OBE MANUAL

M.Tech Computer Science and Engineering

MLRS R 22 Regulation

MARRI LAXMAN REDDY INSTITUTE OF TECHNOLOGY AND MANAGEMENT

OVERVIEW

Outcome Based Education (OBE) forms the foundation of quality assurance in higher technical education, particularly in postgraduate programmes such as M.Tech. Unlike traditional education models that emphasize only syllabus coverage and content delivery, OBE emphasizes what students are expected to achieve by the end of the programme. It focuses on clearly defined, measurable outcomes and ensures that all teaching–learning activities contribute directly to achieving these outcomes.

In the OBE framework, faculty members may function as instructors, facilitators, trainers, or mentors, depending on the learning objectives and targeted outcomes. The approach promotes student-centered learning, continuous feedback, and systematic assessment to evaluate learning achievement.

The National Board of Accreditation (NBA) is the authorized body responsible for accrediting technical programmes in India. NBA accreditation is programme-specific and not institution-specific. As a full signatory of the Washington Accord, the NBA ensures that accredited engineering programmes meet international quality standards based on outcomes and graduate attributes.

NBA classifies Higher Education Institutions into:

- **Tier–1:** IITs, NITs, Central Universities, State Universities, and Autonomous Institutions. Tier-1 institutions benefit fully from Washington Accord recognition.
- **Tier–2:** Affiliated colleges offering professional programmes.

Institutions offering M.Tech programmes adopt OBE to revise and refine curriculum design, assessment practices, and teaching methodologies based on feedback from various stakeholders such as students, faculty, alumni, employers, industry professionals, and recruiters. OBE ensures that learning is outcome-driven, dynamic, and aligned with global expectations.

Figure1: OBE process

The four key levels of outcomes in the OBE framework are:

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

These outcomes reflect the competencies expected from M.Tech graduates, including technical expertise, research capability, innovation, professional ethics, and lifelong learning.

Why OBE for M.Tech Programmes?

1. Facilitates international recognition of qualifications and enhances global employment opportunities.
2. Produces highly skilled, innovative graduates with strong research abilities, professional ethics, and social responsibility.
3. Improves institutional reputation, visibility, and credibility among national and international stakeholders.
4. Enhances participation and ownership of learning among students, faculty, industry partners, and academic bodies.
5. Ensures graduates are prepared for leadership roles, advanced research, and technological advancements.
6. Helps M.Tech graduates achieve professional excellence and contribute meaningfully to industry, academia, and society.

Benefits of Outcome-Based Education

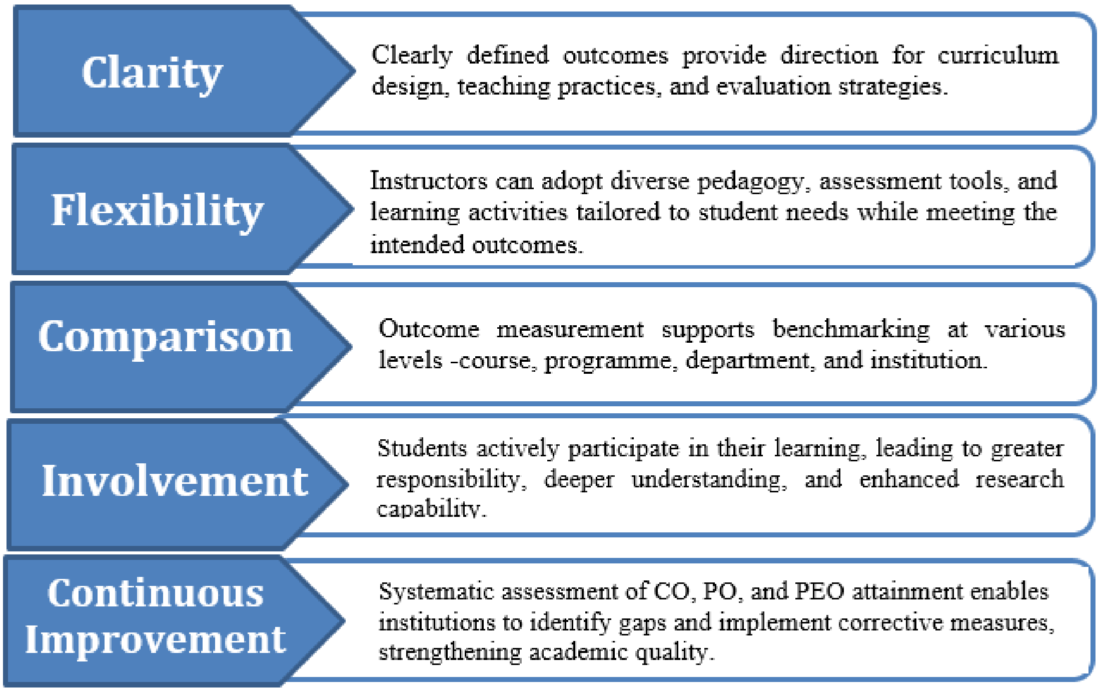


Figure 2: Benefits of Outcome Based Education

Outcome Based Education and Accreditation

India's adoption of Outcome-Based Education (OBE) represents a significant reform in the nation's higher technical education system. The transformation began gaining real momentum when India became a permanent signatory to the Washington Accord on 13 June 2014, a prestigious international agreement that recognizes engineering degree programmes based on the attainment of learning outcomes and graduate attributes. This global recognition demanded a shift from conventional, content-heavy teaching practices to a student-centric, measurable, and competency-oriented education system.

NBA formally introduced an OBE-based accreditation framework in 2013, encouraging institutions to redesign their curriculum delivery mechanisms. Under this framework, all engineering and technical programmes must clearly articulate Programme Educational Objectives (PEOs), Programme Outcomes (POs), and Course Outcomes (COs). Institutions are expected to adopt well-defined assessment strategies, evaluate attainment levels regularly, and maintain systematic documentation.

The implementation of OBE in India requires:

- Clear formulation of outcomes at all levels—course, programme, and graduate attributes.
- Appropriate mapping between COs, POs, and PEOs.
- Use of direct and indirect assessment tools to evaluate student performance.
- Data-driven analysis of attainment levels to identify strengths and weaknesses.
- Continuous improvement measures based on the attainment analysis and stakeholder feedback (students, faculty, alumni, industry, employers).
- Integration of modern pedagogies, industry practices, and technology-driven learning methods.

Through this outcome-based approach, Indian institutions aim to enhance not only academic knowledge but also the professional skills, ethical values, and problem-solving abilities of graduates. The emphasis on measurable outcomes ensures that students acquire competencies aligned with global engineering standards, enabling them to compete internationally and meet industry expectations effectively.

