MLRS-R24

OBE Hand Book

Department of MechanicalEngineering

MARRI LAXMAN REDDY
INSTITUTE OF TECHNOLOGY
AND MANAGEMENT

OVERVIEW

Outcome Based Education (OBE) is the foundation of quality assurance in higher technical education, especially in postgraduate programs like M.Tech.
Unlike traditional models that focus on syllabus completion, OBE emphasizes what students are able to do at the end of the program.

Key Focus of OBE

- Clearly defined and measurable learning outcomes
- Alignment of teaching–learning activities with outcomes
- Continuous assessment and feedback
- Student-centric and competency-driven education

Role of Faculty in OBE

Faculty members function as:

- **Instructors** – delivering core concepts
- **Facilitators** – guiding active learning
- **Trainers** – developing professional and technical skills
- **Mentors** – supporting academic and research growth

OBE Framework – Levels of Outcomes

The OBE system is structured across four key levels:

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

These outcomes ensure graduates develop:

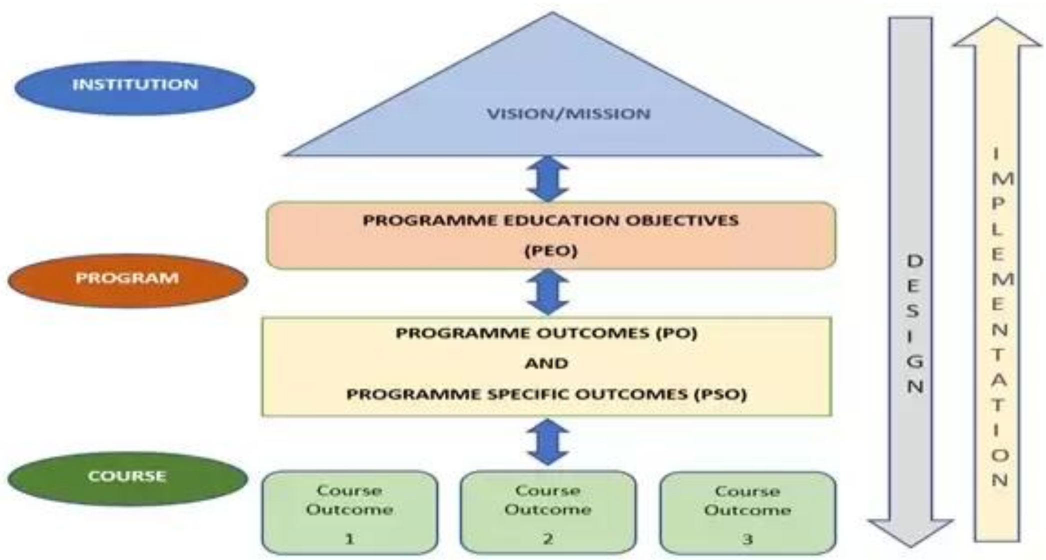
- Advanced technical expertise
- Research and innovation capability
- Professional ethics and social responsibility
- Lifelong learning skills

Why OBE for M.Tech Programs?

- Facilitates international recognition of qualifications
- Enhances global employability and mobility
- Produces highly skilled and research-oriented graduates
- Strengthens industry relevance and leadership potential
- Improves institutional reputation and accreditation readiness
- Encourages stakeholder participation (students, faculty, alumni, industry)

Key Features of Outcome Based Education

- Transparent and measurable learning achievement
- Improved student engagement and ownership of learning
- Strong linkage between curriculum, assessment, and outcomes
- Continuous improvement through feedback and analysis
- Alignment with global engineering standards



About NBA Accreditation

The concept of OBE gained global recognition through international accreditation frameworks such as the Washington Accord (1989)**,** which emphasized that engineering education should be outcome-oriented rather than input-oriented. The Accord established equivalence of accredited engineering programs among signatory countries based on the achievement of outcomes and graduate attributes rather than traditional curriculum content or duration.

India became a permanent signatory to the Washington Accord in 2014 through the National Board of Accreditation (NBA)**.** This marked a major shift in India's higher education evaluation system—from a system based on syllabus and content coverage to one that measures the attainment of Course Outcomes (COs), Program Outcomes (POs), and Program Educational Objectives (PEOs)**.**

The NBA accreditation framework has undergone several refinements to improve the quality and global recognition of technical education:

- **2013:** Introduction of the first comprehensive OBE-based accreditation format aligned with Washington Accord graduate attributes.
- **2017:** Inclusion of CO–PO mapping, assessment tools, and continuous improvement metrics.
- **2021:** Integration of digital evidence, innovation, entrepreneurship, and sustainability indicators into the Self-Assessment Report (SAR).
- **2024:** Launch of Graduate Attributes and Professional Competencies, emphasizing knowledge attributes (K1–K6 levels), skills, and attitudes in accordance with international educational standards.

Benefits of Outcome-Based Education

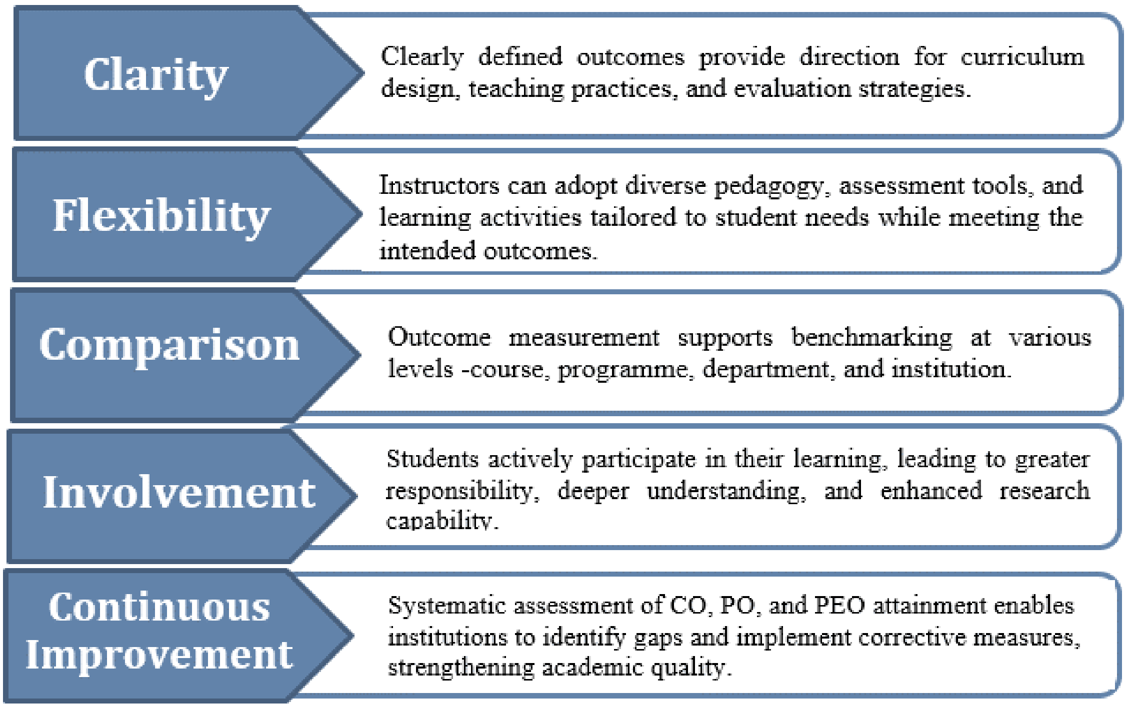


Figure 2: Benefits of Outcome Based Education

VISION OF THE INSTITUTE

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.

MISSION OF THE INSTITUTE

- 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.

