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A Systematic Framework for Designing and Implementing Outcome-Based Curriculum in Engineering Education: A Comprehensive Approach

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Abstract— Higher educational institutions and Universities are facing challenges to produce skilled graduates capable of addressing anticipated industry needs. This is due to implementation of traditional curricula and adoption of teacher centric approach. Eventually, traditional curriculum creates a significant gap between the skills acquired by students through education and the skills needed at the workplace. To bridge the gap, national and international accreditation bodies are enforcing educational institutions to implement Outcome Based Education (OBE) in their educational processes. The OBE is a student-centric teaching and learning approach that focuses on skills anticipated by the industries. The implementation OBE in engineering education is driven by design and implementation OBE curriculum. In this context, the current article presents a systematic framework for designing, developing, and implementing outcome-based curriculum for engineering education. The framework comprises of six phases including identification of a new program, formulation of mission, vision, and educational objectives for the identified program, curriculum development, the procedure to outline course syllabus, and finally, implementation of developed curriculum. Furthermore, the framework ensures that students must acquire skills, competencies, and knowledge aligned with industry needs at the time of their graduation. Thus, the proposed framework aids institutions in designing, developing, and implementing OBE curriculum, leading to cater industry needs.

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I. INTRODUCTION

In today's rapidly evolving technological landscape, Information Technology(IT) industry expects engineering institutions to produce graduates who are technically skilled to solve real world IT challenges, adaptable and learn new technologies (Markes, 2006), collaborative (Galeon & Palaoag, 2020), aware of professional ethics and equipped with a strong mix of technical and soft skills. Despite these expectations, engineering institution and higher education universities are struggling to equip graduates with the skills necessary to meet industry demands. This is due to the traditional curricula followed in engineering institution. There are several drawbacks associated with traditional engineering curricula such as adopting to rigid scheme and structure, course content will not be updated as per industry requirement, no interdisciplinary approaches, lack of hands on experience, no scope for soft skills development and student do not address ethical, environmental and social responsibility and so on. Above all, teacher-centric teaching and learning approach is employed in traditional curricula. Unfortunately, a significant gap is created between the skills acquired by students through education and the skills needed in the workplace. However, the gap is reduced by

introducing outcome-based education in engineering institutions (Hadgraft & Kolmos, 2020).

Outcome-Based Education (OBE) is a student-centric teaching and learning approach that focuses on defining specific learning outcomes or goals that students should achieve by the end of a course, program, or educational experience. Instead of just focusing on the content to be covered, OBE emphasizes the desired outcomes, skills, competencies, and knowledge that students should gain. Assessment and teaching strategies` are aligned with these outcomes, allowing for a more structured and transparent educational process. Furthermore, course content revision and addition of new course to the curriculum are undertaken when desired outcome are not achieved with the existing curriculum.

Accrediting bodies for engineering programs are striving to implement policies that ensure the adoption of OBE approach in education. The accreditation agency in India for engineering and other programs is the National Board of Accreditation (NBA). The NBA assesses and accredits the professional programs of various technical institutions based on standard norms (National Board of Accreditation, 2019). The norms ensures that programs work towards preparing the students with intellectual and professional skills to meet the requirements of their profession globally and regionally(Trevelyan, 2019)(Winberg et al., 2020). The NBA recommends the institutions to adopt OBE delivery model, in this direction, it has outlined twelve Program Outcomes (POs) or graduating attributes common to all engineering programs. These POs relate to skills, knowledge, analytical ability, attitude and behaviour that students' possess through program. Among twelve POs, first five attributes (PO1-PO5) are defined as disciplinary outcomes or program dependent POs and remaining seven attributes (PO6-PO12) are professional outcomes or program independent POs.

Outcome-based curriculum plays a pivotal role in implementation of OBE in engineering education. In addition to curriculum, the following factors contribute for implementation of OBE.

- *Learning outcomes*: Defining clear and measurable learning outcomes that describe the knowledge, skills, and abilities that students are expected attain by the end of the program.
- *Assessment methods*: Designing assessment methods and tools that align with the learning outcomes.
- *Teaching strategies*: Adoption of appropriate teaching strategies will promote active learning, student engagement and that leads to meet the desired outcomes.
- *Curriculum design*: Curriculum has to be designed in such a way that it should align with expected outcomes. It is a continuous process and whenever desired outcomes are not met, it is necessary to revise the contents, introduce the new courses or restructuring the existing courses, incorporating new teaching and learning strategies.
- *Student's feedback*: Students performance data is collected and analysed to assess the attainment of set outcomes. This analysis leads to make refinement in the curriculum and teaching strategies, if needed.
- *Stakeholders involvement*: It is necessary to involve stakeholders while designing and developing a curriculum.

