MLRS

MARRI LAXMAN REDDY
INSTITUTE OF TECHNOLOGY AND MANAGEMENT

Outcome Based Education (OBE) Manual

MLRS - R24

Department of Mechanical Engineering

M. Tech CAD / CAM

Contents

PREAMBLE

Outcome Based Education (OBE) is an educational model that forms the base of a quality education system. There is no single specified style of teaching or assessment in OBE. All educational activities carried out in OBE should help the students to achieve the set goals. The faculty may adapt the role of instructor, trainer, facilitator, and/or mentor, based on the outcomes targeted.

OBE enhances the traditional methods and focuses on what the Institute provides to students. It shows the success by making or demonstrating outcomes using statements "able to do" in favour of students. OBE provides clear standards for observable and measurable outcomes.

National Board of Accreditation (NBA) is an authorized body for the accreditation of higher education institutions in India. The National Board of Accreditation (NBA) is also a full member of the Washington Accord. The Washington Accord recognizes NBA-accredited programs, not the institutions themselves.

Higher Education Institutions are classified into two categories by NBA

Tier - 1: Institutions consists of all IITs, NITs, Central Universities, State Universities and Autonomous Institutions.
Tier - 1 Institutions can also claim the benefits as per the Washington Accord.
Tier - 2 Institutions consists of affiliated colleges of universities.

What is Outcome Based Education (OBE)?
Institutions adopting OBE try to bring changes to the curriculum by dynamically adapting to the requirements of the different stakeholders like Students, Parents, Industry Personnel and Recruiters. OBE is all about feedback and outcomes.

Four levels of outcomes from OBE are:

1. Vision, Mission
2. Program Educational Objectives (PEOs)
3. Program Outcomes (POs)
4. Course Outcomes (COs)

Why OBE?

1. International recognition and global employment opportunities.
2. More employable and innovative graduates with professional and soft skills, social responsibility and ethics.
3. Better visibility and reputation of the technical institution among stakeholders.
4. Improving the commitment and involvement of all the stakeholders.
5. Enabling graduates to excel in their profession and accomplish greater heights in their careers.
6. Preparing graduates for the leadership positions and challenging them and making them aware of the opportunities in the technology development.

Benefits of OBE

Clarity: The focus on outcome creates a clear expectation of what needs to be accomplished by the end of the course.
Flexibility: With a clear sense of what needs to be accomplished, instructors will be able to structure their lessons around the students need.
Comparison: OBE can be compared across the individual, class, batch, program and institute levels.
Involvement: Students are expected to do their own learning. Increased student's involvement allows them to feel responsible for their own learning, and they should learn more through this individual learning.

- Teaching will become a far more creative and innovative career
- Faculty members will no longer feel the pressure of having to be the "source of all knowledge".
- Faculty members shape the thinking and vision of students towards a course.

India, OBE and Accreditation:

From 13th June 2014, India has become the permanent signatory member of the Washington Accord. Implementation of OBE in higher technical education also started in India. The National Assessment and Accreditation Council (NAAC) and National Board of Accreditation (NBA) are the autonomous bodies for promoting global quality standards for technical education in India. NBA has started accrediting only the programs running with OBE from 2013.

1 Vision, Mission, Quality Policy, Philosophy & Core Values

The National Board of Accreditation mandates establishing a culture of outcome-based education in institutions that offer Engineering, Pharmacy, and Management programs. Reports of outcome analysis help to find gaps and carryout continuous improvements in the education system of an institute, which is very essential.

TABLE 1: Vision, Mission, Quality Policy, Philosophy & Core Values

Institute Vision	**Department Vision**
To be a globally recognized institution that fosters innovation, excellence, and leadership in education, research, and technology development, empowering students to create sustainable solutions for the advancement of society.	The Mechanical Engineering Department strives to foster innovation, excellence and leadership in education and research, advancing sustainable development globally.
Institute Mission	**Department Mission**
• To foster a transformative learning environment that empowers students to excel in engineering, innovation, and leadership. • To produce skilled, ethical, and socially responsible engineers who contribute to sustainable technological advancements and address global challenges . • To Shape future leaders through cutting-edge research, industry collaboration and community engagement.	• To provide innovative and sustainable technology solutions to solve a wide range of complex scientific and technological challenges in the Mechanical Engineering field. • To enhance employability, leadership skills, and research capabilities through industry collaboration and experimental learning. • To nurture students as ethical and resilient professionals committed to lifelong learning. • To promote excellence in emerging interdisciplinary fields support global progress.

Commitment to Excellence

Our policy is to provide world-class education that prepares our students for the challenges of tomorrow. Through our comprehensive approach to learning, cutting-edge facilities, and experienced faculty, we create an environment where innovation thrives and dreams become reality.

Philosophy

The essence of learning lies in pursuing the truth that liberates one from the darkness of ignorance, Marri Laxman Reddy Institute of Technology and Management firmly believes that education is for liberation. Contained therein is the notion that engineering education includes all fields of science and technology that plays a pivotal role in the development of world-wide community contributing to the progress of civilization. This institute, adhering to the above understanding, is committed to the development of science and technology in congruence with the natural environs. It lays great emphasis on intensive research and education that blends professional skills and high moral standards with a sense of individuality and humanity. We thus promote ties with local communities and encourage transnational interactions in order to be socially accountable. This accelerates the process of transfiguring the students into complete human beings making the learning process relevant to life, instilling in them a sense of courtesy and responsibility.

Core Values

Excellence: All activities are conducted according to the highest international standards.

Integrity: Adheres to the principles of honesty, trustworthiness, reliability, transparency and accountability.

Inclusiveness: To show respect for ethics, cultural and religious diversity and freedom of thought.

Social Responsibility: Promotes community engagement, environmental sustainability, and global citizenship. It also promotes awareness of, and support for, the needs and challenges of the local and global communities.

Innovation: Supports creative activities that approach challenges and issues from multiple perspectives to find solutions and advance knowledge

2 Outcome Based Education - Introduction

Outcome-based education emphasizes clearly defined, high-quality demonstrations of meaningful learning outcomes in authentic contexts. This approach organizes the educational system to ensure that all students develop the critical knowledge, skills, and competencies needed for success by the end of their learning journey.

This means starting with a clear picture of what is important for students to be able to do, then organising the curriculum, instruction, and assessment to make sure this learning ultimately happens to all students.

The curriculum structure and features of the programs offered at MLRITM are developed in accordance with the principles of Outcome Based Education (OBE) and accredited by the National Board of Accreditation (NBA), India is one of the signatory members of the Washington Accord, an international agreement that recognizes engineering degrees from other member countries that are signatories to the Accord.

Employability Statement: This curriculum embeds the development of employability skills throughout the course and is designed to equip students with the ability to relate the knowledge and skills that they have learnt to real world contexts in which they work or may work in the future. The use of

TABLE 2: Key Parameters and Assessment Mechanisms for Outcome-Based Education

Key Parameter	Assessment Mechanism
What do we want the students to be able to do?	Have Knowledge, Develop Skills and be able to solve problems.
How can we help students best to achieve it?	Student Centric Learning
How will we know whether the students have achieved it?	Through various assessment schemes
How do we close the loop for further i.e. continuous quality improvement?	Plan – Do – Check – Act

expert guest lecturers from industry is the important assets for students attending the program.
What does OBE address? - OBE addresses the following key questions:

OBE Implementation

Outcome-Based Education (OBE) is a student-centric learning model that helps teachers to plan the course delivery and assessment. It is implemented as per the following steps:

1. Define Vision statements, Mission statements for the institute and department
2. Define Program Educational Objectives
3. Statements of Program Outcomes and Program Specific Outcomes
4. Role of Knowledge and Attitude Profiles (WKs)
5. Engineering Competencies (EC): Complex engineering problems solving and complex engineering activities (CA)
6. Define Course Outcomes
7. Map courses with Program Outcomes and Program Specific Outcomes
8. Define Course Outcomes with Bloom's Taxonomy for each course
9. Map topics with Course Outcomes
10. Prepare lecture-wise, Course Lesson Plan - Schedule of instruction
11. Define pedagogical tools for course outcomes delivery
12. Define Self Learning and Teamwork activities like Tutorial, Practical, seminar, Mini Project etc.
13. Track students' performance and propose remedial actions
14. Identify Gaps in the Curriculum and adopt suitable measures to bridge the Gap

15. Compare PO/PSO for last 3 academic years and propose action taken and corrective measures

16. Assess the attainment of Program Educational Objectives

3 OBE Outcomes and Profiles

The list of outcome-based education outcomes and profiles are as follows:

1. Program Educational Objectives (PEOs)

2. Program Outcomes (POs)

3. Knowledge and Attitude Profiles (WKs)

4. Engineering Competencies (EC): Range of Complex Engineering Problems (CP) and Complex Engineering Activities (CA)

5. Sustainable Development Goals (SDGs)

PEO and PO have been established through a rigorous process involving key stakeholders (which include faculty, industries, students, and parents). The process was initiated in 2024 through a series of workshops and assessments.