Thus, the adoption of OBE in India supported by NBA has significantly elevated the quality, transparency, and global credibility of technical education. It strengthens accountability, encourages innovation, and promotes continuous improvement, ultimately preparing graduates who are competent, employable, and capable of contributing to technological and societal development.

Vision, Mission, Philosophy & Core Values

1.1Vision 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.

1.2 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.

1.3 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.

1.4 Philosophy

The essence of meaningful education lies in the pursuit of truth that dispels ignorance, and Marri Laxman Reddy Institute of Technology and Management firmly believes that education must serve as a tool for liberation and empowerment. Engineering education, encompassing all major fields of science and technology, plays a vital role in the advancement of society and the progress of civilization.

Guided by this philosophy, the Institute is committed to fostering scientific and technological development in harmony with natural and societal needs. It emphasizes rigorous research, advanced technical learning, and the cultivation of professional competence combined with strong ethical foundations. The Institute encourages collaboration with local communities and promotes global engagement to ensure that education remains socially relevant and responsible.

This holistic approach aims to transform students into complete individuals professionally skilled, ethically grounded, socially conscious, and capable of contributing meaningfully to the world.

1.5 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.

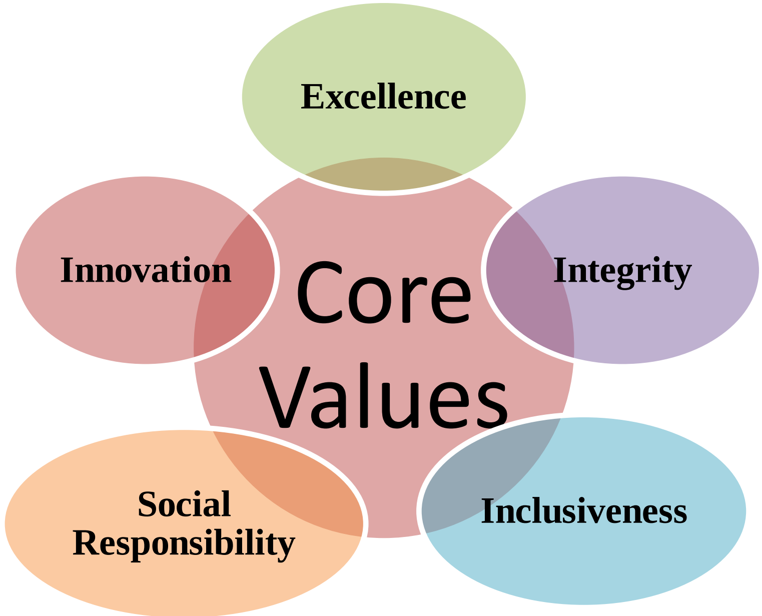


Figure.3: Core Values of OBE

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.

1.6 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) and Program Specific Outcomes (PSOs)

POs represent the graduate attributes as defined by the NBA, while PSOs represent 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, Analyze, Evaluate, and 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 and PSO 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, Mission & PEOs of the Department

2.1 Vision of the Department

To empower the students to be technologically adept, innovative, self-motivated and responsible global citizen possessing human values and contribute significantly towards high quality technical education by harmonizing innovation with sustainability.

2.2 Mission of the Department

M1: To offer high-quality education in the computing fields by providing an environment where the knowledge is gained and applied to participate in research, for both students and faculty.
M2: To develop the problemsolving skills in the students to be ready to deal with cutting edge technologies of the industry.
M3: To make the students and faculty excel in their professional fields by inculcating the communication skills, leadership skills, team building skills with the organization of various co-curricular and extra-curricular programmes.
M4: To provide the students with theoretical and applied knowledge, and adopt an education approach that promotes lifelong learning and ethical growth.

2.3 Program Educational Objectives (PEOs)

PEO1

Graduates will achieve professional excellence and success in the field of Computer Science and Engineering by applying strong technical foundations and problem-solving skills to contribute effectively to industry, academia, and

PEO2

Graduates will demonstrate a commitment to lifelong learning by continuously enhancing their knowledge and skills through professional development and self-directed learning to effectively adapt to evolving global challenges.

Graduates of the Computer Science and Engineering program will actively pursue advanced research, contributing to the development of solutions for complex problems and the generation of new knowledge to effectively address real-world challenges.

PEO3

PEO4

Graduates will exhibit professionalism, effective communication, leadership skills, and ethical responsibility while working in multidisciplinary teams to deliver computing solutions that address societal needs and contribute to sustainable development.

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. Since assessing long-term professional achievements is challenging in the Indian context, the NBA has not made PEO assessment mandatory, and assessors generally do not evaluate it during accreditation. PEOs may be framed from different perspectives such as career advancement, technical competence, ethical conduct, and societal contribution. While drafting PEOs, technical jargon should be avoided, as these statements must be easily understandable to aspiring students and other stakeholders. Typically, three to five well-defined PEOs are recommended for any program.

Program Outcomes (POs)

A 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 Structural Engineering. For Postgraduate Programs POs descriptions are generally aligned with national standards

PO1
Research/ investigation

An ability to independently carry out research / investigation and development work to solve practical problems

PO2
Report Preparation

An ability to write and present a substantial technical report/document

PO3
Domain Mastery

Students should be able to demonstrate advanced proficiency in computer science and allied emerging areas of Engineering

PO4
Application of Engineering Principles

Students should be able to identify, Analyze and effectively solve complex real-world problems by applying advanced computing concepts, while considering solutions from a global perspective

PO5
Design and Sustainability

An ability to acquire and apply advanced technical knowledge, professional skills, and modern computing tools to develop sustainable

PO6
Lifelong Learning and Professional Development

An Ability to recognize the significance of lifelong learning and actively pursue continuous professional development by adapting technologies in emerging areas.