QUALITY POLICY

- Ensure excellence in education through innovative teaching and continuous improvement.
- Promote ethical, skilled, and employable graduates who drive sustainable technologies.
- Encourage research, industry collaboration, and community engagement for societal benefit.

PHILOSOPHY

At Marri Laxman Reddy Institute of Technology and Management, we believe that the true essence of meaningful education lies in the pursuit of truth—one that removes ignorance and empowers individuals. Education is viewed not merely as the transfer of knowledge, but as a powerful instrument for liberation, empowerment, and societal transformation.

Holistic Development Approach

- The Institute emphasizes:
- promoting scientific inquiry, technological innovation, and academic excellence aligned with societal and environmental needs.
- Rigorous research and advanced technical learning
- Development of professional competence with strong ethical values
- Harmony between technological growth, nature, and society
- Collaboration with local communities
- Active global engagement for socially relevant education
- Nurturing well-rounded, ethically grounded, and socially conscious professionals
- Preparing graduates for meaningful contributions to industry, academia, and society

CORE VALUES

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

Integrity:
Adheres to the principles of honesty, trust worthiness, 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 in order to find solutions and advance knowledge.

OBE IMPLEMENTATION FRAMEWORK

Vision and Mission Statements
The Vision and Mission of the Institute and each Department are defined and reviewed to ensure alignment with institutional goals and societal needs.

Program Educational Objectives (PEOs)
PEOs describe the career and professional achievements that graduates are expected to attain a few years after completing the program.

Program Outcomes (POs)
POs represent the graduate attributes as defined by the NBA, while some POs reflect the discipline specific skills that students acquire during the program.

Identify Knowledge and Attitude Profiles (WKs)
The required knowledge, skills, and attitudes are mapped as per international engineering education standards.

Engineering Competencies (ECs)
Engineering competencies are identified based on the ability to solve complex engineering problems and perform complex engineering activities.

Course Outcomes (COs)
Each course specifies well-defined and measurable Course Outcomes, written using Bloom's Taxonomy action verbs to indicate the level of learning (Remember, Understand, Apply, Analyse, Evaluate, Create).

Map Courses with POs
Each course outcome (CO) is mapped to relevant program outcomes (POs) to ensure alignment.

Map Topics with Course Outcomes
Every topic or module within a course is linked to one or more COs for structured delivery and assessment.

Prepare Course Lesson Plan and Schedule of Instruction
Lecture-wise lesson plans are prepared indicating learning objectives, teaching pedagogies, and assessment components.

Pedagogical Tools
Appropriate pedagogical tools are chosen for effective delivery of course outcomes such as case studies, group discussions, flipped classrooms, and problem-based learning

Define Self-Learning and Team Work Activities
Activities like tutorials, practical sessions, seminars, projects, and assignments are designed to enhance self-learning and practical understanding.

Use of Learning Management System (LMS)
The Anvaya and Akshara Learning Management Portal is used for complete course management, including lesson plans, assessments, and feedback.

Assessment and Attainment Analysis
The OBE module in Anvaya is used to measure the attainment of each Course Outcome (CO) through both direct and indirect assessments.

Performance Tracking and Continuous Improvement
Student performance is tracked continuously, and results are analysed to identify strengths and areas for improvement.

Curriculum Gap Analysis
Gaps between curriculum outcomes and industry requirements are identified and bridged through additional learning modules, workshops, and expert lectures.

Program Outcome Attainment Review
PO attainment levels are compared for the past three academic years. Remedial actions are proposed and implemented based on the analysis.

Program Educational Objectives (PEO) Assessment
PEO attainment is assessed periodically using alumni feedback, employer surveys, and higher studies/placement data.

VISION OF THE DEPARTMENT

The Mechanical Engineering Department strives to foster innovation, excellence and leadership in education and research, advancing sustainable development globally.

MISSION OF THE DEPARTMENT

DM1: To provide innovative and sustainable technology solutions to solve a wide range of complex scientific and technological challenges in the Mechanical Engineering field.
DM2: To enhance employability, leadership skills, and research capabilities through industry collaboration and experimental learning.
DM3: To nurture students as ethical and resilient professionals committed to lifelong learning.
DM4: To promote excellence in emerging interdisciplinary fields to support global progress.

PROGRAM EDUCATIONAL OBJECTIVES

Program Educational Objectives (PEOs) are defined by the Head of the Department in consultation with various stakeholders such as industry experts, employers, alumni, and students. PEOs represent the department's commitment to prospective students, outlining what graduates are expected to achieve few years after completing the program.

PEO1: To develop a strong foundation in mechanical engineering principles for analyzing, designing, and innovating engineering solutions.

PEO2: To equip graduates with skills and knowledge to address industry challenges and contribute effectively to societal needs.

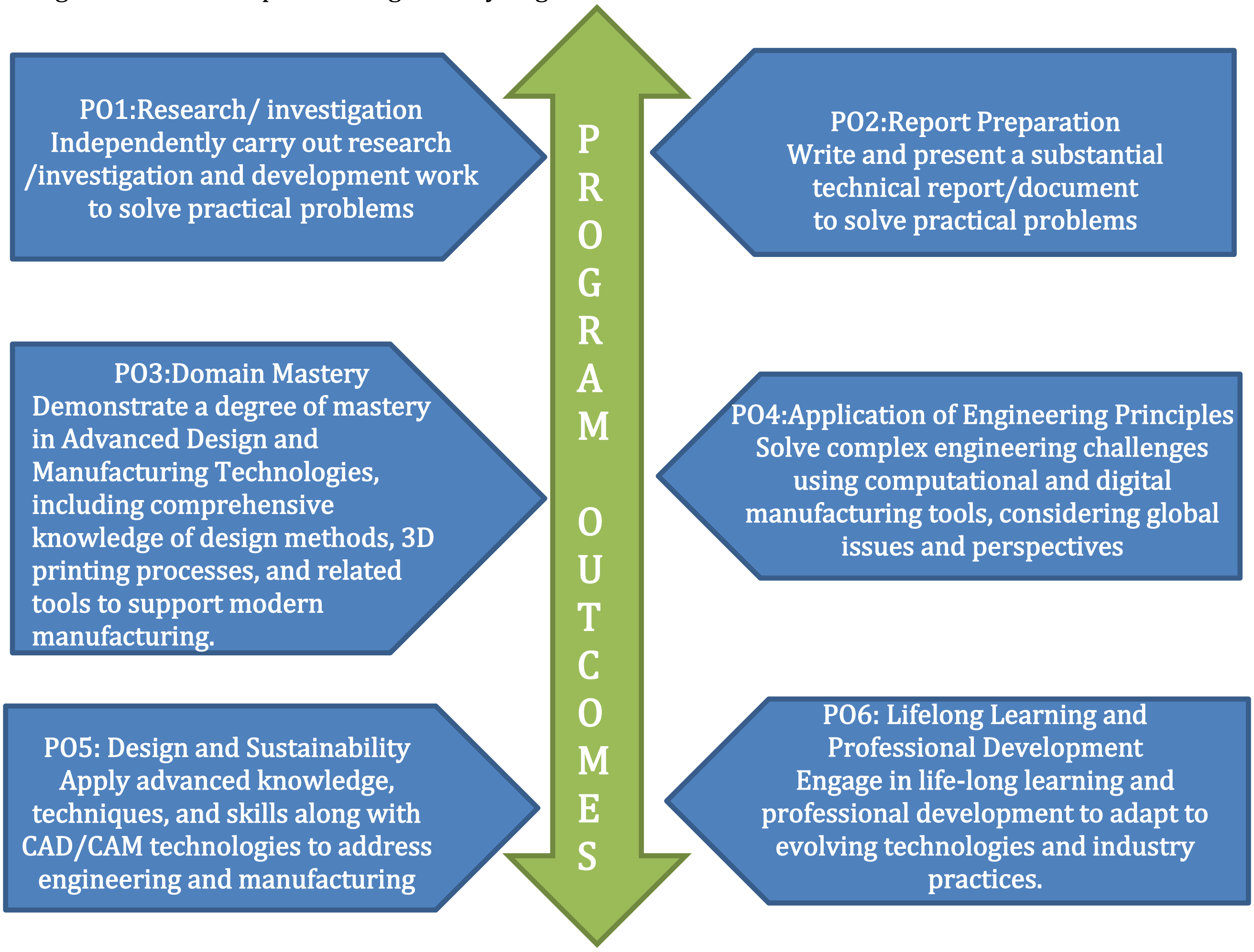
PEO3: To foster the ability to collaborate across multidisciplinary teams while upholding professional ethics and responsibility.