The lists of WKs are obtained from the recent document published by NBA (August, 2024). The list of learning domains are based on the three categories of cognitive, affective and psychomotor domains based on the revised Bloom's Taxonomy.

Outcome-Based Curriculum Planning and Development

The basic objective of the outcome-based approach to curriculum planning and development is to focus on demonstrated achievement of outcomes expressed in terms of knowledge, understanding, skills, attitudes and values and academic standards expected of a program of study. This also enables prospective students, parents, employers and others to understand the nature and level of learning outcome i.e. knowledge, skills, attitudes and values or attributes a graduate of a program should be capable of demonstrating on successful completion of the program of study.

Two words "knowledge and skill" can describe a person's competence! Both seem synonymous at first glance but given more thought, they depict different concepts.

Knowledge refers to learning concepts, principles and information regarding a particular subject(s) by a person through books, media, encyclopedias, academic institutions and other sources. The following is the categorization of different levels of mastery: Assessment, Usage, and Familiarity. The Assessment encompasses both Usage and Familiarity, and Usage encompasses Familiarity.

Familiarity: The student understands what a concept is or what it means. This level of mastery concerns a basic awareness of a concept as opposed to expecting real facility with its application. It provides an answer to the question "What do you know about this?"

Usage: The student is able to use or apply a concept in a concrete way. Using a concept may include, for example, appropriately using a specific concept in a program, using a particular proof technique, or performing a particular analysis. It provides an answer to the question "What do you know how to do?"

Assessment: The student is able to consider a concept from multiple viewpoints and/or justify the selection of a particular approach to solve a problem. This level of mastery implies more than using a concept; it involves the ability to select an appropriate approach from understood alternatives. It provides an answer to the question "Why would you do that?"

Skill on the other hand refers to the ability of using that information and applying it in a context. Knowledge refers to theory and skill refers to successfully applying that theory in practice and getting expected results.

Competency based approach

A competency is the graduate's ability to apply knowledge, skills, and attitudes to effectively complete tasks. This philosophy and definition acknowledge cognitive (Thinking, and learning) and metacognitive skills (knowledge and understanding), demonstrated use of knowledge and applied skills, and interpersonal skills that often work in concert.

Hence competencies are the traits, behaviors, and abilities, the graduate must demonstrate to capably perform in a job, role, function, task, or duty. Job-relevant behaviors, motivations, and technical knowledge-skills are utilized together in the accomplishment of the task.

Benefits of Competency-based approach are:

1. Competencies focus on what the students need to learn, not what educators need to teach.
2. Competencies effectively communicate expectations of graduates to external stakeholders.
3. Competencies encourage reflection on student learning.
4. Competencies can be used globally in diverse contexts.
5. Competencies fit well with most accrediting agencies that use an outcome-focused approach

Competency = [knowledge + Skills + Dispositions]

Knowledge is the "know-what" component of a competency that is most familiar and commonly associated with any curriculum. These are the factual elements we embed in our catalogues, syllabi, lectures, and associated materials. These are critically important nouns that define the "what" that is taught in an IS curriculum. Available through the publications and other intellectual contributions from scholars and practitioners.

Skills are the verbs in competency-task statements that suggest the approach to the application of knowledge. Skill development requires a progression through experience and the application of higher orders of cognitive load adopting a modified Bloom's taxonomy of learning objectives as shown in figure 1, for clarity on complexity and specificity as well.

TABLE 3: Bloom's Taxonomy Levels with Definitions and Action Verbs

I Remember	II Understand	III Apply	IV Analyze	V Evaluate	VI Create
Bloom's Definition Exhibit memory of previously learned materials by recalling facts, terms, basic concepts, and answers.	**Bloom's Definition** Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions.	**Bloom's Definition** Solve problems to new situations by applying acquired knowledge, facts, techniques, and rules in a different way.	**Bloom's Definition** Examine and break information into parts by identifying motives or causes. Make inferences and find evidence.	**Bloom's Definition** Present and defend opinions by making judgments about information, validity of ideas, or quality.	**Bloom's Definition** Compile information together in a different way by combining elements in a new pattern or proposing alternatives.
Verbs • Choose • Define • Find • Label • List • Match • Name • Recall • Relate • Select • Show • Spell • Tell • What • When • Where • Which • Who • Why	**Verbs** • Classify • Compare • Contrast • Demonstrate • Explain • Extend • Illustrate • Infer • Interpret • Outline • Relate • Rephrase • Show • Summarize • Translate	**Verbs** • Apply • Build • Choose • Construct • Develop • Experiment with • Identify • Interview • Make use of • Model • Organize • Plan • Select • Solve • Utilize	**Verbs** • Analyze • Assume • Categorize • Classify • Compare • Contrast • Discover • Dissect • Distinguish • Divide • Examine • Function • Inference • Inspect • Motive • Relationships • Simplify • Survey • Test	**Verbs** • Agree • Appraise • Assess • Award • Choose • Compare • Conclude • Criticize • Decide • Deduct • Defend • Determine • Disprove • Estimate • Evaluate • Explain • Judge • Justify • Prioritize • Prove • Recommend • Support • Value	**Verbs** • Adapt • Build • Change • Choose • Combine • Compile • Compose • Construct • Create • Design • Develop • Elaborate • Estimate • Formulate • Imagine • Improve • Invent • Modify • Originate • Plan • Predict • Propose • Solve • Suppose • Test • Theory

The inclusion of Bloom's levels illustrates in Table , the close linkage between knowledge-based and competency-based approaches. On the lower skill levels, students are expected to "remember" or "understand" knowledge, which refers to more cognitive aspects of learning. However, to reach the level "applying" or higher, assignments where students practice the use of knowledge in specific tasks provided by a teacher are required.

*A **Master of Technology** graduate is knowledge oriented while a **Bachelor of Technology** graduate is skill oriented.*

Engineering and engineering technology are separate but closely related professional areas. They differ in curricular focus and career paths. On curricular focus, engineering programs often focus on theory and conceptual design, while engineering technology programs usually focus on application and implementation. Also, engineering programs typically require additional, higher-level mathematics, including multiple semesters of calculus and calculus-based theoretical science courses. Engineering technology programs typically focus on algebra, trigonometry, applied calculus, and other courses that are more practical than theoretical in nature.

4 Program Educational Objectives (PEO)

Broad statements that describe the career and professional accomplishments of graduates within five (5) years upon graduation. The graduates are expected to achieve one or more of the following PEO:

1. Success in M. Tech CAD / CAM
2. Industrial awareness and research.
3. Successful employment and professional ethics
4. Being a leader professional and societal environment

Mapping program educational objectives to program outcomes shown in Fig 4, which ensures the curriculum aligns with key competencies, enabling students to develop the skills and knowledge required for professional success. Fig 1, gives the correlation between the PEOs and the POs

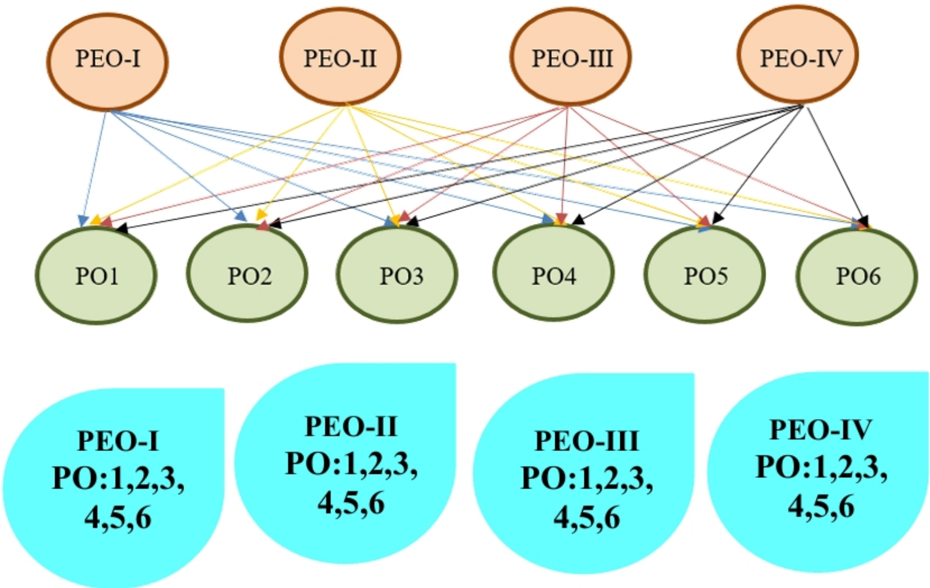

FIGURE 1: The correlation between the PEOs and the POs

5 Program Outcomes (POs)

Program outcomes are the statements of what a student is expected to know, understand and/or be able to demonstrate after completion of a process of learning. The process of learning could be, for example, a lecture, module, or an entire program. These POs mainly relate to the knowledge, skills and attitudes that students acquire while progressing through the program. Specifically, it is to be established that the students have acquired the defined Program Outcomes.