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

3.1 Relation between the Program Educational Objectives and the 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.

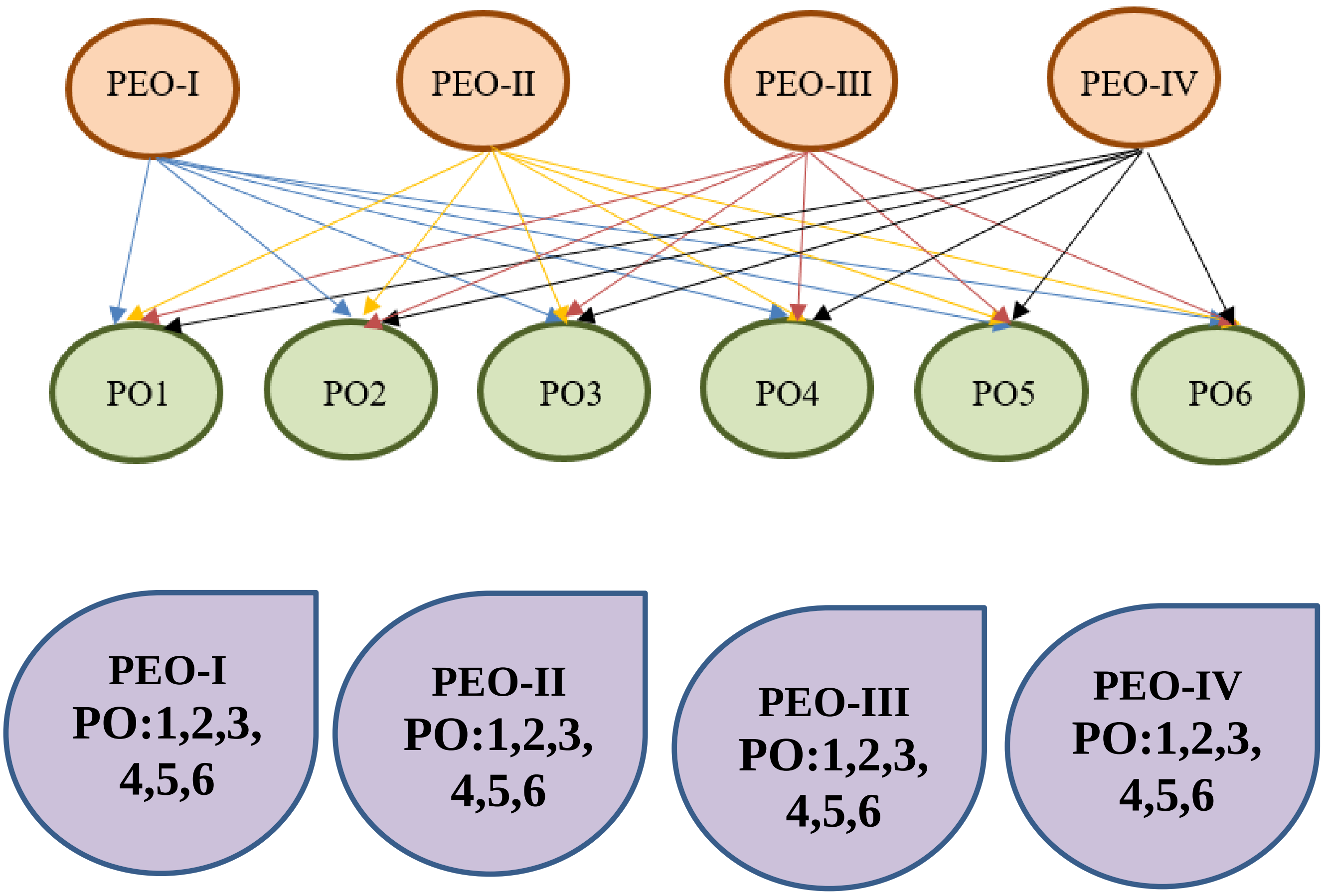


Figure 4: Correlation between the PEOs and the POs

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) Professional Excellence**	**(2) Life Long Learning**	**(3) Research**	**(4) Ethical Responsibility**
PO1	An ability to independently carry out research / investigation and development work to solve practical problems	3	3	2	1
PO2	An ability to write and present a substantial technical report/document	3	2	1	2
PO3	Students should be able to demonstrate advanced proficiency in computer science and allied emerging areas of Engineering	3	3	2	1
PO4	Students should be able to identify, Analyse and effectively solve complex real-world problems by applying advanced computing concepts, while considering solutions from a global perspective	3	3	3	2
PO5	An ability to acquire and apply advanced technical knowledge, professional skills, and modern computing tools to develop sustainable solutions.	3	2	2	3
PO6	An Ability to recognize the significance of lifelong learning and actively pursue	3	2	3	2

	continuous professional development by adapting technologies in emerging areas.				

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),
- Mid-term examinations, and
- Semester-end examinations.

Indirect Assessment is carried out through:

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

Blooms Taxonomy

4.1 What is Bloom's Taxonomy?

Bloom's Taxonomy provides a structured classification of learning stages, progressing from the simple recall of facts to the creation of new ideas based on acquired knowledge. The taxonomy is built on the understanding that learning is a sequential and hierarchical process. A learner must first remember key facts before they can understand a concept; only after gaining understanding can they apply the knowledge in real-life situations. Originally introduced as a conceptual framework, Bloom's Taxonomy is now often represented as a pyramid to visually express this progression. At the base of the pyramid lies Knowledge (Remembering), followed by Comprehension**,** Application**,** Analysis**,** Synthesis, and finally Evaluation at the top. Each level depends on mastery of the preceding one, emphasizing that effective learning requires moving step-by-step through these cognitive stages to achieve higher-order thinking skills.

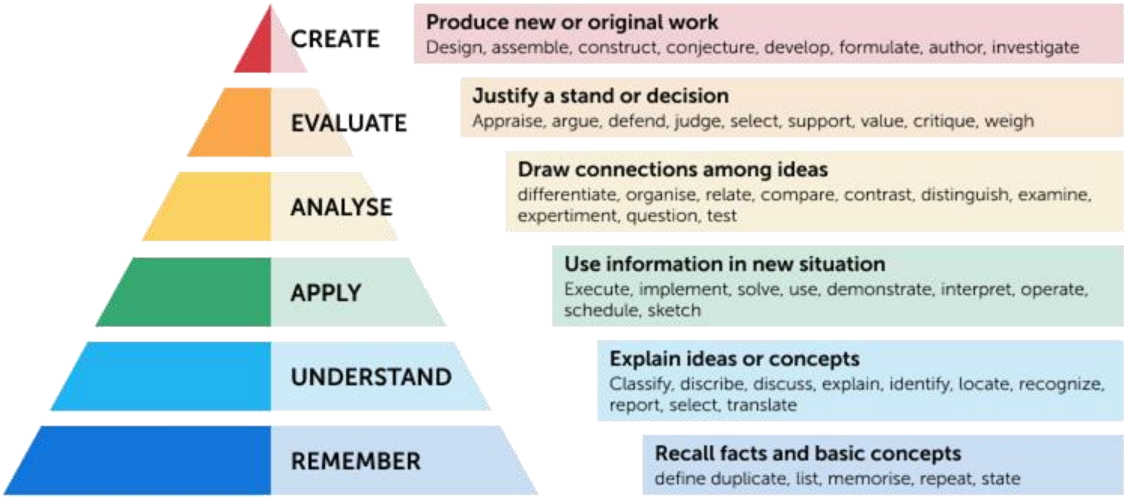


Figure 5: Blooms Taxonomy

4.2 Bloom's Taxonomy (Original and Revised)

Bloom's Taxonomy is a foundational framework for classifying educational learning objectives. First introduced in 1956 by Benjamin Bloom and his colleagues Max Englehart, Edward Furst, Walter Hill, and David Krathwohl in the book Taxonomy of Educational *Objectives*, the original taxonomy organized cognitive skills into six hierarchical levels: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation**.** Its primary purpose was to provide educators with a common terminology and systematic approach for designing curriculum, formulating learning outcomes, and developing assessment methods. Although initially designed for use in higher education, it quickly gained acceptance across all educational sectors, from school education to professional and corporate training, becoming one of the world's most widely used instructional design models.