Considering the factors mentioned above, the authors in this article have made an effort to present a framework for designing, developing, and implementing an outcome-based curriculum. The proposed framework provides systematic approach to design and organize courses and activities, so that it leads to develop outcome-based curriculum. The framework outlines the essential components, principles, and goals of a curriculum and provides a comprehensive and organized structure for educators to implement. The comprehensive curriculum development process is strategically divided into six distinct phases. Several committees are involved in each phase. Composition , roles, responsibilities, collaboration and engagement with stakeholders of committee members are outlined. Each committee's tasks are aligned with the expected outcomes of the program.

Engineering institutions may adopt this proposed framework to develop outcome-based curriculum. By putting this approach into practice, students will attain the necessary skills, knowledge, and competencies at the time of graduation.

The contents of the article are organized as follows. Section II summarises the literature review of existing articles on the curriculum design and OBE. The proposed systematic framework to design and develop OBE curriculum is presented in section III. Finally, discussions and conclusions are made in section IV.

II. RELATED WORKS

Higher education Universities and Institutions are striving to reinvent a way to teach engineering to produce graduates skilled enough to meet the needs of current and future industries. As the curriculum plays a major role in the skill development of graduates, the design and development of the engineering curriculum is a critical stage in an engineering program. Thus, concerned authorities and researchers are operating in this direction, as a result there exists various frameworks and procedures to design the curriculum for engineering education which are presented briefly in this section.

Various curriculum innovations are developed by the University of Twente for engineering programs. The innovative approaches are successfully implemented in the university, and the authors in (Visscher-Voerman & Muller, 2017) have considered three year data from the university and conducted a study to showcase the effectiveness of implemented models. Authors in (Preethy Ayyappan, Rajmohan Parthasarathi, Leelavathi Rajamanickam, 2019) have presented an effective procedure for curriculum design based on the OBE paradigm. As the engineering curriculum evolves continuously with industry demands, a study on the existing curriculum design process is presented in (Mishra & Sethi, 2019) by considering the electrical engineering program as a case study. The study concluded that the current system has a lacuna among curriculum and industry demands from students' perspectives.

The necessity of the revisions for the curriculum is highlighted in (Ahmad Faris Ismail, 2010) to inculcate the advanced skills among the students to be inline with the emerging technology. In-depth analysis of education sectors in India is presented in (Parashar & Parashar, 2012) revealing the major challenges concerned with policy formulation and its implementation. Mainly, the curriculum design processes aspects such as objectives, policies, contents, and evaluation and analysis methods are reviewed. Finally, the authors conclude that there is a transformation need for curriculum design. As the English language is a primary part of the curriculum teaching-learning process, the authors have presented the syllabus framing method and its importance in (Sari et al., 2020)(Elizondo González et al., 2020)(Nurfitriah, 2014). An effective approach for designing a project-based learning course for a mechanical program is presented in (Kuppuswamy & Mhakure, 2020). While a CDIO (Conceive Design Implement Operate) based approach to design digital electronics course is presented in (B et al., 2022).

The course content to be taught in each semester is to be planned meticulously to align the courses in a stream. A systematic approach for designing the streamlined curriculum for engineering programs in support of OBE is illustrated in (Idachaba, 2018) to improve the quality of graduating students. Typically, the syllabus coverage of some courses should be planned based on the student's prior knowledge and the industry requirements. In this view, the introductory courses of engineering are critical and hence the authors in (Hashim et al., 2022) have discussed framing the syllabus for first-year students to streamline the students towards engineering. The authors in (Pusca & Northwood, 2016) have analyzed whether lean principles can be applied in designing the courses. The heart of lean principles is continuous improvement which is the key concept of OBE. Whereas, a design thinking framework is applied in (Fila et al., 2018)(Boyle et al., 2022) to design the courses. Design thinking is an effective and creative methodology to identify and solve real-world problems. Course design process to be applied during unusual pandemic situations like COVID-19 is outlined in (Streveler & Smith, 2020). Academicians and the students' views on the engineering curriculum and the industry's requires skills are studied and discussed in (Gope & Gope, 2022) to explore the necessary actions to be taken and policies to be formulated to improve the skills of graduating students. The authors in (Sumathi et al., 2023) have presented a model to improve curriculum compliance with respect to the attainment of graduating attributes.