The program must demonstrate that by the time of graduation the students have attained a certain set of knowledge, skills and behavioural traits, at least to some acceptable minimum level. The minimum threshold value should not be less than 50% even to begin with; however, as the program progresses through its evolution, it is expected that this minimum threshold value would subsequently be raised to higher value. Specifically, it is to be demonstrated that all students of a batch to be accredited have acquired the following POs set by NBA as shown below.

TABLE 4: Program Outcomes for Engineering Graduates

PO1	**Research and Investigation:** Independently carry out research investigation and development work to solve practical problems
PO2	**Report Preparation:** Write and present a substantial technical report/document.
PO3	**Domain Mastery:** Demonstrate a degree of mastery in Advanced Design and Manufacturing Technologies, including comprehensive knowledge of design methods, 3D printing processes, and related tools to support modern manufacturing .
PO4	**Application of Engineering Principles:** Solve complex engineering challenges using computational and digital manufacturing tools, considering global issues and perspectives.
PO5	**Design and Sustainability:** Apply advanced knowledge, techniques, and skills along with CAD/CAM technologies to address engineering and manufacturing challenges,emphasizing innovation and sustainable development.
PO6	**Lifelong Learning and Professional Development:** Engage in life-long learning and professional development to adapt to evolving technologies and industry practices.

6 Relation between the Program Educational Objectives (PEOs) and the PO

The relationship between Program Educational Objectives (PEOs) and Program Outcomes (POs) is crucial as it ensures that the educational goals are aligned with specific outcomes, equipping students with the skills and knowledge needed for their professional success. Broad relationship between the program objectives and the program outcomes is given in Table 5:

TABLE 5: Relationship between Program Outcomes and Program Educational Objectives

PEO's→ ↓ PO's		(1) **Technical Proficiency**	(2) **Research & Innovation**	(3) **Professional Competence**	(4) **Leadership & Sustainability**
PO1	Independently carry out research investigation and development work to solve practical problems.	3	3	2	2
PO2	Write and present a substantial technical report/document.	3	2	2	2
PO3	Demonstrate a degree of mastery in Advanced Design and Manufacturing Technologies, including comprehensive knowledge of design methods, 3D printing processes, and related tools to support modern manufacturing.	3	3	3	2
PO4	Solve complex engineering challenges using computational and digital manufacturing tools, considering global issues and perspectives.	3	3	3	2

PO5	Apply advanced knowledge,techniques, and skills along with CAD/CAM technologies to address engineering and manufacturing challenges,emphasizing innovation and sustainable development.	3	2	2	3
PO6	Engage in life-long learning and professional development to adapt to evolving technologies and industry practices.	3	2	3	3

Key: 3 = High; 2 = Medium; 1= Low

Note:

- The assessment process of POs can be direct or indirect.
- The direct assessment will be done through interim assessment by conducting continuous internal exam and semester end exams.
- The indirect assessment on the other hand could be done through student's programme exit questionnaire, alumni survey and employment survey.

7 Learning Domains - Blooms Taxonomy

Benjamin Bloom in 1956 developed a three part model known as the Taxonomy of Learning Domains. He splits learning into 3 different categories:

1. Cognitive domain (intellectual capability, i.e., knowledge, or ’think’)

2. Affective domain (feelings, emotions and behaviour, i.e., attitude, or ’feel’)

3. Psychomotor domain (manual and physical skills, i.e., skills, or ’do’)

Bloom’s Taxonomy is commonly used for the cognitive domain, Simpson’s for the psychomotor domain, and Krathwohl’s for the affective domain. Bloom sees the domains as progressive; with the learner moving through the six stages of each domain as their knowledge, attitude and skills increase or develop. For the purpose of student assessment, these categories will be reclassified into twelve levels of LD. These levels are listed are shown in below Tables 7, 8 and 9.

7.1 Six levels of the Cognitive Domain

Bloom’s taxonomy / Cognitive Domain is frequently used for writing learning outcomes as it provides a ready-made structure and list of verbs. These verbs are the key to writing learning outcomes.since learning outcomes are concerned with what the students can do at the end of the learning activity, all of these verbs are active (action) verbs. as shown in Fig 2, and the justification is explained in Table 6.

FIGURE 2: Six levels of the Cognitive Domain

TABLE 6: Justification of Cognitive Domain

Create	Produce new or original work Design, assemble, construct, conjecture, develop, formulate, author, investigate.
Evaluate	Justify a stand or decision appraise, argue, defend, judge, select, support, value, critique, weigh.
Analyze	Draw connections among ideas differentiate, organize, relate, compare, contrast, distinguish, examine, experiment, question, test.
Apply	Use information in new situations execute, implement, solve, use, demonstrate, interpret, operate, schedule, sketch.
Understand	Explain ideas or concepts classify, describe, discuss, explain, identify, locate, recognize, report, select, translate.
Remember	Recall facts and basic concepts define, duplicate, list, memorize, repeat, state.

The categories after Knowledge were presented as "skills and abilities," with the understanding that knowledge was the necessary precondition for putting these skills and abilities into practice. Bloom's taxonomy / Cognitive Domain is frequently used for writing learning outcomes as it provides a ready-made structure and list of verbs. These verbs are the key to writing learning outcomes. Since, the outcomes are concerned with what the students can do at the end of the learning activity, all of these verbs are active (action words) verbs.
These "action words" describe the cognitive processes by which thinkers encounter and work with knowledge:

◇ **Remember**
1. Recognizing
2. Recalling

◇ **Understand**
1. Interpreting
2. Exemplifying
3. Classifying
4. Summarizing
5. Inferring
6. Comparing
7. Explaining

◇ **Apply**
1. Executing
2. Implementing

◇ **Analyze**
1. Differentiating
2. Organizing

3. Attributing

◇ **Evaluate**

1. Checking
2. Critiquing

◇**Create**

1. Generating
2. Planning
3. Producing

In the revised taxonomy, knowledge is at the basis of these six cognitive processes, but its authors created a separate taxonomy of the types of knowledge used in cognition:

◇ **Factual Knowledge**

1. Knowledge of terminology
2. Knowledge of specific details and elements

◇ **Conceptual Knowledge**

1. Knowledge of classifications and categories
2. Knowledge of principles and generalizations
3. Knowledge of theories, models, and structures

◇ **Procedural Knowledge**

1. Knowledge of subject-specific skills and algorithms
2. Knowledge of subject-specific techniques and methods
3. Knowledge of criteria for determining when to use appropriate procedures

◇ **Metacognitive Knowledge**

1. Strategic Knowledge
2. Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge
3. Self-knowledge

8 Knowledge and Attitude Profile (WK)

The list of WKs defines indicated volume of learning and attributes against which graduates must be able to perform. The list is used to extend and clarify the definition of the Program Outcomes.
In order to inculcate different dimensions of thinking mathematical, computational, design and creativeness among students in cognitive, affective and psychomotor domains, the curriculum is designed to cover the following nine knowledge and attitude profiles. These profiles reflect an indicated volume of learning and the work attitude against which graduates must be able to perform.
This list of WKs extracted verbatim from the 2024 NBA document are shown in Fig 2, and table 7 is representing their indicators of attainment.

1. Well-Defined Knowledge Profiles (WKs) specify the expected volume of learning and graduate attributes required for effective professional performance.