In 2001, the taxonomy was revised by a group led by David Krathwohl and Lorin Anderson to better align with contemporary educational practices and the need for measurable learning outcomes. The revised taxonomy replaced the original noun-based categories with action-oriented verbs and repositioned the highest levels, resulting in the cognitive stages: Remember, Understand, Apply, Analyze, Evaluate, and Create**.** The revision also defined specific cognitive processes associated with each level, such as recognizing, recalling, interpreting, applying, critiquing, and generating. This updated, action-focused structure is particularly well suited for Outcome-Based Education (OBE)**,** as it enables institutions to clearly articulate, observe, and assess learning outcomes with precision and consistency.

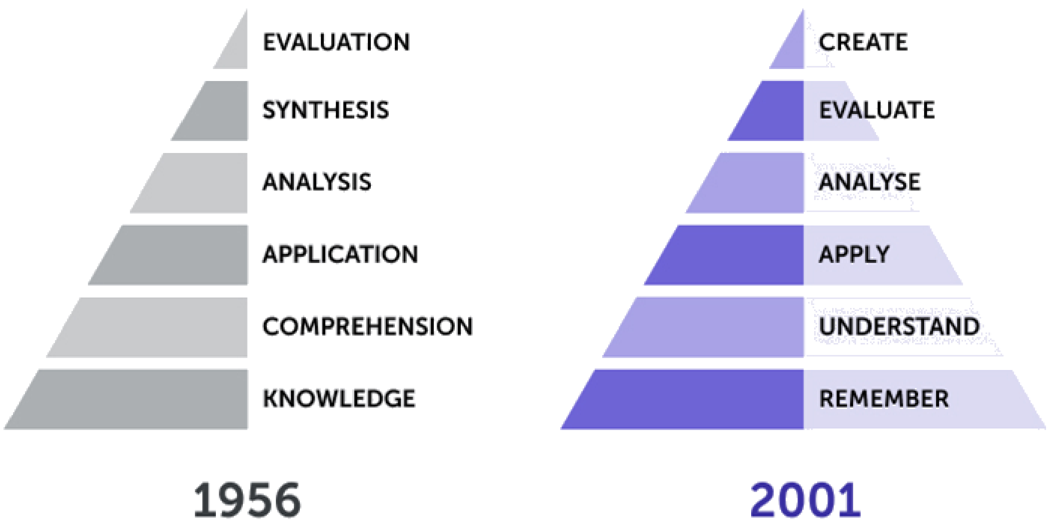


Figure 6: Blooms Taxonomy (Original and Revised)

4.3 Incorporating Critical Thinking Skills into Course Outcome Statements

In Outcome-Based Education (OBE), Course Outcomes (COs) must reflect the development of cognitive abilities at every level, ensuring that students gradually build the capacity to think clearly, logically, and independently. Critical thinking is not restricted to any single stage of Bloom's Taxonomy; rather, it develops progressively across all six levels from Remember to Create. Each level contributes uniquely to strengthening learners' ability to interpret information, solve problems, and make informed decisions.

At the foundational levels of Remember and Understand, learners begin critical thinking by recalling essential concepts, explaining ideas, identifying relationships, and interpreting information. These skills create the base for more advanced reasoning. As students move to *Apply*, they demonstrate critical thinking by using concepts in relevant situations, choosing appropriate methods, and drawing meaningful conclusions from their actions.

As learning deepens through *Analyze*, *Evaluate*, and *Create*, students continue to refine their critical thinking through breaking down information, comparing alternatives, validating solutions, and generating new ideas. These stages help learners handle complex tasks, make justified decisions, and approach problems with a systematic mindset.

To effectively incorporate critical thinking into CO statements, instructors should use action verbs from all levels of Bloom's Taxonomy. Verbs such as identify, describe, explain, apply, differentiate, justify, and create provide clarity and measurability, ensuring proper alignment of teaching, learning, and assessment.

Integrating critical thinking skills across all levels of COs fosters holistic learning, enhances problem-solving ability, and prepares students for professional practice, research, and lifelong learning. This comprehensive approach ensures that critical thinking is nurtured continuously throughout the curriculum.

4.4. Definitions of the different levels of thinking skills in Bloom's 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.

4.5 List of Action Words Related to Critical Thinking Skills

Here is a list of action words that can be used when creating the expected student learning outcomes related to critical thinking skills in a course. These terms are organized according to the different levels of higher-order thinking skills contained in Anderson and Krathwohl's (2001) revised version of Bloom's taxonomy.

Here is the revised Bloom's document with action verbs, which we frequently refer to while writing COs for our courses.

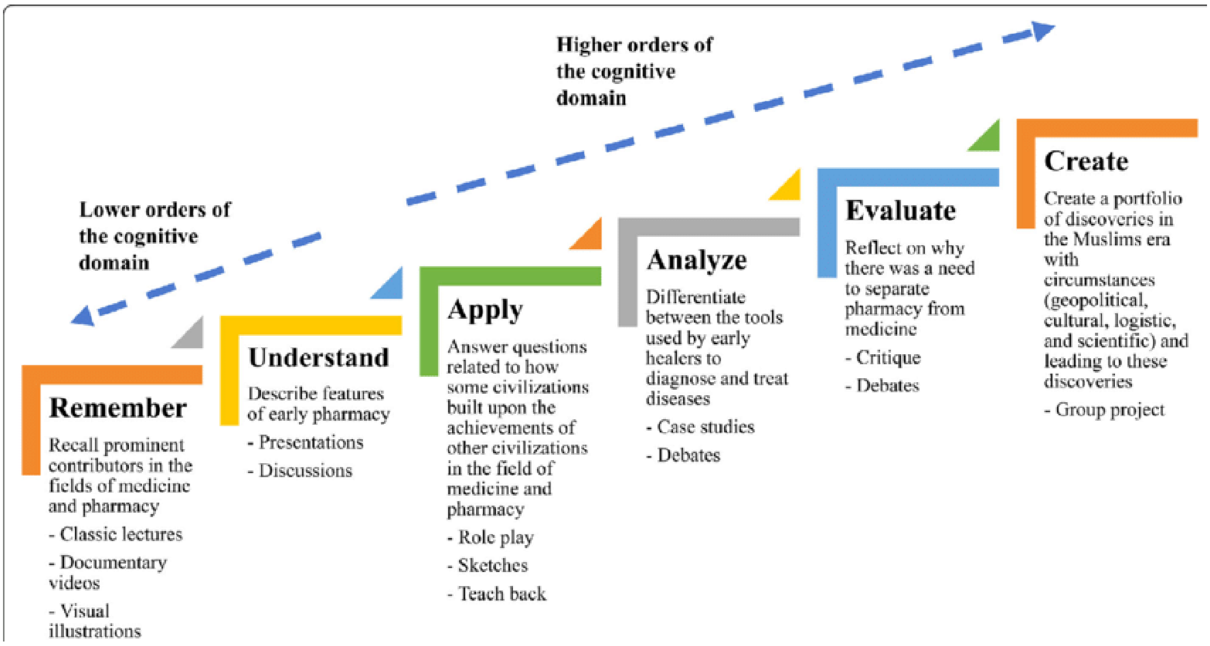


Figure 7: The cognitive process dimensions – categories

Table 2: The Knowledge Dimension

KNOWLEDGE DIMENSION		**Remember**	**Understand**	**Apply**	**Analyze**	**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 orginal 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 orginal learning style theory

