand
Knowledge: Effect of all the devices in Local Area Network (Conceptual)
Condition: Simulation using NS2
Criterion: None

A. Basic level course

Locating COs in Cognitive Bloom's TABLE: Here five COs of Computer Network course are placed in the following TABLE VI.

TABLE VI
COS MAPPING COGNITIVE LEVEL

	Course Outcome	POs	CL	Class Sessions
CO1	Identify the various network architectures.	PO1	Und	08
CO2	Describe various LAN possibilities	PO1	Und	08
CO3	Identify various routing and congestion control algorithms	PO1	Und	12
CO4	Explain various protocols	PO1	Und	09
CO5	Intrepret cryptography and network security techniques	PO1	Und	08

In this course 45 sessions out of 45 (100%) are devoted to PO1. Hence, this course mapping level is 3 for PO1. This is presented in TABLE VII.

TABLE VII
COS MAPPING WITH POS

Course	Mapping Strength with POs
	PO1
Computer Networks	3

B. Medium level course

Locating COs in Cognitive Bloom-Anderson TABLE: Here five COs of CN course are placed in the following TABLE VIII. Here four knowledge categories are added. Number of hours planned for the covering the content is also presented. Here, engineering knowledge and problem analysis are covered extensively.

TABLE VIII
COs MAPPING WITH PO -COGNITIVE- BLOOM-ANDERSON

	Course Outcome	POs	CL	KC	Class Sessions
CO1	Identify the various network architectures.	PO1	Und	FK	08
CO2	Describe various LAN implementations	PO1	Und	FK, CK	08
CO3	Calculate various routing and congestion control options	PO2	App	CK, PN	12
CO4	Analyze various protocols performance	PO2	Ana	CK, PN	09
CO5	Describe cryptography and network security techniques	PO1	Und	FK, CK	08

In this course 24 sessions out of 45 (53%) are devoted to PO1. 21 sessions out of 45 (47%) are devoted to PO2. Hence, this course mapping level is 3 for PO1 and PO2. This is presented in TABLE IX.

TABLE IX
COs MAPPING WITH POs

Course	Mapping Strength with POs	
	PO1	PO2
CN	3	3

Medium level course mapping to POs is illustrated in the Fig.2.

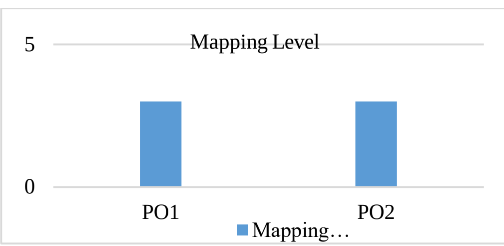

Fig. 2 Medium level course mapping with POs

C. High level course:

Locating COs in Cognitive Bloom-Anderson -Vincenti TABLE: Here five COs of CN course are placed in the following TABLE X.

TABLE X
COs MAPPING COGNITIVE BLOOM-ANDERSON-VINCENTI

	Course Outcome	POs	CL	KC	Class Sessions
CO1	Understand the various network architectures.	PO1	Und	FK, CK	08
CO2	Design the LAN	PO1, PO3	App	CK,PK, FDP	08
CO3	Judge the effectiveness of existing routing and congestion control algorithms	PO2	Ana	CK,PK, CS	08
CO4	Create better protocols	PO2, PO3	Cre	CK, PK FDP, CS,	12
CO5	Apply cryptography and network security techniques as per the organisation requirements	PO3	App	CK, PK FDP	09

Here eight knowledge categories are added. In this course 12 sessions out of 45 (27%) are devoted to PO1. 14 sessions out of 45 (31%) are devoted to PO2. 19 sessions out of 45 (42%) are devoted to PO3. The course mapping level is 2 for PO1 and PO2. However, the course mapping level is 3 for PO3. This is presented in TABLE XI.

TABLE XI
COs MAPPING WITH POs

Course	Mapping Strength with POs		
	PO1	PO2	PO3
CN	2	2	3

High level course mapping to POs is illustrated in the Fig.3.