2. WKs help extend and clarify Program Outcomes (POs) by defining measurable knowledge, skills, and attitudes.

3. The curriculum is designed to develop mathematical, computational, design, and creative thinking abilities.
4. Learning is addressed across the cognitive, affective, and psychomotor domains.
5. A total of nine knowledge and attitude profiles are incorporated to ensure holistic graduate development.
6. These profiles reflect both the depth of learning and the work attitude expected from graduates.

TABLE 7: Knowledge and Attitude Profile (WK)

WK1	A systematic, theory-based understanding of the natural sciences applicable to the discipline and awareness of relevant social science.
WK2	Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline.
WK3	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
WK4	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.
WK5	Knowledge, including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area.
WK6	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.
WK7	Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development.
WK8	Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues.
WK9	Ethics, inclusive behavior and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability etc. with mutual understanding and respect, and of inclusive attitude.

KNOWLEDGE AND ATTITUDE PROFILE - KEY INDICATORS

TABLE 8: Key Indicator of Knowledge and Attitude Profile

WK No.	Knowledge & Attitude Profile	Key Indicators	No of Key Indicators
WK1	Engineering Knowledge & Natural Sciences	1. Principles of physics utilized in solving complex engineering problems. 2. Concepts of chemistry applied in analyzing engineering materials and processes. 3. Mathematical principles used for solving engineering problems. 4. Social science concepts integrated to address societal and environmental factors. 5. Discipline-specific engineering fundamentals applied in analysis and design.	5
WK2	Mathematical, Statistical & Data Analysis.	1. Algorithms and numerical methods applied in engineering analysis. 2. Statistical principles used to summarize data and draw conclusions. 3. Data cleaning, exploration, and visualization performed with ethical practices. 4. Analytical results interpreted, evaluated, and compared using appropriate tools.	4
WK3	Modelling & System Analysis.	1. Analytical models of engineering systems developed. 2. Numerical and empirical models developed to predict system behavior. 3. Physical models used to test and validate engineering assumptions. 4. Model accuracy and validity of assumptions evaluated.	4

WK4	Computational Tools & Digital Systems.	1. Computer systems used to store and manage large datasets. 2. Computational tools applied for simulation and modelling. 3. Data visualization techniques used for analysis and interpretation. 4. Limitations of computational tools and results evaluated.	4
WK5	Problem Identification & Engineering Analysis.	1. Constraints, requirements, and impacts of engineering problems identified. 2. Accurate and realistic problem statements formulated. 3. Analytical methods applied for problem investigation. 4. Assumptions and analytical outcomes validated.	4
WK6	Engineering Design, Sustainability & Safety.	1. Innovative and sustainable design solutions developed. 2. Feasibility evaluated considering technical, economic, and environmental factors. 3. Life-cycle analysis conducted for sustainability assessment. 4. Hazards identified and risk mitigation strategies applied. 5. Compliance with environmental and safety regulations ensured.	5
WK7	Engineering Management & Professional Practice.	1. Engineering management principles applied in decision-making. 2. Economic analysis performed for project implementation. 3. Resources, time, and budget managed effectively. 4. Professional responsibility demonstrated in engineering practice.	4

WK8	Research, Investigation & Critical Thinking.	1. Current research literature reviewed to identify gaps. 2. Experiments and investigations designed and executed. 3. Qualitative and quantitative research methods applied. 4. Data analyzed considering sources of error. 5. Valid conclusions drawn and justified. 6. Emerging technologies including Generative AI evaluated.	6
WK9	Ethics, Law, Diversity & Inclusivity.	1. Ethical responsibility and professional integrity demonstrated. 2. Laws, regulations, and professional codes applied in practice. 3. Ethical courses of action identified and justified. 4. Diversity is respected and inclusivity promoted in professional environments. 5. Ethical implications of emerging technologies evaluated.	5

9 Engineering Competence Profiles

A professionally or occupationally competent person has the attributes necessary to perform the activities within the profession or occupation to the standards expected in independent employment or practice. The engineering competence (EC) profiles - complex engineering problems (CP) and complex engineering activities (CA) record the elements of competence necessary for performance that the professional is expected to be able to demonstrate in a holistic way the stage of attaining registration. Complex Engineering Problems have characteristic WK1 and some or all of WK2 to WK9. Also, there are a Range of Complex Engineering Activities (CA) involved in when solving complex engineering problems.

Engineering competence can be described using a setoff attribute corresponding largely to the program outcomes (POs), but with different emphases. For example, at the professional level, the ability to the responsibility in the real-life situation is essential. Unlike the program outcomes, engineering competence is more than a set of attributes that can be demonstrated individually. Competence must be assessed holistically Seven elements of engineering competences for a global benchmarking is mentioned below.Complex Engineering Problems need to think broadly and systematically and see the big picture

TABLE 9: Engineering Competence Profiles

S No.	Keyword / Aspect	Description for Rubric Design	Category
EC1	**Depth of Knowledge Required**	Cannot be resolved without in-depth engineering knowledge at the level of one or more of WK3, WK4, WK5, WK6, or WK8, enabling a fundamentals-based and first-principles analytical approach.	CP
EC2	**Range of Conflicting Requirements**	Involve wide-ranging and often conflicting technical, engineering, economic, environmental, and societal issues.	CP
EC3	**Depth of Analysis Required**	Have no obvious solution and require abstract thinking, originality, and advanced analytical skills to formulate appropriate models and solution strategies.	CP
EC4	**Familiarity of Issues**	Involve issues that are infrequently encountered and not routine in professional engineering practice.	CP
EC5	**Extent of Applicable Codes**	Lie outside the scope of problems fully addressed by existing standards and codes of professional engineering practice.	CP
EC6	**Extent of Stakeholder Involvement & Level of Conflicting Requirements**	Involve diverse stakeholder groups with widely varying and often conflicting needs, expectations, and constraints.	CP
EC7	**Interdependence**	Represent high-level problems comprising many interdependent components or sub-problems that must be addressed holistically.	CP
EC8	**Design and Development of Solutions**	Support sustainable development solutions by ensuring functional requirements, minimizing environmental impact, and optimizing resource utilization throughout the life cycle while balancing performance and cost-effectiveness.	CA
EC9	**Infrequently Encountered Issues**	Conceptualize alternative engineering approaches and evaluate potential outcomes against appropriate criteria to justify an optimal solution choice.	CA
EC10	**Protection of Society**	Identify, quantify, mitigate, and manage technical, health, environmental, safety, economic, and other contextual risks to achieve sustainable outcomes in the designed engineering discipline.	CA
EC11	**Continuing Professional Development (CPD)**	Undertake CPD activities to maintain and extend competencies and enhance the ability to adapt to emerging technologies and the ever-changing nature of work.	CA
EC12	**Judgement**	Recognize complexity and assess alternatives in light of competing requirements and incomplete knowledge.	CA

1. Complex problems
2. Difficult decision
3. Uncertain strategy
4. Confusion idea
5. Contentious Product
6. Interactable change

The differences between technical problems and complex engineering problems based on various criteria is shown in Table below.

TABLE 10: Comparison Between Technical Problems and Complex Engineering Problems

Aspect	Technical Problems	Complex Engineering Problems
Definition	Problems with well-defined solutions requiring basic technical knowledge	Problems that are broad, ambiguous, and require advanced knowledge across multiple domains
Scope	Narrow and well-defined	Broad, involving multiple interconnected systems and disciplines
Difficulty Level	Stable and/or predictable problem parameters	Unstable and/or unpredictable problem parameters
Knowledge Requirement	Multiple low-risk experiments are possible	Multiple experiments may not be feasible
Solution Approach	Solutions are straightforward and based on standard practices	Solutions involve iteration, optimization, and may require novel approaches
No. of Solutions	Limited set of alternative solutions	No bounded set of alternative solutions
Uncertainty	Low uncertainty; variables are usually known and controlled	High uncertainty; may involve unknown variables and unpredictable factors
Example	Single optimal solution that can be clearly recognized and tested	No single optimal solution; solutions are not easily testable
Collaboration Needed	Usually solved by an individual or small team	Requires collaboration among large, diverse teams and stakeholders

10 Guidelines for writing Course Outcome Statements

A Course Outcome is a formal statement of what students should able to know, do and value by the end of the course. When creating Course Outcomes remember that the outcomes should clearly state what students will do or produce to determine and/or demonstrate their learning.
The CO statement is intended or desired learning gains, faculty members expect the students to develop, learn master during the course in terms of:

1. Declarative knowledge (factual, conceptual, procedural),
2. Functional knowledge (knowledge transfer),
3. Metacognitive knowledge (Improved Problem-Solving Skills)
4. Cognitive skills (Improved Critical Thinking, Stronger Analytical Skills and Greater Creativity)
5. Practical skills (Enhanced Technical Proficiency, Improved Application of Knowledge, Greater Adaptability, Increased Collaboration and Teamwork and Boosted Confidence in Real-World Tasks)
6. Habits of mind (Enhanced Persistence and Resilience, Greater Flexibility in Thinking, Increased Reflective Practice, Strengthened Ethical and Responsible Decision-Making)
7. Performance (Enhanced Skill Mastery, Stronger Communication and Presentation Skills) and
8. Ways to respond to events and people as a result of the learning experiences in the course/module.