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

Course Outcomes (COs)

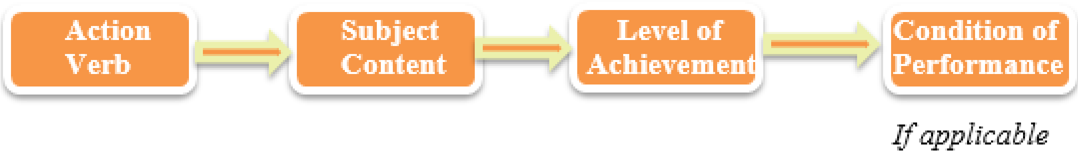
A Course Outcome is a formal statement of what students are expected to learn in a course. When creating Course Outcomes, remember that the outcomes should clearly state what students will do or produce to determine and/or demonstrate their learning. Course learning outcome statements refer to specific 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 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.

5.1 Guide lines for writing Course Outcome Statements:

Well-written course out comes involve the following parts:

1. Action verb
2. Subject content
3. Level of achievement
4. Conditions of performing task (if applicable)



5.2 Developing Course Outcomes

When creating course outcomes consider the following guidelines as you develop them either individually or as part of a multi-section group:

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)].
Focus on overarching knowledge and/or skills rather than small or trivial details.
Emphasize knowledge and skills that are central to the course topic and/or discipline.

Create statements that have a student focus rather than an instructor-centric approach. (Example: Demonstrate the stability behavior of columns under axial, flexural, and torsional buckling with and without lateral bracing.)

Student-focused outcome: "Upon completion of this course, students will be able to demonstrate the stability behavior of columns under axial, flexural, and torsional buckling with and without lateral bracing by outlining theoretical principles, analyzing critical load conditions, modeling structural responses, and depicting solutions through sketches, simulations, or design examples."

Instructor-centric objective (to avoid): "One objective of this course is to teach students the concepts of axial, flexural, and torsional buckling of columns with and without lateral bracing."

Focus on the learning that results from the course rather than describing activities or lessons that are in the course.

Incorporate and/or reflect the institutional and departmental mission.
Include various ways for students to show success (e.g., 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.

When developing learning outcomes, here are the core questions to ask yourself:

- What do we want students in the course to learn?
- What do we want the students to be able to do?
- Are the outcomes observable, measurable, and able to be performed by the students?

Course outcome statements at the course level describe:

- What faculty members want students to know at the end of the course AND
- What faculty members want students to be able to do at the end of the course.

Course outcomes have three major characteristics:

- They specify an action by the students/learners that is observable.
- They specify an action by the students/learners that is measurable.
- 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.

5.3 Relationship of Course Outcome to Program Outcome

Learning outcomes formula:

STUDENTS SHOULD BE ABLE TO + BEHAVIOR + RESULTING EVIDENCE

The Course Outcomes need to link to the Program Outcomes.

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)."

5.4 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.

5.5 Examples of Effective Course Outcomes

After successful completion of the course, Students will be able to:

- Critically analyze the stability behavior of columns subjected to axial, flexural, and torsional buckling with and without lateral bracing.
- Design reinforced concrete and steel structural components in accordance with relevant IS codes.
- Evaluate the seismic performance of multi-storey buildings and propose appropriate retrofitting strategies.
- Apply finite element methods to model and interpret the response of complex structural systems.
- Assess the durability and sustainability aspects of construction materials for long-term performance.
- Develop structural health monitoring approaches using sensor data and diagnostic techniques.
- Produce and present a comprehensive technical report on a design or research problem.
- Demonstrate professional ethics, teamwork, and leadership skills in solving multidisciplinary engineering problems.

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 Behaviour	Standard
1	Given a column subjected to axial load with specified end conditions	The student will be able to determine the critical buckling load using Euler's theory	Within ±5% error compared to theoretical values
2	Immediately after a lecture on earthquake-resistant design principles	The student will be able to outline and explain the key provisions of IS 1893 for seismic analysis of buildings	Mentioning at least four out of five key provisions
3	Using finite element analysis software and a provided beam model	The student will be able to Analyze bending stress distribution and validate results with theoretical calculations	Achieving correlation within 10% of hand calculations

The following examples 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 5: Refinement of Course Outcomes – From Original to Improved Measurable Statements

Original course out-come	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 would be measurable with 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...

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

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

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

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

- ...will be able to read and demonstrate good comprehension of text in areas of the student's interest or professional field.
- ...will demonstrate the ability to apply basic research methods in psychology, including research design, data analysis, and interpretation.

- ...will be able to identify environmental problems, evaluate problem-solving strategies, and develop science-based solutions.
- ...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

- 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.
- Look over your list and check the one most important student outcome. If you could only achieve one outcome, which one would it be?
- Look for your outcome on the list of key competencies or outcomes society is asking us to produce. Is it there? If not, is the reason a compelling one?
- Check each of your other "most important" outcomes against the list of outcomes. How many are on the list of key competencies?
- 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?

5.6 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:

- What role does this course play within the program?
- How is the course unique or different from other courses?
- Why should/do students take this course? What essential knowledge or skills should they gain from this experience?
- What knowledge or skills from this course will students need to have mastered to perform well in future classes or jobs?
- Why is this course important for students to take?

CO-PO Course 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 PO's. 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.

Table 3 provides information about the action verbs used in the Program Outcomes (POs) and the Bloom's Taxonomy levels associated with them. Understanding the intention of each PO and the Bloom's levels linked to its verbs allows faculty to appropriately design Course Outcomes (COs). Once the COs are defined, the faculty can determine the extent of correlation between each CO and each PO.

The mapping of COs to POs is evaluated using descriptors such as High**,** Medium**,** Low, or No Correlation**.** These assigned values are later used to compute PO attainment for the course.