PEO4: To promote lifelong learning, adaptability, and leadership skills for continuous personal and professional growth in a dynamic environment.

PROGRAM OUTCOMES

Program Outcome (PO) is broad in scope and describes what a student is expected to achieve at the end of the program. Program Outcomes (POs) should be specific, measurable, and achievable.

Out of the six POs, three are defined by the NBA and are common to all institutions in India, remaining three are program-specific, framed by the department to reflect specialization in CAD/CAM. For Postgraduate Programs POs descriptions are generally aligned with national standards



NBA-Defined Common POs

1. Research/ investigation
2. Report Preparation
3. Domain Mastery

Department Defined Program Outcomes

4. Application of Engineering Principles
5. Design and Sustainability
6. Lifelong Learning and Professional Development

RELATION BETWEEN PEOs AND POs

The relationship between Program Educational Objectives (PEOs) and Program Outcomes (POs) is essential, as it ensures that the long-term goals of the program are systematically aligned with measurable outcomes attained by students during the course of study. Establishing this alignment helps the department verify that the curriculum, teaching–learning processes, assessments, and continuous improvement practices are effectively preparing graduates for professional careers, higher education, lifelong learning, and societal contribution. The broad correlation between the PEOs and POs is presented in Figure 4.

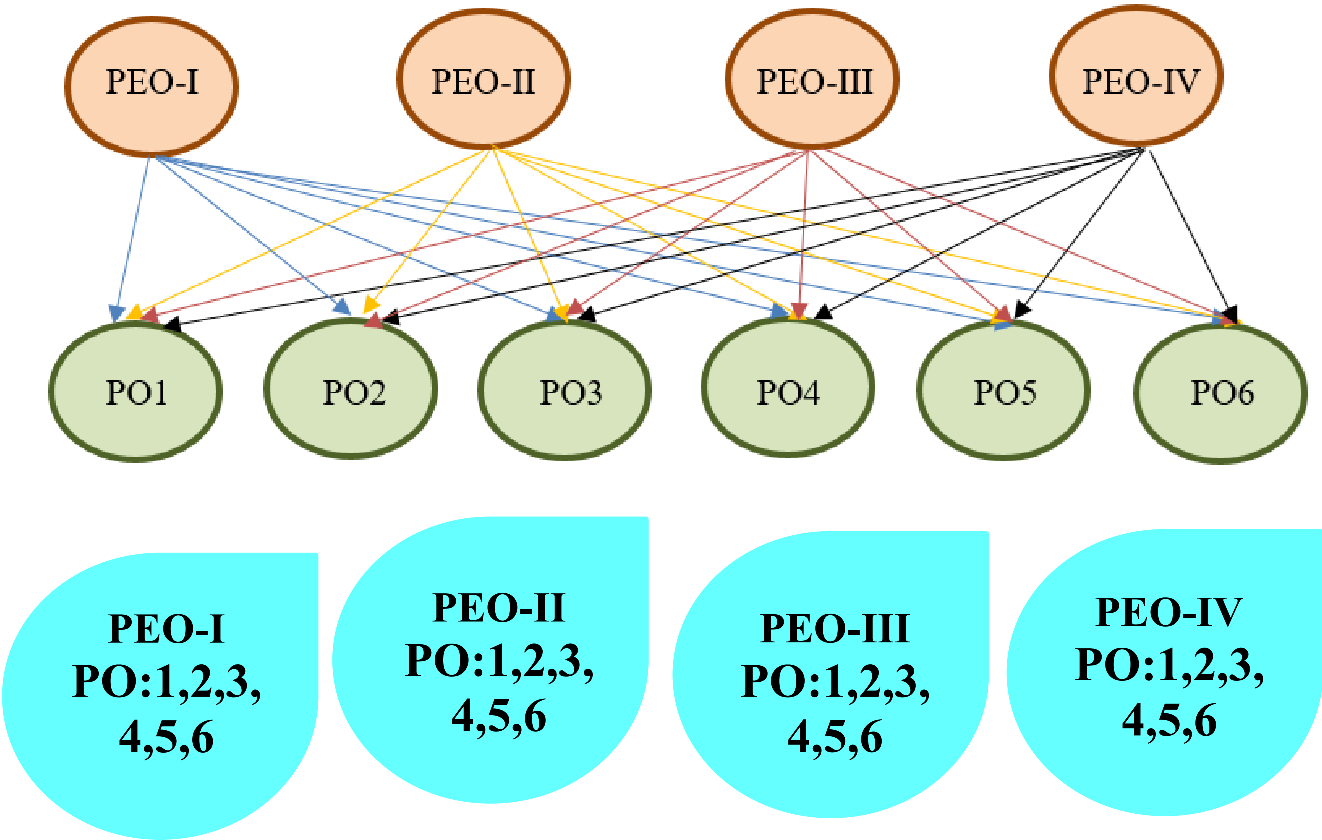
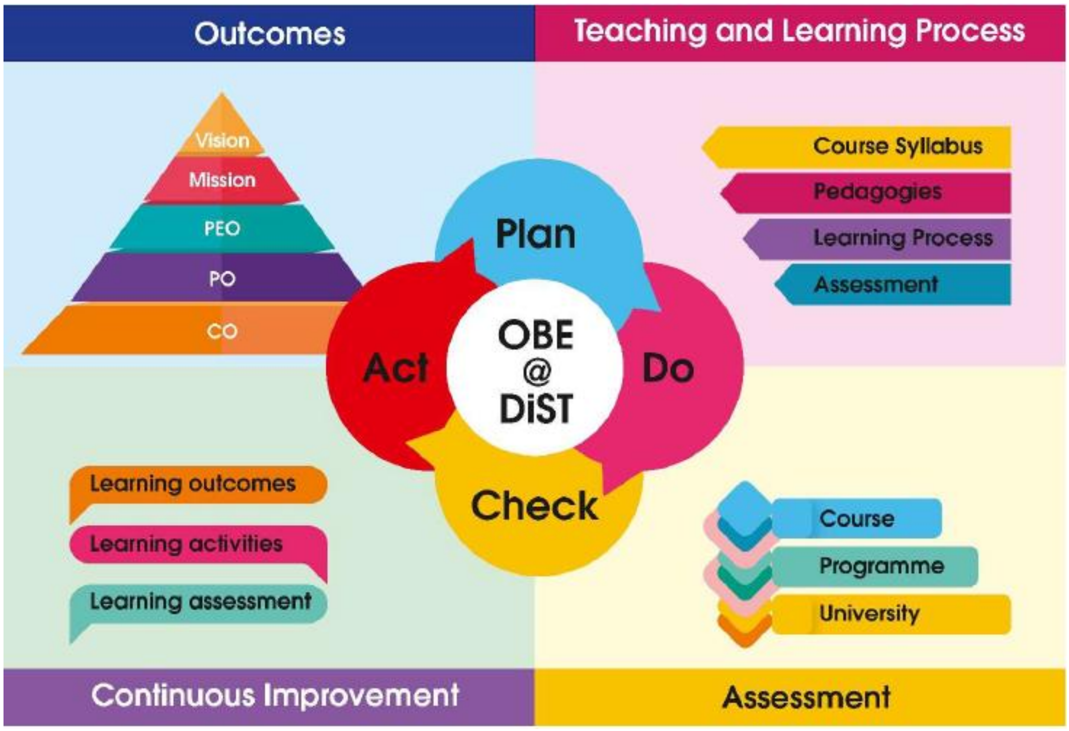


Figure 4: Correlation between the PEOs and the POs



The detailed mapping illustrating the extent to which each Program Outcome contributes to the attainment of the Program Educational Objectives is shown in Table 1.