It contains the measurable action verbs, the substance/content to be learned, and the targeted competency level.
A well-formulated set of Course Outcomes will describe what a faculty member hopes to successfully accomplish in offering their particular course(s) to prospective students, or what specific skills, competencies, and knowledge the faculty member believes that students will have attained once the course is completed. The learning outcomes need to be concise descriptions of what learning is expected to take place by course completion.

10.1 Developing Course Outcomes

When creating course outcomes consider the following guidelines as to develop them either individually or as part of a multi-section group:
10.1.1. Limit the course outcomes to 5-6 statements for the entire course [more detailed outcomes can be developed for individual units, assignments, chapters, etc. if the instructor(s) wish (es)].
10.1.2. Focus on overarching knowledge and/or skills rather than small or trivial details.
10.1.3. Focus on knowledge and skills that are central to the course topic and/or discipline.

10.1.4. Create statements that have a student focus rather than an instructor centric approach (basic e.g., “upon completion of this course students will be able to list the names of the 28 states and 8 union territories ” versus “one objective of this course is to teach the names of the 28 states and 8 union territories”).
10.1.5. Focus on the learning that results from the course rather than describing activities or lessons that are in the course.
10.1.6. Incorporate and/or reflect the institutional and departmental missions.
10.1.7. Include various ways for students to show success (outlining, describing, modelling, depicting, etc.) rather than using a single statement such as “at the end of the course, students will know” as the stem for each expected outcome statement.
10.1.8. The keywords used to define COs are based on Bloom’s Taxonomy When developing learning outcomes, here are the core questions to ask yourself:
10.1.9. What do we want students in the course to learn?
10.1.10. What do we want the students to be able to do?
10.1.11. Are the outcomes observable, measurable and are they able to be performed by the students?
Course outcome statements on the course level describe:

1. What faculty members want students to know at the end of the course and
2. What faculty members want students to be able to do at the end of the course? Course outcomes have three major characteristics
3. They specify an action by the students/learners that is observable
4. They specify an action by the students/learners that is measurable
5. They specify an action that is done by the students / learners rather than the faculty members.

Effectively developed expected learning outcome statements should possess all three of these characteristics. When this is done, the expected learning outcomes for a course are designed so that they can be assessed.
When stating expected learning outcomes, it is important to use verbs that describe exactly what the student(s)/ learner(s) will be able to do upon completion of the course.

Relationship of Course Outcome to Program Outcome The Course Outcomes need to link to the Program Outcomes. Use the following learning outcomes formula:

STUDENTS SHOULD BE ABLE TO + BEHAVIOR + RESULTING EVIDENCE
For example,
you can use the following template to help you write an appropriate course level learning outcome.
“Upon completion of this course students will be able to (knowledge, concept, rule or skill you expect them to acquire) by (how will they apply the knowledge or skill/how will you assess the learning).”

Characteristics of Effective Course Outcomes:

1. Describe what you want your students to learn in your course.
2. Are aligned with program goals and objectives.
3. Tell how you will know an instructional goal has been achieved.
4. Use action words that specify definite, observable behaviours.
5. Are assessable through one or more indicators (papers, quizzes, projects, presentations, journals, portfolios, etc.)
6. Are realistic and achievable
7. Use simple language

Examples of Effective Course Outcomes: After successful completion of the course, Students will be able to:

1. Critically review the methodology of a research study published in a scholarly sociology journal.
2. Design a Web site using HTML and JavaScript.
3. Describe and present the contributions of women to American history.
4. Recognize the works of major Renaissance artists.
5. Facilitate a group to achieve agreed-upon goals.
6. Determine and apply the appropriate statistical procedures to analyse the results of simple experiments.
7. Develop an individual learning plan for a child with a learning disability.
8. Produce a strategic plan for a small manufacturing business.
9. Analyse a character's motivation and portray that character before an audience.
10. Differentiate among five major approaches to literary analysis
11. List the major ethical issues one must consider when planning a human-subjects study.
12. Locate and critically evaluate information on current political issues on the Web.
13. List and describe the functions of the major components of the human nervous system.
14. Correctly classify rock samples found in...
15. Conduct a systems analysis of a group interaction.
16. Demonstrate active listening skills when interviewing clients.

17. Apply social psychological principles to suggest solutions to contemporary social problems.

A more detailed model for stating learning objectives requires that objectives have three parts: a condition, an observable behaviour, and a standard. The table 13 provides three examples. Relationship of Course Outcome to Program Outcome.The Course Outcomes need to link to the Program Outcomes. Use the following learning outcomes formula.

TABLE 11: Learning Objectives with Conditions, Observable Behaviour, and Standards

S.No	Learning Objective	Condition	Observable Behaviour	Standard
1	Students will be able to solve algebraic equations	Given a set of algebraic equations	Solve linear and quadratic algebraic equations	Correctly solve 90% of equations presented in the exercise
2	Students will be able to write an essay	After reading a provided article	Write a well-organized argumentative essay	The essay must have a clear thesis, supporting arguments, and a conclusion, with minimal grammatical errors
3	Students will be able to conduct a scientific experiment	With a laboratory kit and procedure manual	Set up and conduct an experiment	Conduct the experiment according to the procedure with no major errors, and record accurate data
4	Students will be able to use proper punctuation in writing	Given a short story to edit	Identify and correct punctuation errors in the text	Correct all punctuation errors with 95% accuracy
5	Students will be able to use critical thinking to solve problems	Given a complex case study	Analyse the problem and propose a solution	Provide a solution that addresses at least three key issues with logical reasoning

Continued on next page

S.No	Learning Objective	Condition	Observable Behaviour	Standard
6	Students will be able to present a research project	During a class presentation	Present findings to the class using visual aids	The presentation must be clear, within 10 minutes, and answer at least 3 questions from the audience
7	Students will be able to perform basic first aid	Given a first aid kit and a simulation scenario	Apply the correct first aid techniques to a simulated injury	Provide first aid for the scenario in accordance with standard first aid protocols, with no critical steps omitted
8	Students will be able to use a spreadsheet program	Using a computer with spreadsheet software	Create and format a spreadsheet with formulas	The spreadsheet must include at least 3 formulas and be formatted according to provided specifications
9	Students will be able to recognize historical events	Given a list of historical events and dates	Match events to the correct dates and locations	Correctly match 85% of the events with their corresponding dates and locations
10	Students will be able to participate in group discussions	In a small group setting	Contribute relevant ideas and respond to peers' comments	Contribute at least 3 relevant ideas and respond to at least 2 peers during the discussion

The following table 12, is the example describe a Course Outcome that is not measurable as written, an explanation for why the Course Outcome is not considered measurable, and a suggested edit that improves the Course Outcome.

TABLE 12: Improvement of Course Outcome Statement

Original Course Outcome	**Evaluation of Language Used in this Course Outcome**	**Improved Course Outcome**
Explore in depth the literature on an aspect of teaching strategies	"Exploration" is not a measurable activity, but the quality of the product of exploration can be measured using a suitable rubric.	Upon completion of this course, the students will be able to write a paper based on an in-depth exploration of the literature on an aspect of teaching strategies.

Examples that are TOO general and VERY HARD to measure...

1. will appreciate the benefits of learning a foreign language.
2. will be able to access resources at the Institute library.
3. will develop problem-solving skills.
4. will have more confidence in their knowledge of the subject matter.

Examples that are still general and HARD to measure...

1. value knowing a second language as a communication tool.
2. will develop and apply effective problem-solving skills that will enable one to adequately navigate through the proper resources within the institute library.
3. will demonstrate the ability to resolve problems that occur in the field.
4. will demonstrate critical thinking skills, such as problem solving as it relates to social issues.