Observations:

1. For theory courses**,** COs should generally be designed within Bloom's Levels 1 to 4.
2. 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.
3. For laboratory courses**,** COs may be framed within Bloom's Levels 1 to 5.
4. Only in mini-projects and major projects may COs be designed up to Bloom's Level 6.
5. 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.
6. When correlating COs with POs, ensure that the action verbs in the COs align with the intent and scope defined in the PO's.

6.1 Tips for Assigning the values while mapping COs to POs

1 Choose action verbs from appropriate Bloom's levels based on the importance of each CO.
2 Use **one primary action verb** per CO; additional verbs may be used only when necessary.
3 Each assigned CO-PO value must be **justified** with a short statement (1–2 lines) that references words or phrases from the CO, PO, and course syllabus.

4 Values for the CO-PO mapping may be assigned as follows:

5
   1. **(High):** Strong alignment between the CO and the PO.
   2. **(Medium):** Moderate alignment.
   3. **1 (Low):** Minimal alignment.
   4. **“-” (No alignment):** No meaningful correlation.

6 If an action verb appears across multiple Bloom’s levels, determine which level best matches how the verb is used in the CO.

6.2 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
$0 \leq C \leq 510\%$	No correlation	0
$10\% < C \leq 40\%$	Low/Slight correlation	1
$40\% < C < 60\%$	Moderate correlation	2
$60\% \leq C < 100\%$	Substantial/High correlation	3

6.3 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	An ability to independently carry out research/investigation and development work to solve practical problems.	1. Research problems in Computer Science and Engineering 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.	An ability to 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 audience.	**6**
PO 3.	Students should be able to demonstrate advanced proficiency in Computer Science and allied emerging areas of Engineering.	1. In-Depth Technical Knowledge 2. Advanced Problem-Solving and Algorithmic Skills. 3. Hands-On Practical Expertise 4. Research and Innovation Aptitude 5. Interdisciplinary Integration	**5**

PO 4.	Students should be able to identify, analyze, and effectively solve complex real-world problems by applying advanced computing concepts while considering solutions from a global perspective	1. Ability to break down multifaceted problems into manageable parts and develop effective solutions using advanced computing techniques. 2. Analytical Thinking and Critical Reasoning 3. Advanced Computing Knowledge. 4. Capability to understand and model complex systems, considering interdependencies and dynamic behaviors within global contexts. 5. Global and Societal Awareness. 6. Aptitude for developing novel approaches and innovative solutions to address complex challenges. 7. Ability to work effectively in diverse teams and integrate knowledge from multiple disciplines to solve global problems. 8. Skill in clearly presenting problem analyses, solutions, and their implications to technical and non-technical global audience	**8**
PO 5.	An ability to acquire and apply advanced technical knowledge, professional skills, and modern computing tools to develop sustainable solutions	1. Ability to continuously learn and apply cutting-edge technical knowledge in computing and related fields. 2. Proficiency with Modern Computing Tools. 3. Capability to design and implement solutions that are environmentally, and economically feasible. 4. Understanding of professional ethics and responsibility in creating technology solutions with long-term positive impact. 5. Integration of Multidisciplinary Knowledge. 6. Adaptability to Sustainable Practices.	**6**
PO 6.	An Ability to recognize the significance of lifelong learning and actively pursue continuous professional development by	1. Self-Directed Learning. 2. Skill in quickly learning new technologies and tools as they emerge in the field. 3. Capability to assess the relevance and impact of emerging technologies and decide on their applicability. 4. Continuous Professional	**6**

	adapting technologies in emerging areas.	Development Planning. 5. Ability to engage with professional communities, attend workshops, and collaborate to stay updated. 6. Habit of regularly reflecting on personal growth, learning experiences, and professional competencies to improve continuously.	

6.3 Program Outcomes Attained through course modules:

Courses offered in Computer science and Engineering Curriculum (MLRS-R20) and POs attained through course modules for I, II, III and IV semesters.

Table 7: CO-PO articulation Matrix for M.Tech Computer Science and Engineering (MLRS R 22) regulation

Code	Subject	PO					
		1	2	3	4	5	6
I M. Tech –I Semester							
2215801	Artificial Intelligence	✓	✓	✓	✓	✓	✓
2215802	Advanced Data Structures	✓	✓	✓	✓	✓	✓
2215813	Database Programming With PL/SQL	✓	✓	✓	✓	✓	✓
2215804	Software Quality Engineering	✓	✓	✓	✓	✓	✓
2215831	Advanced Data Structures Lab	✓	✓	✓	✓	✓	✓
2215832	Database Programming With PL/SQL Lab	✓	✓	✓	✓	✓	✓
2211234	Research Methodology & IPR	✓	✓	-	✓	✓	✓
2215856	Disaster Management	-	✓	-	✓	✓	-
I M. Tech –II Semester							
2225804	Advanced Algorithms	✓	✓	✓	✓	✓	✓
2225805	Machine Learning	✓	✓	✓	✓	✓	✓
2225820	Advanced Computer Networks	✓	✓	✓	✓	✓	✓
2225824	Robotic Process Automation	✓	✓	✓	✓	✓	✓
2225835	Advanced Algorithms Lab	✓	✓	✓	✓	✓	✓
2225837	Advanced Computer Networks Lab	✓	✓	✓	✓	✓	✓

2225839	Mini Project with Seminar	✓	✓	✓	✓	✓	✓
2220008	Constitution Of India	-	✓	-	✓	✓	✓
IIM. Tech –I Semester							
2235826	High Performance Computing	✓	✓	✓	✓	✓	✓
2235503	Fundamentals Of Nano Technology	✓	✓	✓	✓	✓	✓
2234004	Dissertation Work Review – I	✓	✓	✓	✓	✓	✓
II M. Tech –II Semester							
2245846	Dissertation Work Review – II	✓	✓	✓	✓	✓	✓
2245847	Dissertation Viva -Voce	✓	✓	✓	✓	✓	✓

Methods for measuring Learning

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

The above assessment indicators are detailed below.

7.1 Continuous Internal Assessment (CIA)

Two Continuous Internal Assessment (CIAs) 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.

7.2 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 departmental academic council and to the principal for taking necessary actions to better the course for subsequent semesters.

7.3 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 the overall progress and to produce terminal marks and grading.

7.4 Course End Surveys

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 forth entire faculty. Based on this, alterations or changes to the course objectives are undertaken by thorough discussions in faculty and meetings.

7.5 Programme Exit Survey

The Program Exit Questionnaire is to be completed by all students leaving the institution. The questionnaire is designed to gather information from students regarding program educational objectives, overall program experiences, career choices, and any suggestions or comments for program improvement. The opinions expressed in the exit interview forms are reviewed by the Department Advisory Committee (DAC) for potential implementation.