Table 1. Relation between the Program Educational Objectives and the POs

PEO's→ ↓PO's		(1) Strong Foundation in ME principles	(2) Industry & societal problem solving	(3) Teamwork, ethics & responsibility	(4) Lifelong learning & leadership
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

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

Note: PO assessment is carried out through both direct and indirect assessment procedures.

Direct Assessment is conducted through:

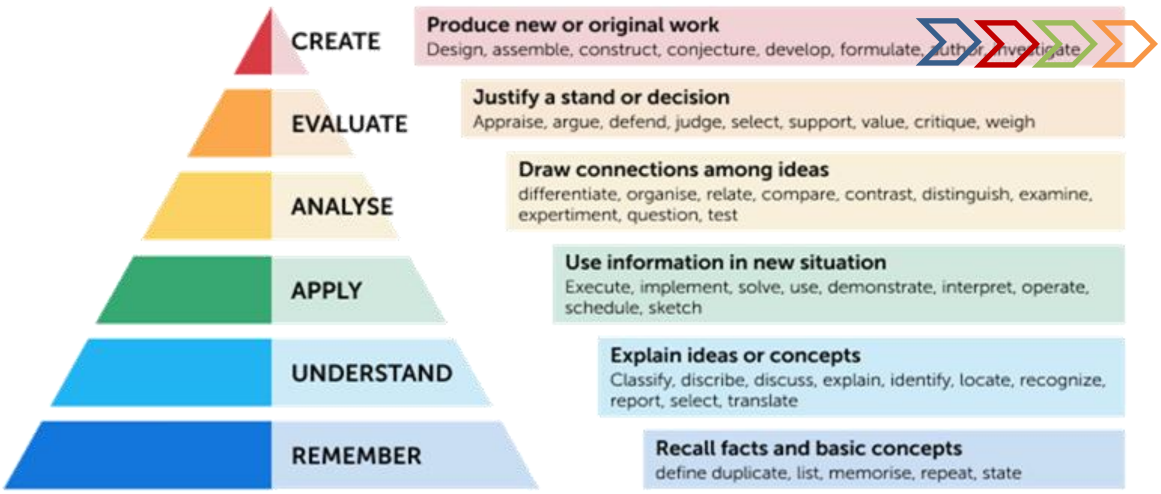
- Continuous Internal Evaluation (CIE),
- CAT and Assignments/Quiz, and
- Semester-end examinations.

Indirect Assessment is carried out through:

- Program Exit Surveys from graduating students,
- Alumni Surveys, and
- Employer/Employment Surveys.

About Blooms Taxonomy

Bloom's Taxonomy is widely recognized as the global language of education. It is extensively used by educators for framing Course Outcomes, as it offers a well-defined hierarchical structure along with a comprehensive list of measurable action verbs. This structured approach helps ensure clarity, consistency, and alignment between learning objectives, teaching strategies, and assessment methods. A concise overview of the revised Bloom's Taxonomy of critical thinking, proposed by Anderson and Krathwohl, is presented in the figure below.



DIFFERENT LEVELS OF THINKING SKILLS IN BLOOMS TAXONOMY

Remember

- This is the foundation of learning, where students recall basic information such as facts, definitions, formulas, events, and important concepts.
- Students may be asked to:
  - Recall definitions or key terms from a chapter
  - List steps in a process
  - Identify important dates, people, or events
  - Recognize symbols, diagrams, or formulas
- This level includes recognizing and recalling information from memory.

Understand

- At this level, students demonstrate that they comprehend the meaning of what they have learned. They should be able to explain ideas in their own words or interpret information.
- Examples of tasks include:
  - Explaining the concept behind
  - Summarizing a topic, or lesson
  - Classifying types of phenomena, materials, or data
  - Interpreting graphs, charts, and diagrams
  - Comparing two theories or methods
  - Drawing conclusions from a given situation
  - Key processes include interpreting, summarizing, inferring, comparing, and explaining.

Apply

- Students use their knowledge in practical or new situations. This requires using learned concepts, formulas, rules, or methods in real-life or academic problems.
- Example activities:
  - Solving numerical problems using a learned formula
  - Applying a scientific principle in a lab experiment
  - Using a learned method to analyze a case study
  - Implementing a procedure to complete a task
- This level includes executing (using knowledge in familiar contexts) and implementing (using it in new contexts).

Analyze

- This level focuses on breaking information into parts to understand how they relate, identify patterns, and examine underlying structures.
- Students may be asked to:
  - Analyze data to identify trends
  - Distinguish relevant information from irrelevant details
  - Break down a concept into components
  - Examine causes and effects in a situation
  - Compare different solutions or viewpoints
- Key processes involve differentiating, organizing, and attributing.

Evaluate

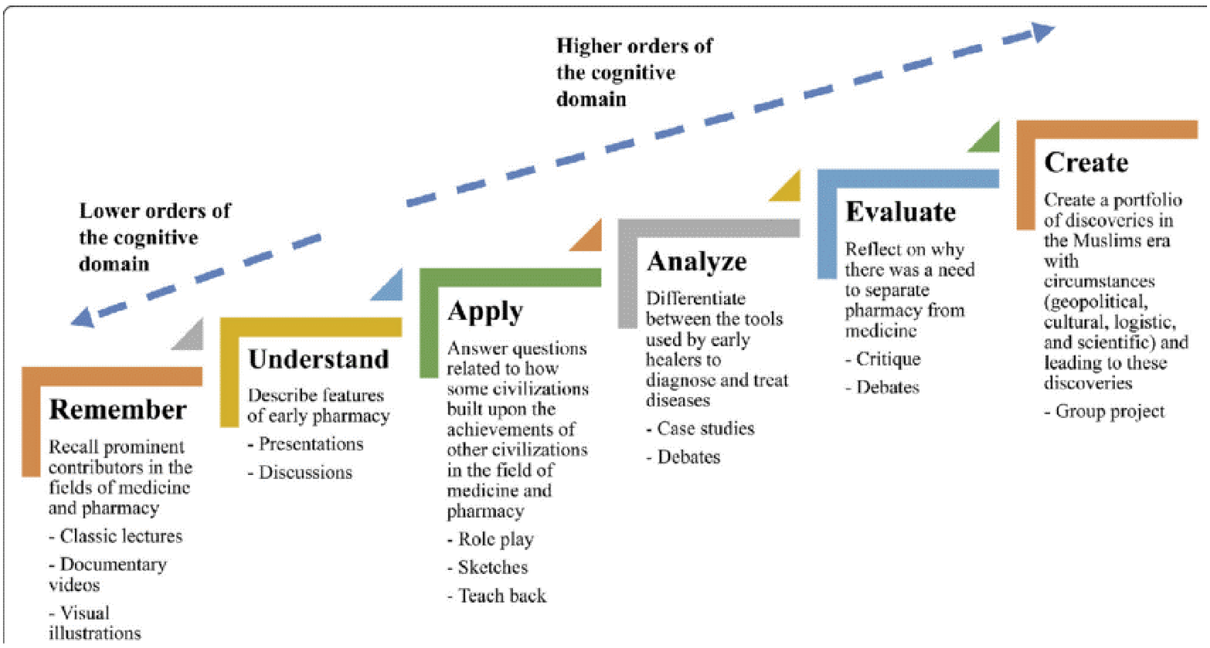
- Students make judgments based on criteria, standards, or evidence. This level requires critical thinking and reasoned decision-making.
- Examples include:
  - Justifying the selection of a method or solution
  - Critiquing an experiment or an argument
  - Assessing the effectiveness of a process or design
  - Checking the validity or accuracy of data and conclusions
- This level involves checking and critiquing using logical reasoning.