III. PROPOSED SYSTEMATIC FRAMEWORK FOR DESIGNING AND IMPLEMENTING OBE CURRICULUM

Implementation of OBE in undergraduate engineering education is primarily driven by curriculum. In this section, we present and discuss a comprehensive framework for the design, development, and implementation of an OBE curriculum. The proposed framework, depicted in Figure 1, consists of six phases, each of which will be explored in the following sections

A. ***PHASE-I: Identification of new engineering program***

Engineering institutions and higher education universities, before launching a new engineering program, engage in extensive market research to assess the demand for engineering professionals having expertise in the domain of new engineering programs. Additionally, they conduct surveys to identify local and global challenges that could be addressed through the application of this new engineering domain. In this phase, higher authorities of institutions/ universities constitute a Program Committee (PC) comprising of experienced academicians, subject experts, and industry professionals. PC performs following actions:

Action-1*:* The Program Committee

- *Conducts* feasibility studies to evaluate the potential success and sustainability of the program, considering factors such as financial viability and resource availability.
- *Performs* requirement analysis though surveys, interviews, and research to understand needs and demands of the industry and potential employers.
- *Compares* with similar engineering programs offered by other institutions to identify uniqueness and areas of differentiation.
- *Assess* viability and necessity of an engineering program and make informed decisions accordingly.

Action-2*:* PC constitutes Curriculum Development Team (CDT) comprising of 6-8 members at the department level. CDT is responsible for design and development of the curriculum for the program. The composition of the CDT consists of industry professionals and experienced subject experts from various cadres within the department, along with experts from interdisciplinary engineering programs if needed.

B. ***PHASE-II: Define vision, mission, and Program Educational Objectives***

In this phase, CDT performs the following actions:

Action-1**:** *CDT collects* information from potential students, alumni, local businesses, industries, and other stakeholders to ascertain the specific knowledge and skills they expect from graduates.

Action-2: *CDT defines* vision statement of the program based on the insights provided by stakeholders and considering the desired accomplishments of the program graduates in the future. The *vision statement* embodies the long-term aspirations and direction of the program. In line with the vision statement, CDT formulates *a mission statement* that outlines the specific activities and initiatives necessary to achieve the goals set forth in the vision.

Action-3: *CDT describes* Program Educational Objectives (PEOs) (Rogers, 2020). These statements outline the career and professional achievements that the program aims to equip graduates with the skills and knowledge to accomplish.

Action-4: *CDT defines* Program Specific Outcomes (PSOs) are the statements which describe skills of a specific program that must be possessed by students at the time of graduation.