Examples that are SPECIFIC and relatively EASY to measure...

1. will be able to read and demonstrate good comprehension of text in areas of the student's interest or professional field.
2. will demonstrate the ability to apply basic research methods in psychology, including research design, data analysis, and interpretation.
3. will be able to identify environmental problems, evaluate problem-solving strategies, and develop science-based solutions.
4. will demonstrate the ability to evaluate, integrate, and apply appropriate information from various sources to create cohesive, persuasive arguments, and to propose design concepts.

An Introspection - Examine Your Own Course Outcomes

1. If you have written statements of broad course goals, take a look at them. If you do not have a written list of course goals, reflect on your course and list the four to six most important student outcomes you want your course to produce.
2. Look over your list and check the one most important student outcome. If you could only achieve one outcome, which one would it be?
3. Look for your outcome on the list of Indicators of Attainment or outcomes society is asking us to produce. Is it there? If not, is the reason a compelling one?
4. Check each of your other ”most important” outcomes against the list of outcomes. How many are on the list of key competencies?
5. Take stock. What can you learn from this exercise about what you are trying to accomplish as a teacher? How clear and how important are your statements of outcomes for your use and for your students'? Are they very specifically worded to avoid misunderstanding? Are they supporting important needs on the part of the students?

10.2 Write Your Course Outcomes!

One of the first steps you take in identifying the expected learning outcomes for your course is identifying the purpose of teaching the course. By clarifying and specifying the purpose of the course, you will be able to discover the main topics or themes related to students' learning. Once discovered, these themes will help you to outline the expected learning outcomes for the course. Ask yourself:
10.2.1. What role does this course play within the program?
10.2.2. How is the course unique or different from other courses?
10.2.3. Why should/do students take this course? What essential knowledge or skills should they gain from this experience?
10.2.4. What knowledge or skills from this course will students need to have mastered to perform well in future classes or jobs?
10.2.5. Why is this course important for students to take?

11 CO-PO Course Articulation Matrix Mapping

Course Articulation Matrix shows the educational relationship (Level of Learning achieved) between Course Outcomes and Program Outcomes for a Course. This matrix strongly indicates whether the students are able to achieve the course learning objectives. The matrix can be used for any course and is a good way to evaluate a course syllabus.

Observations:

1. The first three POs are NBA given while the other three POs are program specific outcomes defined by department.
2. For the theory courses, while writing the COs, you need to restrict yourself between Blooms Level L1 to Level L4. Again, if it is a programming course, restrict yourself between Blooms Level L1 to Level L 3 but for the other courses, you can go up to Blooms Level L4.
3. For the laboratory courses, while composing COs, you need to restrict yourself between Blooms Level L1 to Level L5.
4. Only for Mini-project and Main project, you may extend up to Blooms Level 6 while composing COs.
5. For a given course, the course in-charge has to involve all the other Professors who teach that course and ask them to come up with the CO-PO mapping. The course in-charge has to take the average value of all of these CO-PO mappings and finalize the values or the course in-charge can go with what the majority of the faculty members prefer for. Ensure that none of the Professors who are handling the particular course discuss with each other while marking the CO-PO values.
6. If you want to match your COs with non-technical POs, then correlate the action verbs used in the course COs with the thumb rule given in the table and map the values. (Applies only for mapping COs to non-technical Pos).

11.1 Tips for Assigning the values while mapping COs to POs.

1. Select action verbs for a CO from different Bloom's levels based on the importance of the particular CO for the given course.
2. Stick on to single action verbs while composing COs but you may go for multiple action verbs if the need arises. You need to justify for marking of the values in CO-POs articulation matrix. Use
3. A combination of words found in the COs, POs and your course syllabus for writing the justification. Restrict yourself to one or two lines.
4. Values to CO-PO (technical POs in particular) matrix can be assigned by Judging the importance of the particular CO in relation to the POs. If the CO matches strongly with a particular PO criterion, then assign 3, if it matches moderately then assign 2 or if the match is low then assign 1 else mark with "-" symbol. If an action verb used in a CO is repeated at multiple Bloom's levels, then you need to judge which Bloom's level is the best fit for that action verb.

TABLE 13: Method for Articulation

Level	**Correlation Range (C)**	**Correlation Description**
0	$0 \leq C \leq 5\%$	No correlation
1	$5\% < C \leq 40\%$	Low / Slight
2	$40\% < C < 60\%$	Moderate
3	$60\% \leq C < 100\%$	Substantial / High

11.2 Method for Articulation

1. Identify the Indicators of Attainment POs to each CO and make a corresponding mapping table with assigning $\surd$ mark at the cell. One observation to be noted is that the first three POs are NBA given while the other three POs are program specific outcomes defined by department.

2. Justify each CO - PO mapping with a justification statement and recognize the number of Indicators Attainment (IA) features mentioned in the justification statement that are matching with the given Key Attributes for Assessing Program Outcomes. Use a combination of words found in the COs, POs and your course syllabus for writing the justification.

3. Make a table with number of Indicators of Attainment for CO – PO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.

4. Make a table with percentage of Indicators of Attainment for CO – PO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.

5. Finally, Course Articulation Matrix (CO - PO Mapping) is prepared with COs and POs and COs on the scale of 0 to 3, 0 being no correlation (marked with (“-”) , 1 being the low/slight correlation, 2 being medium/moderate correlation and 3 being substantial/high correlation based on the following strategy which is shown Table 14.

12 Competencies of Attainments for Assessing Program Outcomes

TABLE 14: Competencies of Attainments for Assessing Program Outcomes

PO No.	NBA Statement / Vital Features	Key Components	No.
PO1	Independently carry out research /investigation and development work to solve practical problems	1. Research problems in CAD/CAM are clearly identified and defined. 2. Literature review highlights research gaps and suitable methods. 3. Experiments or simulations are conducted using appropriate tools. 4. Data is collection, analyses, and interpretation systematically. 5. Innovative approaches are applied to engineering problem-solving. 6. Results are validated against established theories and standards	6
PO2	Write and present a substantial technical report/document.	1. Technical reports, dissertations, and papers are well-structured. 2. Referencing and academic integrity practices are properly maintained. 3. Content is presented with clarity,precision, and logical flow. 4. Oral communication and presentation skills are effectively demonstrated. 5. Digital tools are used for documentation and visualization. 6. Research findings are communicated to both technical and non-technical audiences.	6
PO3	Demonstrate a degree of mastery in Advanced Design and Manufacturing Technologies, including comprehensive knowledge of design methods, 3D printing processes, to support modern manufacturing.	1. Apply advanced design methodologies. 2. Demonstrate proficiency in additive manufacturing. 3. Integrate automation and digital manufacturing tools. 4. Analyze and optimize manufacturing systems. 5. Incorporate emerging smart technologies. 6. Promote sustainability and advanced material utilization.	6
PO4	Solve complex engineering challenges using computational and digital manufacturing tools, considering global issues and perspectives.	1. Modeling and Simulation for Problem Solving. 2. Digital Manufacturing Tools and Technologies. 3. Global and Sustainable Perspectives. 4. Emerging Technologies for Complex Challenges.	4
PO5	Apply advanced knowledge, techniques, and skills along with CAD/CAM technologies to address engineering and manufacturing challenges, emphasizing innovation and sustainable development.	1. Advanced Modeling and CAD/CAM Integration. 2. Innovative Design and Product Development. 3. Manufacturing Process Optimization. 4. Sustainable Manufacturing Practices. 5. Prototyping and Validation with Emerging Technologies. 6. Global and Ethical Perspectives in Engineering.	6

PO No.	NBA Statement / Vital Features	Key Components	No.
PO6	Engage in life-long learning and professional development to adapt to evolving technologies and industry practices.	1. Continuous Knowledge Upgradation. 2. Research and Innovation Skills. 3. Adaptation to Digital Transformation. 4. Interdisciplinary Learning. 5. Professional Skill Development. 6. Global and Ethical Awareness. 7. Self-Directed and Lifelong Learning. 8. Adaptability to Industry Practices.	8

13 Adopting United Nations Sustainable Development Goals in Engineering Program

The Engineering Programs are vital for achieving sustainable development while addressing socio-economic issues and challenges envisaged in United Nation's Sustainable Development Goals (UNSDGs), as shown in Figure 3.