Create

- The highest level, where students generate new ideas, products, or processes by combining knowledge and skills creatively.
- Students may:
  - Design a model, project, or experiment
  - Develop a new solution to a problem
  - Construct a plan, report, or prototype
  - Produce original work such as a research project or presentation
- Key processes include generating, planning, and producing.

LOWER AND HIGHER ORDER BLOOMS TAXONOMY

Bloom's Taxonomy is broadly classified into Lower-Order Cognitive Skills and Higher-Order Cognitive Skills. The lower-order levels—Remember, Understand, and Apply—develop foundational knowledge, comprehension, and basic application skills. The higher-order levels—Analyze, Evaluate, and Create—focus on critical thinking, judgment, and creativity, enabling students to examine relationships and generate original solutions. This distinction supports balanced course design and helps educators write clear, measurable Course Outcomes aligned with teaching and assessment.



KNOWLEDGE DIMENSION

The Knowledge Dimension of the revised Bloom's Taxonomy classifies knowledge into Factual, Conceptual, Procedural, and Meta-cognitive categories.

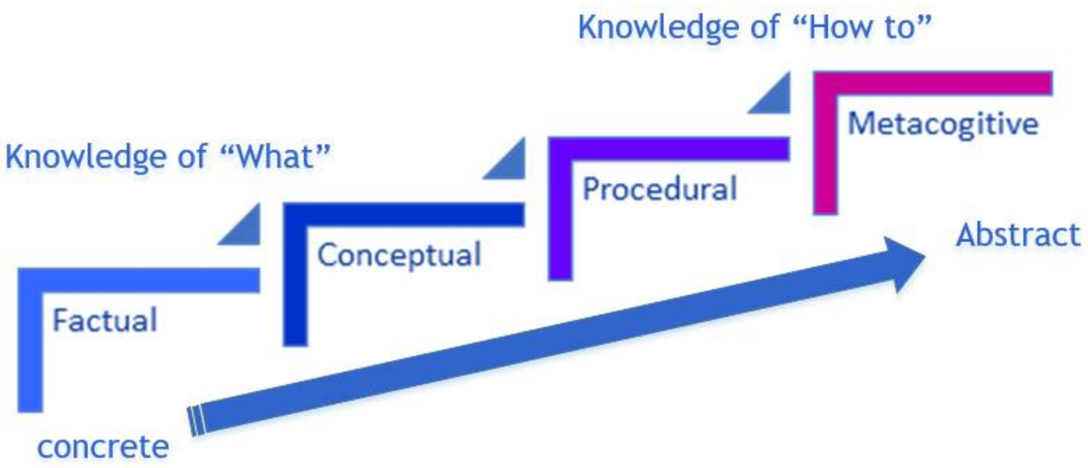


Table 2: The Knowledge Dimension

KNOWLEDGE DIMENSION		Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	Terminology, Elements & Components	Label map, List names	Interpret paragraph, Summarize book	Use math algorithm	Categorize words	Critique article	Create short storey
Conceptual Knowledge	Categories, Principles, Theories	Define levels of cognitive taxonomy	Describe taxonomy in own words	Write objectives using taxonomy	Differentiate levels of cognitive taxonomy	Critique written objectives	Create new classification system
Procedural Knowledge	Specific skills & techniques, Criteria for use	List steps in problem solving	Paraphrase problem-solving process in own words	Use problem-solving process for assigned task	Compare convergent & divergent techniques	Critique appropriateness of techniques used in case analysis	Develop original approach to problem solving
Meta-Cognitive Knowledge	General knowledge, Self-knowledge	List elements of personal learning style	Describe implications of learning style	Develop study skills appropriate to learning style	Compare elements of dimensions in learning style	Critique appropriateness of particular learning style theory to own learning	Create original learning style theory

BLOOMS TAXONOMY ACTION VERBS

Table 3: Action Verbs for Course Outcomes

Lower Order of Thinking(LOT)				Higher Order of Thinking(HOT)		
Definitions	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Bloom's Definition	Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.	Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpret in, giving descriptions, and Stating main ideas.	Solve problems on new situations by applying acquired knowledge, facts, techniques, and rules in a different way.	Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations.	Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria.	Compile information together in a different way by combining elements in a new pattern or proposing alternative solution.
Verbs	• Choose • Define • Find • How • Label • List • Match • Extend	• Classify • Compare • Contrast • Demonstrate • Explain • Illustrate • Infer • Interpret	• Apply • Build • Choose • Construct • Develop • Interview • Make use of • Model	• Analyze • Assume • Categorize • Classify • Compare • Discover • Dissect • Distinguish	• Agree • Appraise • Assess • Award • Choose • Criticize • Decide • Deduct • Importance	• Adapt • Build • Solve • Choose • Combine • Invent • Compile • Compose • Construct
Verbs	• Name • Omit • Recall • Relate • Select • Show • Spell • Tell • What • When • Where • Which • Who • Why	• Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with • Illustrate • Infer • Interpret • Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with	• Organize • Plan • Select • Solve • Utilize • Identify • Interview • Make use of • Model • Organize • Plan • Select • Solve • Utilize • Identify	• Divide • Examine • Function • Inference • Inspect • List Motive • Simplify • Survey • Take part in • Test for Theme • Conclusion • Contrast	• Defend • Determine • Disprove • Estimate • Evaluate • Influence • Interpret • Judge • Justify Mark • Measure • Opinion • Perceive • Prioritize • Prove • Criteria • Criticize • Compare • Conclude	• Create • Design • Develop • Estimate • Formulate • Happen • Imagine • Improve • Makeup • Maximize • Minimize • Modify • Original • Originate • Plan • Predict • Propose • Solution

Knowledge and Attitude Profile

- Well-Defined Knowledge Profiles (WKs) specify the expected volume of learning and graduate attributes required for effective professional performance.
- WKs help extend and clarify Program Outcomes (POs) by defining measurable knowledge, skills, and attitudes.
- The curriculum is designed to develop mathematical, computational, design, and creative thinking abilities.
- Learning is addressed across the cognitive, affective, and psychomotor domains.
- A total of nine knowledge and attitude profiles are incorporated to ensure holistic graduate development.
- These profiles reflect both the depth of learning and the work attitude expected from graduates.