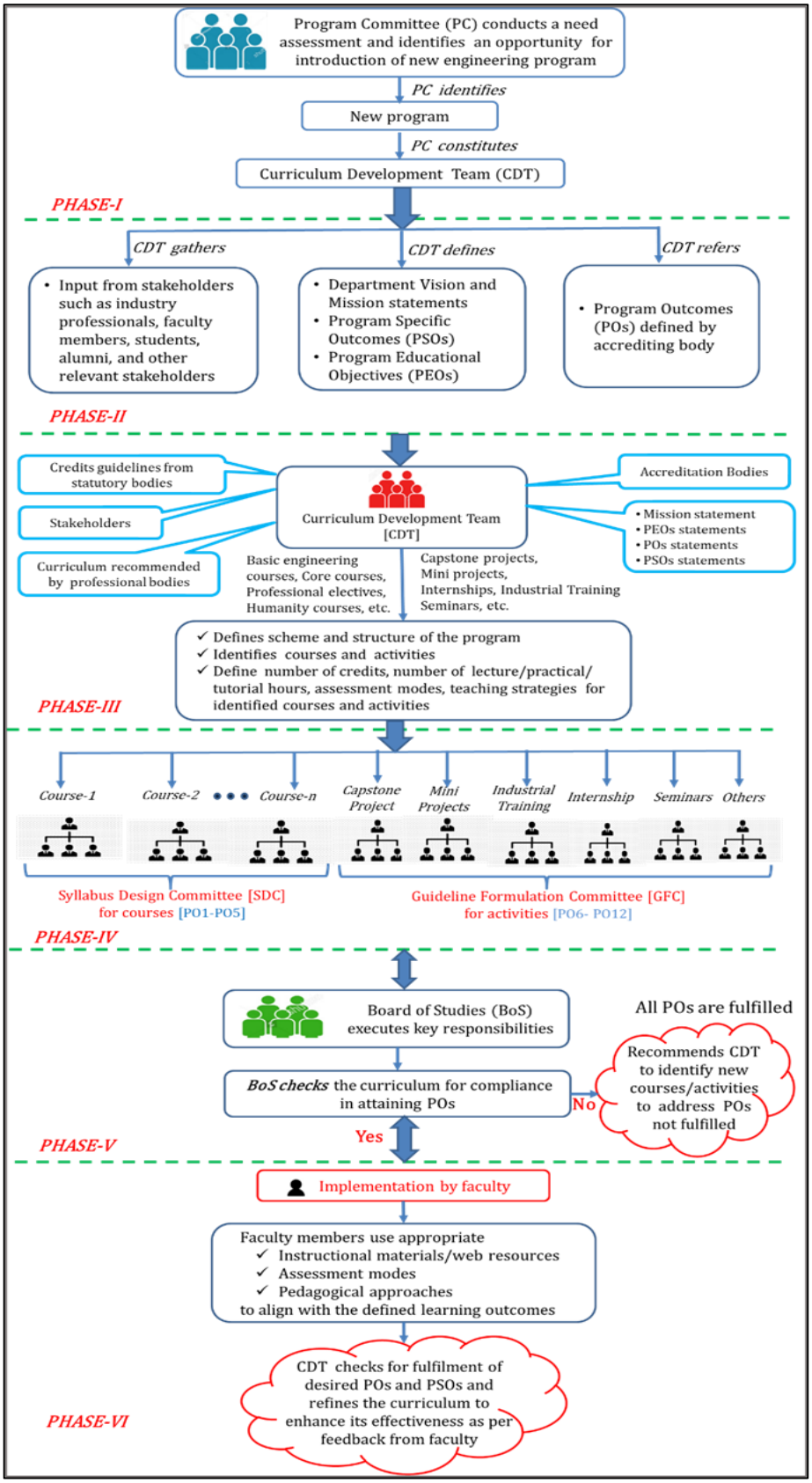
Action-5: *CDT refers* to list of Program Outcome (PO) statements prior to curriculum design. This is to ensure courses and activities within curriculum are in line with PO statements. PO statements are expected outcomes of the program and are defined by NBA.

C. ***PHASE-III: Define scheme and structure of curriculum***

In this phase, The CDT meticulously plans the scheme and structure of the curriculum mainly focusing on outcomes that are inline with outcome defined by accrediting bodies. The scheme and structure outlines arrangements of courses, activities, credits allocation, mode of assessment, and teaching strategies etc. The CDT adheres to the following factors while developing the scheme and structure of an outcome-based curriculum.

- Duration of the program (number of years/semesters) and the credit guidelines provided by statutory bodies.
- The curriculum prescribed by professional organizations of the respective new program.
- Feedback from stakeholders.
- Set goals in Mission statement, PEOs and Program Outcomes.

Figure. 1. A Systematic framework for designing and implementing OBE curriculum



Scheme and structure are a comprehensive blend of two categories namely courses and experiential learning activities. The course category predominantly focuses on

the disciplinary outcomes [PO1-PO5] and activities category emphasizes professional outcome of the program [PO6-PO12]. Fundamental engineering courses, core program courses, specialized professional electives, humanity courses are listed under course category. In the activity category students are provided with hands-on experience and they are made to work on real world problems. Activities under this category include capstone projects, mini projects, seminars, internships, and industrial training etc. Furthermore, the CDT is responsible for ensuring identified courses and activities are aligned with the attainment of the designated goals outlined in the mission statement, PEOs, and POs.