FIGURE 3: United Nation's Sustainable Development Goals (UNSDGs)

Concept Note on the Incorporation of UN SDGs in Curriculum

The United Nations' Sustainable Development Goals (SDGs) provide a global framework for addressing pressing societal and environmental challenges. In the context of engineering education and curriculum, integrating sustainable solutions is essential to contribute towards achieving these SDGs. This note explores how complex engineering problem (CEP) solving and complex engineering activities (CEAs) can align with specific SDGs and emphasizes the role of engineering in promoting sustainable development.

The CEP solving and CEAs play a pivotal role in developing innovative solutions that address societal challenges, fostering sustainable development. Thus, the analysis of a complex engineering problem needs to include consideration for sustainable development in the light of UN SDGs. Prospective sustainable solution

resulting from a CEP-solving activity or CEA can be related to specific SDG(s).
It is pertinent to mention that is not mandatory for an HEI to map all 17 SDGs with its engineering program. Only those SDGs may be mapped which are covered in CEP solving activities, CEAs, semester projects, open-ended labs, capstone projects or co-and-extra-curricular activities with holistic consideration for sustainable development.
The documentation or any deliverable of the activity will stand as evidence of the addressal of the respective SDG. For example, embedding renewable energy concepts, such as solar and wind power, into class / lab CEPs / CEAs and final year/ capstone projects can align them with the targets set of for SDG-7. Similarly, focusing on cutting -edge technologies like the Internet of Things (IoT) and smart grids in class / lab projects and final-year projects can work for SDG-9. By addressing CEPs / CEAs aligned with specific SDGs, engineers can contribute significantly to global efforts to build a more sustainable and equitable word.
The effectiveness of the incorporation of SDG targets in class / lab projects or CEPs / CEAs can be further enhanced by encouraging the students to:

1. Include Life Cycle Assessment (LCA) methods in class / lab projects or CEPs / CEAs to evaluate the environmental impact of products and systems.
2. Collaborate with the students of other disciplines to address interconnected changes.
3. Emphasize the use of sustainable materials and manufacturing processes in the design and production of components.
4. Access the social implications of their projects, considering factors like community well-being, accessibility, and inclusivity.

14 Correlation Matrix POs – ECs – WKs – SDGs

A correlation matrix has been established to link Program Outcomes (POs) with the corresponding engineering competencies, knowledge and attitude profiles, as well as the targeted UN Sustainable Development approved by NBA is shown in table.

TABLE 15: Program Outcomes (POs), Engineering Competencies (ECs), Washington Accord Knowledge Profiles (WKs) and Sustainable Development Goals (SDGs)

POs	ECs	WKs	SDGs
Independently carry out research /investigation and development work to solve practical problems	EC7:Rangeofresources EC11: Continuing Professional Development(CPD) EC12:Judgemen	WK-2: Mathematics and Computing WK-5:Engineering Design and Operation WK-8:ResearchLiterature	SDG-9, 13.
Write and present a substantial technical report/document	EC8:Extent of stakeholder involvement EC10: Interdependence	WK-1: Natural Sciences and Awareness of Relevant Social Sciences WK-9:Ethics, Inclusive Behaviour and Conduct	Selected SDGs from SDG 5, 10, 16.

POs	ECs	WKs	SDGs
Demonstrate a degree of mastery in Advanced Design and Manufacturing Technologies, including comprehensive knowledge of design methods, 3D printing processes,to support modern manufacturing.	EC2: Depth of analysis required EC4: Range of conflicting requirements EC5: Infrequently encountered issues EC8: Extent of stakeholder involvement EC10: Interdependence	WK-1:Natural Sciences and Awareness of Relevant Social Sciences WK-2:Mathematics&Computing WK-3:EngineeringFundamentals WK-4: Engineering Specialist Knowledge WK-5: Engineering Design and Operations WK-6:EngineeringPractices	Selected SDGs from SDG 1–17
Solve complex engineering challenges using computational and digital manufacturing tools, considering global issues and perspectives.	EC2: Depth of analysis required EC4: Range of conflicting requirements EC5: Infrequently encountered issues EC8: Extent of stakeholder involvement EC10: Interdependence	WK-1:Natural Sciences and Awareness of Relevant Social Sciences WK-2:Mathematics&Computing WK-3:EngineeringFundamentals WK-4: Engineering Specialist Knowledge WK-5: Engineering Design and Operations WK-6:EngineeringPractices	Selected SDGs from SDG 1–17
Apply advanced knowledge, techniques, and skills along with CAD/CAM technologies to address engineering and manufacturing challenges, emphasizing innovation and sustainable development.	EC6:ProtectionofSociety EC9: Extent of applicable Codes,Legal and Regulatory	WK-1:Natural Sciences and Awareness of Relevant Social WK-5:Engineering Design and Operations WK-7:Engineering in Society WK-9:Ethics, Inclusive Behaviour and Conduct	Selected SDGs from SDG 1–17
Engage in life-long learning and professional development to adapt to evolving technologies and industry practices.	EC11: Continuing Professional Development (CPD) EC12:Judgement	WK-8:Research Literature	Selected SDGs from SDG 1–17

ECs are expected to be demonstrated by graduates during their practical experiences, which have been mapped with POs to reflect integration in the designed curriculum.

The relationship matrix has been generically designed as a guiding framework and is applicable to all engineering disciplines. When interpreting the matrix within a specific context revisions or amplifications may be incorporated to highlight particular emphasis or compliance with rationalized program requirements.

Program Outcomes attained through course modules:

Courses offered in M. Tech CAD / CAM Curriculum (MLRS-R24) and POs attained through course modules for I, II, III and IV semesters.

15 Methods for measuring Learning Outcomes and Value Addition:

There are many different ways to assess student learning. In this section, we present the different types of assessment approaches available and the different frame works to interpret the results.

i) Continuous Internal Assessment (CIA)

ii) Comprehensive Assessment Tools (CAT)
iii) Semester end examination (SEE)
iv) Laboratory and project work
v) Course end survey
vi) Program exit survey
vii) Alumni survey
viii) Employer survey
ix) Program Assessment and Quality Improvement Committee (PAQIC)
x) Department Advisory Board (DAB)
xi) Faculty meetings
xii) Professional societies

The above assessment indicators are detailed below.

15.1 Continuous Internal Assessment (CIA)

Two Continuous Internal Examinations (CIEs) are conducted for all courses by the department. All students must participate in this evaluation process. These evaluations are critically reviewed by HOD and senior faculty and the essence is communicated to the faculty concerned to analyze, improve and practice so as to improve the performance of the student.

15.2 Comprehensive Assessment Tools (CAT)

This CAT enables faculty to design own assessment patterns during the CIA. The CAT converts the classroom into an effective learning center. The CAT may include tutorial hours/classes, seminars, assignments, term paper, open ended experiments, METE (Modeling and Experimental Tools in Engineering), five minutes video, MOOCs etc. The CAT chosen for this course is given in table.

15.3 Semester End Examination (SEE)

The semester end examination is conducted for all the courses in the department. Before the Semester end examinations course reviews are conducted, feedback taken from students and remedial measures will be taken up such that the student gets benefited before going for end exams. The positive and negative comments made by the students about the course are recorded and submitted to the department advisory board (DAB) and to the principal for taking necessary actions to better the course for subsequent semesters.

15.4 Laboratory and Project Works

The laboratory work is continuously monitored and assessed to suit the present demands of the industry. Students are advised and guided to do project works giving solutions to research / industrial problems to the extent possible by the capabilities and limitations of the student. The results of the assessment of the individual projects and laboratory work can easily be conflated in order to provide the students with periodic reviews of their overall progress and to produce terminal marks and grading.

15.5 Course End Survey

Students are encouraged to fill-out a brief survey on the fulfillment of course objectives. The data is reviewed by the concerned course faculty and the results are kept open for the entire faculty. Based on this, alterations or changes to the course objectives are undertaken by thorough discussions in faculty and DAB meetings.

15.6 Programme Exit Survey

The programme exist questionnaire form is to be filled by all the students leaving the institution. The questionnaire is designed in such a way to gather information from the students regarding the program educational objectives, solicit about program experiences, carrier choices, as well as any suggestions and comments for the improvement of the program. The opinions expressed in exit interview forms are reviewed by the DAB for implementation purposes.

15.7 Alumni Survey

The survey asks former students of the department about the status of their employment and further education, perceptions of institutional emphasis, estimated gains in knowledge and skills, involvement a sunder graduate student, and continuing involvement with Institute of Aeronautical Engineering. This survey is administered every three years. The data obtained will be analyzed and used in continuous improvement.