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 therefore front 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 3: Key Indicator of Knowledge and Attitude Profile

WK No.	Knowledge & Attitude Profile	Key Indicators	No of Key Indicators
WK1	**Engineering Knowledge & Natural Sciences**	❖ Utilizes principles of physics to solve complex engineering problems. ❖ Employs concepts of chemistry in the analysis of engineering materials and processes. ❖ Uses mathematical principles for the formulation and solution of engineering problems. ❖ Integrates concepts from social sciences to address societal, environmental, and human factors in engineering practice. ❖ Employs discipline-specific engineering fundamentals for analysis, design, and problem-solving in specialized domains.	5
WK2	**Mathematical, Statistical & Data Analysis**	❖ Applies algorithms and numerical methods for engineering analysis. ❖ Uses statistical principles to summarize data and draw valid conclusions. ❖ Performs data cleaning, exploration, visualization, and ethical data handling. ❖ Interprets, evaluates, and compares analytical results using appropriate tools.	4
WK3	**Modelling & System Analysis**	❖ Develops analytical models of engineering systems. ❖ Develops numerical and empirical models to predict system behaviour. ❖ Uses physical models to test and validate engineering assumptions. ❖ Evaluates model accuracy and validity of assumptions.	4
WK4	**Computational Tools & Digital Systems**	❖ Uses computer systems to store and manage large datasets ❖ Applies computational tools for simulation and modelling. Uses data visualization techniques for effective analysis and interpretation. ❖ Evaluates limitations of computational tools and results.	3
WK5	**Problem Identification & Engineering Analysis**	❖ Identifies constraints, requirements, and secondary impacts of engineering problems. ❖ Formulates accurate and realistic problem statements ❖ Applies analytical methods for problem investigation. ❖ Validates assumptions and analytical outcomes.	4
WK6	**Engineering Design, Sustainability & Safety**	❖ Develops innovative and sustainable design solutions. ❖ Evaluates feasibility considering technical, economic, environmental, and societal factors. ❖ Conducts life-cycle analysis for sustainability assessment. ❖ Identifies hazards and applies risk mitigation strategies.	5

		❖ Ensures compliance with environmental and safety regulations.	
WK7	**Engineering Management & Professional Practice**	❖ Applies engineering management principles in decision-making. ❖ Performs economic analysis for project implementation. ❖ Manages resources, time, and budget effectively. ❖ Demonstrates professional responsibility in practice.	4
WK8	**Research, Investigation & Critical Thinking**	❖ Reviews current research literature to identify research gaps. ❖ Designs and executes experiments and investigations. ❖ Applies qualitative and quantitative research methods. ❖ Analyses data and considers sources of error. ❖ Draws and justifies valid conclusions. ❖ Evaluates emerging technologies, including Generative AI.	6
WK9	**Ethics, Law, Diversity & Inclusivity**	❖ Demonstrates ethical responsibility and professional integrity. ❖ Applies laws, regulations, and professional codes in practice. ❖ Identifies and justifies ethical courses of action. ❖ Respects diversity and promotes inclusivity in professional environments. ❖ Evaluates ethical implications of new and emerging technologies.	5

PO-WK MAPPING

Table 4 presents the mapping between the Program Outcomes (POs) and the corresponding elements of the Knowledge and Attitude profile (WK) framework for the M.Tech CAD/CAM Engineering programme.

Table 4: PO-WK Mapping

POs		WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9
PO1	Research/ investigation	4	4	4	3	4	5	4	6	4
PO2	Report Preparation	1	2	2	2	2	2	1	2	2
PO3	Domain Mastery	4	3	4	2	4	5	3	6	3
PO4	Application of Engineering Principles	5	3	4	3	4	5	4	6	5
PO5	Design and Sustainability	3	3	4	2	4	5	3	6	3
PO6	Lifelong Learning and Professional Development	4	3	4	2	4	5	4	6	5

COMPLEX ENGINEERING PROBLEMS

Complex Engineering Problems are engineering challenges that are broad, open-ended, and ambiguous, requiring the application of advanced engineering knowledge, professional judgment, and integration of multiple disciplines. These problems do not have a single optimal or readily testable solution and are characterized by uncertainty, multiple constraints, and the need for innovative and iterative approaches.

Key features of Complex Engineering Problems

- Broad scope involving multiple interconnected systems and disciplines
- Unstable and unpredictable parameters that evolve over time
- Require advanced and specialized engineering knowledge beyond routine practice
- Multiple experiments or direct testing may not be feasible
- Solutions are iterative, involving analysis, optimization, and innovation
- No bounded set of alternative solutions; trade-offs must be evaluated
- High levels of uncertainty, including unknown variables and risks
- Solutions cannot be based solely on standard codes or practices
- Demand consideration of safety, economy, sustainability, constructability, and societal impact
- Typically require collaboration among multidisciplinary teams and stakeholders

CHARACTERISTICS OF COMPLEX ENGINEERING PROBLEMS

Table 5: Characteristics of complex engineering problems

S No.	Keyword / Aspect	Description
1	**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.
2	**Range of conflicting requirements**	Involve wide-ranging and often conflicting technical, engineering, economic, environmental, and societal issues.
3	**Depth of analysis required**	Have no obvious solution and require abstract thinking, originality, and advanced analytical skills to formulate appropriate models and solution strategies.
4	**Familiarity of issues**	Involve issues that are infrequently encountered and not routine in professional engineering practice.
5	**Extent of applicable codes**	Lie outside the scope of problems fully addressed by existing standards and codes of professional engineering practice.
6	**Extent of stakeholder involvement & conflicting requirements**	Involve diverse stakeholder groups with widely varying and often conflicting needs, expectations, and constraints.
7	**Interdependence**	Represent high-level problems comprising many interdependent components or sub-problems that must be addressed holistically.

Adopting United Nations Sustainable Development Goals

In the era of rapid industrialization and digital transformation, engineering education plays a decisive role in addressing global challenges such as climate change, energy crises, resource depletion, social inequality, and sustainable urbanization. Recognizing this responsibility, the Engineering Program formally adopts the United Nations' Sustainable Development Goals (SDGs) as a guiding framework to align technical education with sustainable, ethical, and socially responsible development.

The program integrates SDGs within the Outcome-Based Education (OBE) framework to ensure that graduates are equipped not only with advanced technical competence but also with sustainability awareness and global citizenship.

Integration of SDGs within the M.Tech Program

S. No.	Keyword / Aspect of Complex Engineering Problems	Relevant Program Outcomes (POs)	Linked UN SDGs	Justification of Linkage (CAD/CAM Context)
1	Depth of knowledge required	PO3 – Domain Mastery, PO4 – Application of Engineering Principles	SDG 4, SDG 9, SDG 7, SDG 6	By strengthening quality technical education and innovation through advanced CAD/CAM tools, digital modeling, and automated manufacturing practices. The course promotes efficient product design, energy-efficient manufacturing processes, and development of sustainable mechanical components

2	Range of conflicting requirements	PO5 – Design and Sustainability, PO6 – Lifelong Learning & Professional Development	SDG 4, SDG 8, SDG 10, SDG 11	By encouraging sustainable product design, optimization of manufacturing resources, and continuous upskilling in emerging CAD/CAM technologies. This supports employability, economic growth, inclusive technical education, and the development of sustainable industrial systems
3	Depth of analysis required	PO1 – Research / Investigation, PO4 – Application of Engineering Principles	SDG 4, SDG 9, SDG 12	By promoting analytical investigation, design validation, and simulation-based evaluation using CAD/CAM tools to develop innovative, efficient, and environmentally responsible manufacturing solutions
4	Familiarity of issues	PO1 – Research / Investigation, PO6 – Lifelong Learning & Professional Development	SDG 4, SDG 13, SDG 15, SDG 14	The course enables engineers to address environmental and sustainability challenges by adopting energy-efficient manufacturing methods, minimizing material waste, and applying modern digital manufacturing practices
5	Extent of applicable codes	PO4 – Application of Engineering Principles, PO5 – Design and Sustainability	SDG 4, SDG 9, SDG 16	Application of engineering standards, manufacturing codes, and ethical practices in CAD/CAM ensures product quality, safety, accountability, and innovation in automated and digital manufacturing environments.
6	Stakeholder involvement & conflicting needs	PO2 – Report Preparation, PO5 – Design and Sustainability	SDG 4, SDG 5, SDG 11, SDG 16	Technical documentation, design communication, and stakeholder-oriented product development in CAD/CAM promote inclusive decision-making, ethical engineering practice, and socially responsible industrial development.
7	Interdependence of components	PO1 – Research / Investigation, PO3 – Domain Mastery, PO5 – Design and Sustainability	SDG 4, SDG 1, SDG 2, SDG 3, SDG 12	Integration of design, analysis, and manufacturing processes through CAD/CAM supports resource-efficient product development, improved productivity,
8	Collaboration, outreach & global responsibility	PO2 – Report Preparation, PO6 – Lifelong Learning & Professional Development	SDG 4, SDG 17	Industry–academia collaboration, digital manufacturing practices, and professional engagement enhance global cooperation, knowledge sharing, and sustainable engineering development through CAD/CAM applications.