D. ***PHASE-IV: Syllabus and guidelines formulation***

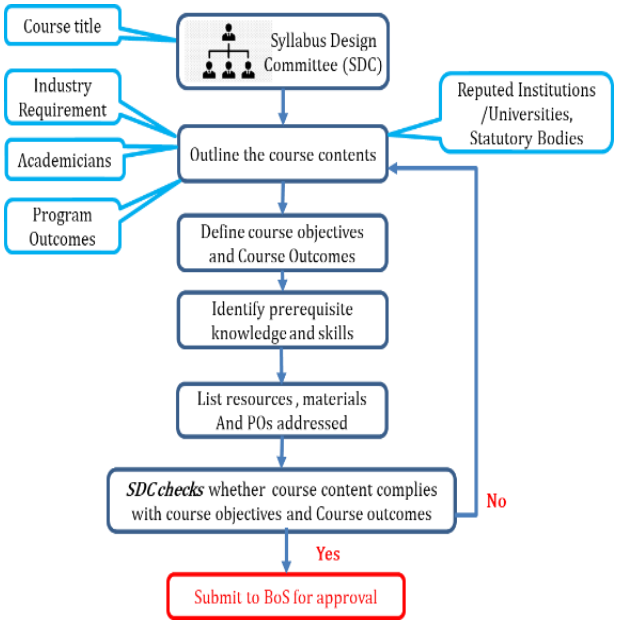
Once the scheme and structure have been finalized, the process of designing course syllabus and defining guidelines for assessment of experiential learning activities begins and these two activities are discussed under distinct headings.

1. Syllabus design process for basic/core/professional elective/open elective/humanity courses: The development of syllabi for the identified courses becomes a crucial step. To accomplish this task, the CDT forms a specialized Syllabus Design Committee (SDC) for each course, considering the domain competency and the faculty's prior teaching experience in related courses. Each committee typically comprises 3-5 faculty members from the same academic area, with one faculty member being nominated as the course coordinator. Developing a course syllabus requires careful planning and consideration of various factors to ensure that the course effectively meets its objectives and the needs of the students. In this direction SDC prepares course content by considering

- Course syllabus which is offered in reputed universities.
- Feedback from industry experts.
- Inputs from academician having expertise in the domain.
- POs to be addressed.

Course content planning and organizing involves step-by-step activities and it is illustrated in ***Figure 2***. After outlining the course content, the SDC proceeds to define the course objectives and Course Outcomes (COs). Course outcomes are the statements that describe the expected knowledge, skills, abilities, or attitudes that students should demonstrate after completing a course. Furthermore, COs help the instructor to use appropriate pedagogical strategies to meet the desired outcomes of the course. Required materials and web resources for course instruction are listed by SDC.

Figure 2. Steps to design course syllabus



2. *Guideline for Assessing Activities:* Experiential activities ensure the students to attain the professional outcomes [PO6-PO12] at the end of graduation. Guidelines Formulation Committee [GFC] is constituted by CDT, comprising 3-4 faculty members from various cadres along with one faculty member nominated as coordinator, to formulate guidelines. The GFC prepares the guidelines to carry out each activity by keeping the duration, credits and assessment modes for the activities as defined by CDT. The process followed by GFC to formulate guidelines is depicted in ***Figure 3***.

E. ***PHASE-V: Curriculum approval and implementation***

Once curriculum is designed and developed, it must be approved by a Board of Studies (BoS), which is a committee constituted by the CDT. This board is comprised of experienced academicians from other reputed universities, industry experts, student

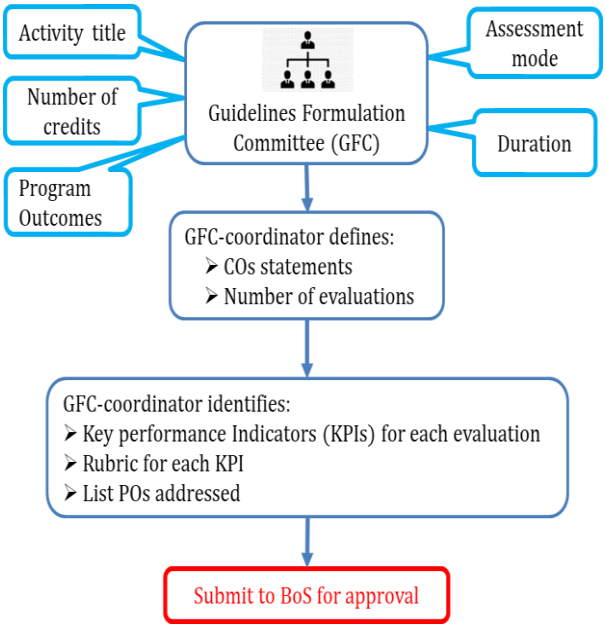
representatives and faculty members from various cadres of relevant discipline in the institute.