7.6 Alumni Survey

The survey gathers insights from former students of the department regarding their employment status, further education, perceptions of institutional emphasis, estimated gains in knowledge and skills, undergraduate involvement, and continued engagement with Marri Laxman Reddy Institute of Technology and Management. This survey is conducted every three years, and the collected data is analysed for continuous improvement.

7.7 Employer Survey

The main purpose of this employer questionnaire is to know employers' views about the skills they require of employees compared to the skills actually possessed by them. The purpose is also to identify gaps in technical and vocational skills, determine the need for required training practices to fill these gaps, and establish criteria for hiring new employees. These employer surveys are reviewed by the College Academic Council (CAC) to modify the present curriculum to suit the requirements of the employer.

7.8 Program Assessment and Quality Improvement Committee (PAQIC)

The course expert team is responsible in exercising the central domain of expertise in developing and renewing the curriculum and assessing its quality and effectiveness to the highest of professional standards. Inform the Academic Committee the ’day-to-day’ matters as are relevant to the offered courses. This committee will consider the student and staff feedback on the efficient and effective development of the relevant courses. The committee also review the course full stack content developed by the respective course coordinator.

7.9 Department Advisory Board

The Departmental Advisory Board (DAB) plays an important role in the development of the department. The department-level Advisory Board is established to provide guidance and direction for the qualitative growth of the department. The board interacts and maintains liaison with key stakeholders.
The DAB will monitor the progress of the program and develop or recommend new or revised goals and objectives for the program. Additionally, the DAB will review and analyse the gaps between the curriculum and industry requirements, providing necessary feedback or advice to improve the curriculum

7.10 Faculty Meetings

The DAC 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.

7.11 Professional Societies

The Department of Computer Science and Engineering actively promotes professional engagement through student chapters of recognized bodies such as the Computer Society of India (CSI) and the Association for Computing Machinery (ACM). These professional bodies function as structured co-curricular platforms within the college, organizing technical talks, workshops, coding competitions, seminars, and industry interaction sessions to enhance students’ technical competence and professional awareness. Regular activities conducted under CSI and ACM facilitate knowledge dissemination in emerging areas of computing, encourage collaborative learning, and strengthen problem-solving and innovation skills. Participation in these bodies fosters leadership qualities, ethical practices, teamwork, and continuous professional development among students, contributing to their overall academic and professional growth.

7.12 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 provided by the students.

The weightage in CO attainment of Direct and Indirect assessments are illustrated in Table.

Table 8: CO-PO Mapping

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

7.13 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.

- Mid Term 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 PO's.
- 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	Midterm Examination	Twice in a semester	30	Answer script
		Viva-voce/PPT/Poster Presentation/Case study	Once in a semester	05	PPT
		Assignment	Twice in a semester	05	Assignment script

S No	Courses	Components	Frequency	Max. Marks	Evidence
		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

7.14 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.

7.15 PO Assessment tools and Processes

The institute has the following methods for assessing the attainment of PO's.

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.

7.16 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.

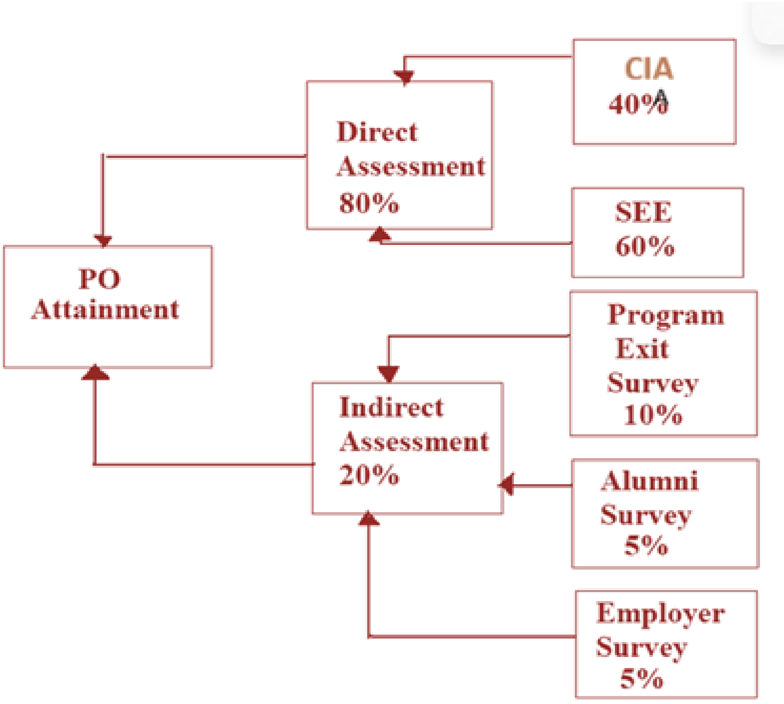


Figure3: Evaluation process of POs attainment

Course Description

8 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

ADVANCED DATA STRUCTURES

1	Department	COMPUTER SCIENCE AND ENGINEERING							
2	Course Name	**ADVANCED DATA STRUCTURES**							
3	Course Code	**2215802**							
4	Year/Semester	I-I							
5	Regulation	MLRS-R22							
7	Structure of the course	Theory				Practical			
		Lecture	Tutorials	Practical	Credit	L	T	P	C
		3	0	0	3	0	0	4	2
8	Type of course	BS	HS	ES	PC	PC	OE	CC	MC
		×	×	×	✓	✓	×	×	×
9	Course Offered	Odd Semester	✓	Even Semester	×				
10	Total lecture, tutorial and practical hours for this course Offered (15 weeks of teaching per semester)								
	Lectures: 45 Hours	Tutorials: 0 hours	Practical: 3 hours						
11	Course Coordinator	Dr. S Prathap Singh							
12	Date Approved by BOS	20.03.2021							
13	Course Webpage	www.mlritm.ac.in/							
14	Prerequisites/ Co-requisites	Level	Course Code	Semester	Prerequisites				
		PG	2020502	B.TECH 1-2	UG level course in Data Structures				

15.Course Overview:

The Advanced Data Structures (PC-II) course is designed to deepen the understanding of complex data structures and their applications. It builds upon foundational data structures by introducing more sophisticated concepts such as heap structures, hashing techniques, balanced search trees, digital search trees, and pattern matching algorithms. The course begins with an exploration of various heap data structures, including Min-Max heaps, Leftist trees, Binomial heaps, and Fibonacci heaps, providing insights into their efficiency in handling ordered data. It then covers hashing, focusing on hash tables, hash functions, and collision handling methods, which are crucial for fast data retrieval. As students progress, they will study search structures like AVL trees, Red-Black trees, Splay trees, and B-trees, which are designed for efficient searching, insertion, and deletion operations. The course further delves into digital search structures, including tries and suffix trees, used for efficient string matching and search operations. Lastly, the course addresses advanced pattern matching algorithms, including Boyer-Moore and Knuth-Morris-Pratt, which are essential for optimizing string search performance. By the end of the course, students will possess the ability to choose appropriate data structures for solving specific problems and understand how the selection impacts the performance of algorithms. This course is vital for students aiming to develop expertise in data-driven applications and optimizing computational problems in real-world systems.