COURSE OUTCOMES

A Course Outcome is a formal statement of what students are expected to learn in a 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. Course learning outcome statements refer to specific knowledge, practical skills, areas of professional development, attitudes, higher-order thinking skills, etc., that faculty members expect students to develop, learn, or master during a course.

A well-formulated set of Course Outcomes will describe what a faculty member hopes to successfully accomplish in offering their 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.

Guidelines for Writing Course Outcome Statements

Effective Course Outcomes are structured using the following components:

- **Action Verb** – Specifies observable student performance
- **Subject Content** – Indicates the knowledge or skill area
- **Level of Achievement** – Reflects cognitive depth (Bloom's Taxonomy)
- **Conditions of Performance** (if applicable) – Defines context or tools used

Developing Effective Course Outcomes

When formulating Course Outcomes, the following best practices should be followed:

- Limit outcomes to 5–6 statements per course
- Focus on core knowledge and essential skills
- Avoid trivial or overly detailed content
- Use student-centred language
- Emphasize learning results, not teaching activities
- Align outcomes with departmental and institutional mission
- Include multiple ways students can demonstrate learning (analyse, model, design, evaluate, present, etc.)
- Ensure outcomes are observable, measurable, and assessable

Relationship of Course Outcome to Program Outcome

Course Outcomes are systematically mapped to Program Outcomes (POs) to ensure that each course contributes meaningfully to the overall program objectives.

Learning outcomes formula:

STUDENTS SHOULD BE ABLE TO + BEHAVIOR + RESULTING EVIDENCE

Characteristics of Effective Course Outcomes

Well written course outcomes:

- Describe what you want your students to learning your course.
- Are aligned with program goals and objectives.
- Tell how you will know an instructional goal has been achieved.
- Use action words that specify definite, observable behaviors.
- Arrases able through one or more indicators (papers, quizzes, projects, presentations, journals, portfolios, etc.)
- Are realistic and achievable.
- Use simple language.

Examples of Effective Course Outcomes

Examples of Effective Course Outcomes: Course: Advanced CAD (2414001)

A structured and measurable approach to stating Course Outcomes involves three essential components:

- **Condition** – the context or tools provided
- **Observable Behaviour** – the action performed by the student
- **Standard** – the level of acceptable performance

A more detailed model for stating learning objectives requires at objectives have three parts: a condition, an observable behavior, and a standard.
The table below provides three examples.

Table 4: Examples of Course Outcomes Using the Condition–Behavior–Standard Model

S. No	Condition	Observable Behavior	Standard
1	Given a mechanical component with specific design requirements and constraints	The student will be able to explain geometric modeling concepts, design intent, and distinguish between parametric and non-parametric modeling approaches.	Correctly addressing at least 80% of identified modeling criteria.
2	Given a component drawing and manufacturing specifications	The student will be able to generate CAD models and develop appropriate CNC tool paths using CAM software.	Generated tool paths and machining parameters meeting design requirements $\pm 5\%$ of manufacturing tolerances.
3	Using a CAD assembly model with defined material and process parameters	The student will be able to analyze manufacturability, identify interferences, and evaluate assembly feasibility.	Correct identification of design or assembly issues with appropriate corrective measures.
4	Given components subjected to manufacturing constraints	The student will be able to select suitable manufacturing processes and optimize design features for efficient production.	Appropriate process selection based on design and manufacturing considerations.
5	Provided with industrial CAD/CAM case studies.	The student will be able to illustrate design-to-manufacturing workflows.	Accurate interpretation and presentation of workflow supported by design

CO-PO ARTICULATION MATRIX

A Course Articulation Matrix (CAM) shows the relationship between the Course Outcomes (COs) and the Program Outcomes (POs). It reflects the level to which each CO contributes to the attainment of specific POs. This matrix helps determine whether students are achieving the intended learning outcomes of a course. It is applicable to any course and is a valuable tool for evaluating and improving a course syllabus.

Observations

- ❖ For theory courses, COs should generally be designed within Bloom's Levels 1 to 4.
- ❖ For programming-oriented courses, COs should usually be limited to Bloom's Levels 1 to 3, while other theory courses may extend up to Level 4.
- ❖ For laboratory courses, COs may be framed within Bloom's Levels 1 to 5.
- ❖ Only in mini-projects and major projects may COs be designed up to Bloom's Level 6.
- ❖ For a given course, the course in-charge should involve all faculty members teaching the course in preparing the CO-PO mapping. The course in-charge may take the average of all submitted mappings or follow the majority. Faculty members should perform the mapping independently, without discussing values among themselves.
- ❖ When correlating COs with POs, ensure that the action verbs in the COs align with the intent and scope defined in the POs.

Method for Articulation

1. Identify the key competencies of POs for each CO and create a corresponding mapping table by assigning marks in the corresponding cell. One important observation is that the first five POs are purely technical in nature, while the other POs are non-technical.
2. Justify each CO-PO mapping with a justification statement and recognize the number of vital features mentioned in the justification statement that match 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. Create a table listing the number of key competencies for CO-PO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
4. Create a table displaying the percentage of key competencies for CO-PO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
5. Finally, prepare a Course Articulation Matrix (CO-PO Mapping) with COs and POs on a scale of 0 to 3, where:
   - 0 = No correlation (marked as "-")
   - 1 = Low/slight correlation
   - 2 = Medium/moderate correlation
   - 3 = Substantial/high correlation

The correlation is based on the following strategy:

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

Key Competencies for Assessing Program Outcomes:

To ensure that Program Outcomes (POs) are effectively achieved, each PO must be broken down into measurable Key Competencies. These competencies explain the specific abilities, skills, and knowledge that students must demonstrate. The table 6 below outlines the detailed key components for each PO, along with the total number of components associated with it. This structured approach enables transparency, accuracy in CO–PO mapping, and consistency during assessment and evaluation.

Table 6: Key Competencies for Assessing Program Outcomes

PO No.	NBA Statement / Vital Features	Key Components	No. of Key Components
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**
PO 2.	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**
PO 3.	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**

PO 4.	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**
PO 5.	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 6.	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**

CO-PO Articulation Matrix

CO-PO articulation matrix for the Courses offered in M.Tech CAD/CAM (MLRS-R24) are given below table.7.