The main responsibilities of BoS to ensure that:

- The developed curriculum aligns with the goals set forth in the mission statement and PEOs.
- The curriculum is relevant to current industry needs and trends.
- Course contents, learning objectives and COs are aligned with the attainment of the designated goals outlined in the mission statement, PEOs, and POs.
- Developed curriculum meets the required standards of statutory, accreditation and professional bodies.
- Assessment methods help in successful implementation of outcome-based education.

Compliance Check: Another major task performed by BoS is to check for compliance of the curriculum for attaining Program Outcomes [PO1 - PO12] and PSOs. If any PO is not mapped by any of the course or activity, BoS members recommend for introduction of new course or activity to meet the attainment of POs (Sumathi et al., 2023). Once all the POs are fulfilled, BoS approves for implementation.

Figure. 3. Steps to formulate the guidelines to implement experiential activities



F. PHASE-VI: Implementation and feedback

Faculty play a major role in the implementation of OBE in engineering education. The primary job of faculty members is to define clear learning outcomes which are specific, measurable, realistic, and achievable. To achieve the defined learning outcomes, faculty members use appropriate instructional resources, adopt pedagogical approaches and assessment methods, collect feedback from students and involve stakeholders. Students' performance data is gathered and analyzed. If the desired outcomes are not achieved, faculty members may refine the content and accordingly change their teaching methods or assessment approaches. Based on this, it can be inferred that design and development of curriculum is a continuous process in OBE. Whenever required, updates will be made to ensure alignment with the established outcomes.

Upon completion of the program duration, CDT collects the feedback from faculty members who have taught courses in proposed curriculum regarding attainment of desired COs, POs and PSOs in their respective courses. Furthermore, CDT checks for attainment all POs and PSOs and refines the curriculum to enhance its effectiveness.

IV. CONCLUSION

Engineering colleges produce large numbers of engineers every year. However, as per survey, only 30% of engineering graduates are employed. Remaining graduates remain unemployed or working for an unrelated field. The main reason for unemployment is that the graduates are not equipped with required skills, attitude and knowledge required to work at IT companies. These companies are expecting graduates must;

- possess technical skills to solve real world IT challenges.
- adapt and learn new technologies.
- collaborate with team members.
- aware of professional ethics.
- equipped with a strong mix of technical and soft skills.

Hence there is a wide gap between skills needed at the workplace and what students' study in institution. To bridge the gap, accrediting bodies are enforcing to implement outcome-based education in engineering institutions or higher education universities. The focus of Outcome Based Education is to impart skills required to work at the workplace to students by the end of their graduation. Implementation of OBE in engineering education is driven by curriculum.

The curriculum is designed in such a way that, outcomes of courses and activities are aligned with desired outcomes, skills, competencies, and knowledge as per the industry needs, so that graduating students shall attain the skills required at workplace.

In this paper, a comprehensive framework is proposed for designing, developing, and implementing an OBE curriculum in undergraduate engineering education and higher education universities. There are six phases in the proposed curriculum development framework. Several committees such as the Program Committee (PC), Curriculum Design Team (CDT), Syllabus Design Committee (SDC), Guidelines Formulation Committee (GFC) and Board of Studies (BoS) are involved in developing the curriculum. In each phase, defined roles and responsibility of various committees have to be executed in such a way that execution must be aligned towards predefined goals and objectives. The step-by-step process for designing the course content and to carry out the activities are outlined. SDC and GFC employ the proposed sequential process in designing the OBE curriculum. We conclude that the proposed framework serves as a guide for educators to implement the OBE curriculum in engineering education.

Nowadays, engineering institutions and higher education universities are in the process of introducing allied branches of computer science and engineering, mechanical engineering, electronics and communication engineering, etc. This is an opportunity for engineering institutions to embrace this *proposed framework to design, develop and implement OBE curriculum that aligns with industry needs.*

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