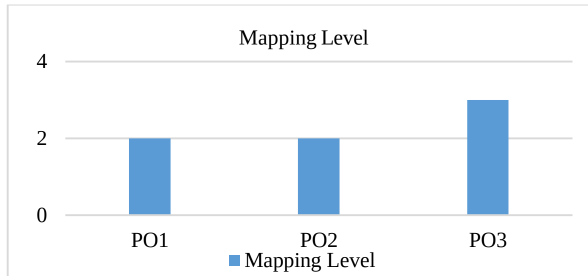

Fig. 3 High level course mapping with POs

D. Best course

Locating COs in Bloom-Anderson -Vincenti TABLE: Here five COs of CN course are placed in the following TABLE XII. Here eight knowledge categories and three Bloom's domains are added. Accordingly, CO statements are changed.

TABLE XII
COs MAPPING BLOOM-ANDERSON-VINCENTI

	Course Outcome	POs	Cog/Psy /Aff	KC	Class Sessions
CO1	Design and implement the LAN for software industries, educational institutes, and industries.	PO1, PO3	Cog-App, Psy- Pre	CK,PK, MK, FDP, CS, PC,DI	08
CO2	Identify deficiencies in existing protocols & create new and better protocols	PO3, PO4	Cog- Cre, Psy- Pre	CK,PK, MK, FDP, CS, PC,DI	08
CO3	Simulate the various networks and analyse their performance in NS2 simulator	PO4, PO5	Cog-Ana Psy- Pre	PK,MK, CS, PC,DI	08
CO4	Implement Physical LAN with internet	PO4, PO5	Cog-App Psy- Pre Aff- Res	PK,MK, CS, PC, DI	09
CO5	Work on industrial networking problems as a team and share at a large gathering	PO4, PO5, PO6, PO9, PO10	Cog-Ana Psy- Art Aff- Val	PK,MK, CS, PC, DI	12

In this course 4 sessions out of 45 (9%) are devoted to PO1. 8 sessions out of 45 (17%) are devoted to PO3. 14 sessions out of 45 (31%) are devoted to PO4. 10 sessions out of 45 (22%) are devoted to PO5. The course mapping level is 2 for PO1 and

PO2. 3 sessions out of 45 (7%) are devoted to PO6. 3 sessions out of 45 (7%) are devoted to PO9. 3 sessions out of 45 (7%) are devoted to PO10. To achieve this theory cum lab or theory cum project courses should be introduced. Further student centric learning approaches are practiced as continuous assessment. Group based or case-based assignments plays a vital role here. Suitable assessment rubrics containing the presentation, teamwork, modern tool usage etc., to be incorporated. PO mapping possibilities for the best course is presented in TABLE XIII. PO mapping levels can be further improved using content matching and number of hours devoted related the course outcomes.

TABLE XIII
COs MAPPING WITH POs

Course	Mapping Strength with POs						
	PO1	PO3	PO4	PO5	PO6	PO9	PO10
CN	1	1	2	2	1	1	1

Best course mapping to POs is illustrated in the Fig.4.

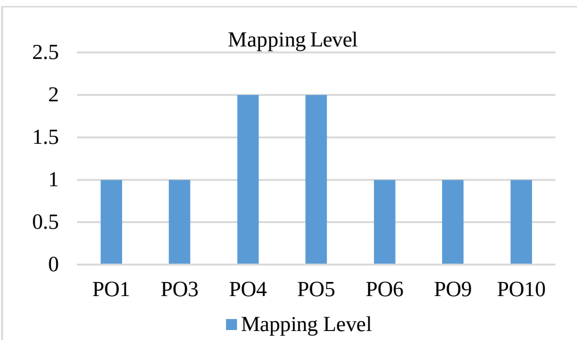

Fig. 4 The best course mapping with POs

IV Conclusions

The OBE process defines several key activities at the course level that involves the reorganization of each course content, COs mapping with the POs, teaching learning practices, assessment techniques, and reporting practices in engineering education. COs representing what level of knowledge, skill, and attitude the students are able to attain upon the successful course completion. In this paper, the engineering course development process is discussed in detail. Four levels of course development process is presented. Three of Bloom's domains are considered. Eight knowledge categories are also explored while preparing COs. The objective process of CO to PO mapping is presented in detail. The best courses are useful for technical education. The best course covers better content to meet COs. Theory cum project or theory cum lab components in a course will match with the characteristics of the best course. Critical thinking and mapping with more Graduate Attributes are possible only with the best courses. Traditional courses are mapped with only one or two POs. Proposed methodologies can map a greater number of POs. Hence, attainment of more Graduate Attributes is possible with the proposed methodologies. The best courses can meet the quality assurance in terms of meeting OBE in engineering education.

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