15.8 Employer Survey

The main purpose of this employer questionnaire is to know employer's views about the skills they require of employees compared to the skills actually possessed by them. The purpose e is also to identify gaps in technical and vocational skills, need for required training practices to fill these gaps and criteria for hiring new employees. These employer surveys are reviewed by the department advisory board (DAB) to affect the present curriculum to suit the requirement so the employer.

15.9 Programme Assessment and Quality Improvement Committee (PAQIC)

PAQIC Monitors the achievements of Program Outcomes (POs), and Program Educational Objectives (PEOs). It will evaluate the program effectiveness and proposes the necessary changes. It also prepares the periodic reports on program activities, progress, status or other special reports for management. It also motives the faculty and students towards attending workshops, developing projects, working models, paper publications and engaging in research activities.

15.10 Department Advisory Board (DAB)

Departmental Advisory Board plays an important role in the development of the department. Department level Advisory Board will be established for providing guidance and direction for qualitative growth of the department. The Board interacts and maintains liaison with key stakeholders. DAB will Monitor the progress of the program and develop or recommend the new or revised goals and objectives for the program. Also, the DAB will review and analyze the gaps between curriculum and Industry requirement and gives necessary feedback or advices to be taken to improve the curriculum.

15.11 Faculty Meetings

The DAB meets bi-annually for every academic year to review the strategic planning and modification of PEOs. Faculty meetings are conducted at least once in fortnight for ensuring the implementation of DAC's suggestions and guidelines. All these proceedings are recorded and kept for the availability of all faculties.

15.12 Professional Societies

The importance of professional societies like ASME, SAE etc., are explained to the students and they are encouraged to become members of the above to carry out their continuous search for knowledge. Student and faculty chapters of the above societies are constituted for a better technical and entrepreneurial environment. These professional societies promote excellence in instruction, research, public service and practice.

16 CO - Assessment processes and tools:

Course outcomes are evaluated based on two approaches namely direct and indirect assessment methods. The direct assessment methods are based on the Continuous Internal Assessment (CIA) and Semester End Examination (SEE) whereas the indirect assessment methods are based on the course end survey and program exit survey provided by the students, Alumni and Employer. The weightage in CO attainment of Direct and Indirect assessments are illustrated in Table.

TABLE 16: Assessment Methods and Weightage in CO Attainment

Assessment Method	**Assessment Tool**	**Weightage in CO attainment**
Direct Assessment	Continuous Internal Assessment	80%
	Semester End Examination	
Indirect Assessment	Course End Survey	20%

16.1 Direct Assessment:

Direct assessment methods are based on the student's knowledge and performance in the various assessments and examinations. These assessment methods provide evidence that a student has command over a specific course, content, or skill, or that the students work demonstrates a specific quality such as creativity, analysis, or synthesis. The various direct assessment tools used to assess the impact of delivery of course content is listed in Table 21.

16.1.1. Continuous internal examination, semester end examinations, CAT (includes assignment, 5 minutes videos, seminars etc.) and quiz are used for CO calculation.

16.1.2. The attainment values are calculated for individual courses and are formulated and summed for assessing the POs.

16.1.3. Performance in CAT is indicative of the student's communication skills.

Table 20: The direct assessment tools used to assess the impact of delivery of course content

- Continuous internal examination, semester end examinations, CAT (includes assignment, 5 minutes videos, seminars etc.) and qiuz are used for CO calculation.
- The attainment values are calculated for individual courses and are formulated and summed for assessing the POs.
- Performance in CAT is indicative of the student's communication skills.

TABLE 17: Assessment Components and Evaluation Pattern

S No	Courses	Components	Frequency	Max. Marks	Evidence
1	Core / Elective	Continuous Internal Examination	Twice in a semester	20	Answer script
		Assignment	Twice in a semester	10	Answer script
		Comprehensive Assessment Tools (CAT)	Twice in a semester	10	Concept Video / Quiz / Hackathons / MOOCs / Tech Talks
		Semester End Examination (SEE)	Once in a semester	60	Answer scripts
2	Laboratory	Day to Day experiment	Once in a week	10	Work sheets
		Internal Examination	Twice in a Semester	10	Answer scripts
		Viva-Voce / Case Study	Twice in a Semester	10	Report
		Laboratory Report/Open Ended Experiment/Project & Presentation/Global Certifications	Once in a Semester	10	Report
		Semester End Examination	Once in a semester	60	Answer script

16.2 Indirect Assessment:

Course End Survey - In this survey, questionnaires are prepared based on the level of understanding of the course and the questions are mapped to Course Outcomes. The tools and processes used in indirect assessment are shown in Table.

TABLE 18: Tools used in Indirect assessment

Tools	Process	Frequency
Course end survey	• Taken for every course at the end of the semester • Gives an overall view that helps to assess the extent of coverage/ compliance of COs • Helps the faculty to improve upon the various teaching methodologies	Once in a semester

Direct Tools: (Measurable in terms of marks and w.r.t. CO) Assessment done by faculty at department level
Indirect Tools: (Non measurable (surveys) in terms of marks and w.r.t. CO) Assessment done at institute level.

17 PO - Assessment tools and Processes

The institute has the following methods for assessing attainment of POs.

1. Direct method
2. Indirect method

The attainment levels of course outcomes help in computing the PO based upon the mapping done.

TABLE 19: Attainment of PO

	Assessment	Tools	Weight
POs Attainment	Direct Assessment	CO Attainment of courses	80%
	Indirect Assessment	Program exit survey	20%
		Alumni survey	
		Employer survey	

The CO values of both theory and laboratory courses with appropriate weightage as per CO-PO mapping, as per Program Articulation Matrix are considered for calculation of direct attainment of POs.

17.1 PO Direct Attainment is calculated using the following rubric:

PO Direct Attainment = (Strength of CO-PO)*CO attainment / Sum of CO-PO strength.

The below figure represents the evaluation process of POs attainment through course outcome attainment.

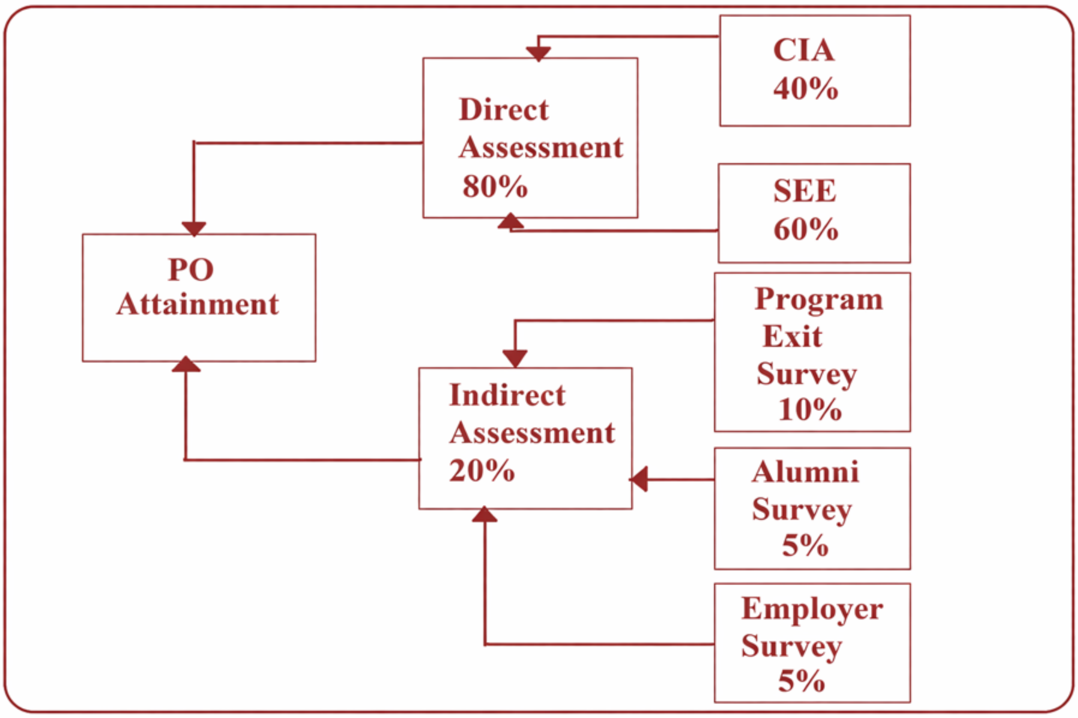

FIGURE 4: Evaluation process of POs attainment