Table 7: CO-PO articulation Matrix for M.Tech CAD/CAM (MLRS R 24) regulation

I M. Tech –I Semester							
2214001	Advanced CAD	2.40	2.40	2.60	2.60	2.20	2.80
2214002	Additive Manufacturing	2.40	2.40	2.40	1.80	2.00	2.60
2214011	Finite Element and Boundary Element Method	2.80	2.60	2.60	2.40	2.20	2.80
2214012	Experimental Stress Analysis	2.60	2.20	2.80	2.60	2.00	2.40
2214013	Green Manufacturing	2.40	1.80	2.60	2.40	2.20	2.40
2214014	Automation in Manufacturing	2.60	2.40	2.60	2.20	2.00	1.80
2214015	Computer Aided Process Planning	2.40	2.00	2.60	2.40	2.00	2.20
2214016	Industrial Robotics	2.40	2.00	2.60	2.40	2.20	2.60
2211234	RM&IPR	2.60	2.80	2.40	2.40	2.20	2.80
2214040	ACAD LAB	2.60	2.40	2.60	2.40	2.60	2.80
2214041	3D Printing Lab	2.60	2.20	2.80	2.60	2.00	2.80
2210401	English for Research Paper Writing	2.40	2.80				2.80
I M. Tech –II Semester							
2224003	Computer Integrated Manufacturing	2.20	2.40	2.20	2.20	2.00	2.80
2224004	Simulation Modelling &Analysis	2.00	2.20	2.40	2.00	1.80	2.60
2224017	Intelligent Manufacturing systems	2.60	2.40	2.60	2.20	2.00	2.80
2224018	IOT & Industry 4.0	2.20	2.00	2.60	2.40	1.80	2.20
2224019	Optimization Techniques & Applications	2.20	2.00	2.60	2.20	1.80	2.40
2224020	Mechatronics	2.20	2.40	2.80	2.40	2.00	2.40
2224021	MEMS	2.60	2.00	2.80	2.40	2.00	2.40
2224022	Fuzzy logic & Neural Networks	2.40	2.00	2.80	2.40	2.20	2.40
2224044	Mini project with Seminar	3.00	3.00	3.00	3.00	3.00	3.00
2224042	Simulation of Manufacturing systems Lab	2.80	2.60	2.60	2.80	2.40	2.80
2224043	CAM Lab	2.80	2.40	2.80	2.60	2.40	2.80
2220006	Pedagogy Studies	2.00	2.40				2.60
II M. Tech –I Semester							
2234023	Design For Manufacturing & Assembly	2.40	2.20	2.60	2.40	1.80	2.40
2234024	Composite Materials	2.60	2.20	2.60	2.60	2.00	2.60
2234025	Artificial Intelligence & Manufacturing	2.40	1.80	2.60	1.80	1.60	2.60
2235503	Fundamentals of Nano Technology	2.00	1.80	2.40	2.20	1.80	2.60

2232076	Dissertation Work Review – I	3.00	3.00	3.00	3.00	3.00	3.00
2242077	Dissertation Work Review – III	3.00	3.00	3.00	3.00	3.00	3.00
2242078	Dissertation Viva -Voce	3.00	3.00	3.00	3.00	3.00	3.00

METHODS FOR MEASURING LEARNING OUTCOMES

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

i) Continuous Internal Assessment (CIA).
ii) Semester end examination (SEE)
iii) Laboratory and project work
iv) Course End survey
v) Program exit survey
vi) Alumni survey
vii) Employer survey
viii) Program Assessment and Quality Improvement Committee (PAQIC)
ix) Department Advisory Board (DAB)
x) Faculty meetings

Table 8: CO-PO Mapping

Assessment Method	Assessment Tool	Weightage in CO attainment
Direct Assessment	Continuous Internal Assessments (CIA-1and CIA-2)	80%
	Semester End Examination	
Indirect Assessment	Course End Survey	20%

Direct Assessment

Direct assessment methods are based on the student's knowledge and performance in various assessments and examinations. These assessment methods provide evidence that a student has command over a specific course, content, or skill. Additionally, they demonstrate that the student's work exhibits specific qualities such as creativity, analysis, or synthesis.

The various direct assessment tools used to assess the impact of the delivery of course content is listed in the table.

- CIE examination, semester end examinations, Assignment and Viva-voce/Tutorial/Case study/Application/Poster presentation (are used for CO calculation.
- The attainment values are calculated for individual courses and are formulated and summed for assessing the POs.
- Performance in Assignment is indicative of the student's communication skills.
- Viva-voce/PPT/Poster Presentation/Case study reflects the student's knowledge, skills, application, and understanding of the course.

Table 9: Tools used in direct assessment methods

S No	Courses	Components	Frequency	Max. Marks	Evidence
1	Core / Elective	Continuous Internal Examination (CIE)	Twice in a semester	20	Answer script
		QUIZ	Twice in a semester	10	Multiple Choice Questions in Anvaya LMS
		Comprehensive Assessment Tool (CAT)	Twice in a semester	10	Scripts/PPT/student videos
		Semester End Examination	Once in a semester	60	Answer script
2	Laboratory	Day to day evaluation	Once in a week	10	Observation and record
		Viva-voce/Tutorial/Case study/Application/Poster presentation	Twice in a semester	10	Work sheets

		Design/software/hardware Model presentation/App development/Prototype presentation	Once in a semester	10	Presentation
		Internal practical examination	Twice in a semester	10	Answer script
		Semester End Examination	Once in a semester	60	Answer script
3	Dissertation Work	Presentation	Twice in a semester	40	Presentation
		Semester End Examination	Once in a semester	60	Thesis report
4	Mini Project with Seminar	Semester End Examination	Twice in a semester	100	Seminar report

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 10.

Table10: 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.

PO Assessment tools and Processes

The institute has the following methods for assessing the 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.

Table11: 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 the Program Articulation Matrix, are considered for the calculation of direct attainment of PO.

7.1 PO Direct Attainment is calculated using the rubric

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

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

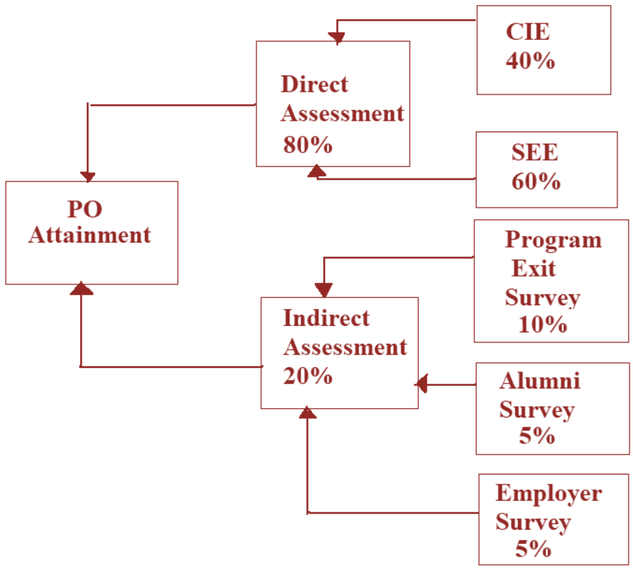


Figure3: Evaluation process of POs attainment

COURSE DESCRIPTION

The "Course Description" provides general information regarding the topics and content addressed in the course. A sample course description is given in Annexure – A for reference.

The "Course Description" contains the following contents:

- Course Overview
- Prerequisite(s)
- Marks Distribution
- Content Delivery / Instructional Methodologies
- Evaluation Methodology
- Course Objectives
- Course Outcomes
- Program Outcomes
- Program Specific Outcomes
- How Program Outcomes are Assessed
- Mapping of each CO with PO(s)
- Justification for CO–PO Mapping - Direct
- Total Count of Key Competencies for CO–PO Mapping
- Percentage of Key Competencies for CO–PO
- Course Articulation Matrix (PO Mapping)
- Assessment Methodology - Direct
- Assessment Methodology - Indirect
- Syllabus
- List of Textbooks / References / Websites