16. Course Objectives:

1. Introduce and explore various types of heaps such as Min-Max Heaps, Leftist Trees, Binomial Heaps, and Fibonacci Heaps.
2. Explore advanced concepts in hash tables, hash functions, and methods for handling collisions.
3. Learn search-based data structures like AVL trees, Red-Black trees, Splay trees, and Multiway search trees such as B-trees and 2-3 trees.
4. Study digital search trees, binary tries, Patricia trees, multiway tries, suffix trees, and compressed tries.
5. Gain an understanding of efficient pattern matching techniques, including the Boyer-Moore, Knuth-Morris-Pratt, and Rabin-Karp algorithms.

17. Course Outcomes:

After successful completion of the course, students should be able to:

CO1	Demonstrate the use of advanced heap structures to address priority-based and optimization problems.
CO2	Analyze hashing functions in conjunction with collision resolution strategies to improve the performance of data retrieval systems.
CO3	Construct balanced search structures to enhance performance in large datasets.

CO4	Conduct an assessment of digital search structures to ensure efficient storage and retrieval of string and sequence data within a designated database
CO5	Distinguish various pattern matching algorithms applied in text processing and analysis.

18. Course Learning Outcome (CLOs):

S.no	Topic Name	CLO No	Course Learning Outcome	Course Outcome	Blooms Level
1	Introduction to Algorithms	CLO 1	Understand the basic concepts of algorithms, including their definition and importance.	CO1	Understand
2	Performance Analysis	CLO 2	Analyze the space and time complexity of algorithms using different asymptotic notations (Big O, Omega, Theta, Little o).	CO1	Apply
3	Disjoint Sets	CLO 3	Understandand implement union and find operations in disjoint sets.	CO1	Apply
4	Divide and Conquer	CLO 4	Apply the divide and conquer strategy to solve problems and understand its applications.	CO1	Apply
5	Greedy Method	CLO 5	Understand and apply the greedy approach to problem-solving.	CO2	Apply
6	Applications	CLO 6	Solve specific problems using the greedy method	CO2	Analyze
7	Dynamic Programming	CLO 7	Understand and apply the dynamic programming approach to solve problems efficiently.	CO3	Apply
8	Applications	CLO 8	Solve problems using dynamic programming and understand their optimal solutions.	CO3	Analyze
9	Backtracking	CLO 9	Understand and apply the backtracking method to solve combinatorial problems.	CO4	Apply

10	Applications	CLO 10	Solve specific problems using backtracking techniques	CO4	Analyze
11	Branch and Bound	CLO 11	Solve specific problems using branch and bound techniques.	CO5	Apply
12	Applications	CLO 12	Analyze the real-time databases using python DB-API	CO5	Analyze
13	NP-Hard	CLO 13	Understand basic concepts of NP-Hard	CO5	Understand
14	NP-Complete Problems	CLO 14	Understand basic concepts of NP-Complete problems, including non-deterministic algorithms	CO5	Understand
15	Cook's Theorem	CLO 15	Understand and explain Cook's Theorem and its implications in computational complexity.	CO5	Understand

19. Employability Skills:

Example 1: Software Engineering:
Analytical Thinking: Ability to break down complex problems (e.g., selecting suitable heap structures, hashing techniques, or search trees) into smaller parts and devise efficient solutions. Creative Thinking: Developing innovative algorithms (e.g., hybrid search structures, custom hashing functions) to solve novel or challenging problems.
Example 2: Programming Skills
CodingProficiency in writing implementations for heaps, hashing, search trees, tries, and pattern matching algorithms using languages like Python, Java, C++, etc. Debugging: Identifying and fixing logical errors in code implementing algorithms like Boyer–Moore, Rabin–Karp, AVL Trees, and Patricia Tries.
Example 3: Project Management
Planning & Execution Managing projects involving the design, implementation, and testing of efficient data structures and algorithms, ensuring timelines and objectives are met.

Team Collaboration Working effectively in teams for algorithm design and implementation, integrating heaps, trees, and pattern matching algorithms in real-world applications.

20. Content Delivery / Instructional Methodologies:

✓	PowerPointPresentation	✓	Chalk&Talk	✓	Assignments	✓	MOOC
✓	ALP	✓	Seminars	x	Mini Project	x	Videos

21. Evaluation Methodology:

The performance of a student in a course will be evaluated for 100 marks each, with 40 marks allotted for CIA (Continuous Internal Assessment) and 60marksfor SEE(SemesterEnd-Examination). In CIA, for theory subjects, during a semester, there shall be two mid-term examinations. Each Mid-Term examination consists of two parts i) **Part – A** for 10 marks, ii) **Part – B** for 20 marks with a totaldurationof2hours as follows:

MidTermExaminationfor30marks:

a. Part-A: Objective/quiz/short answer type paper for 10marks.
b. Part-B: Descriptive paper for 20marks.

The average of two midterm examinations shall be taken as the final marks for mid-term examinations.

The semester end examinations (SEE), will be conducted for 60marksconsistingoftwopartsviz.i) **Part-A**for10marks,ii)**Part-B**for50marks.

a. Part-A is a compulsory question which consists of ten sub-questions from all units carrying equal marks.
b. Part-B consists of five questions (numbered from 2 to 6) carrying 10 marks each. Each of these questions is from each unit and may contain sub-questions. For each question there will be an “either” “or” choice, which means that there will be two questions from each unit and the student should answer either of the two questions.
c. ThedurationofSemesterEndExaminationis3hours.

Table 1: Outline for Continues Internal Evaluation (CIA-I and CIA-II) and SEE

Activities	CIA-I	CIA-II	Average of CIA	SEE	Total Marks
Continues Internal Evaluation (CIE)	30Marks	30Marks			Average of CIE + SEE
Assignment	5 Marks	5 Marks			
Viva-Voce/PPT/Poster Presentation/Case Study	5 Marks	5 Marks			
Total Marks	**40 Marks**	**40 Marks**	**40 Marks**	**60 Marks**	**100 Marks**

22. Course content - Number of modules: Five:

MODULE 1	**Heap Structures:** Introduction, Min-Max Heaps, Leftist trees, Binomial Heaps, Fibonacci heaps.	No. of Lectures: 12
MODULE 2	**Hashing and Collisions:** Introduction, Hash Tables, Hash Functions, different Hash Functions: Division Method, MultiplicationMethod, Mid-Square Method, Folding Method, Collisions	No. of Lectures:8
MODULE 3	**Search Structures:** OBST, AVL trees, Red-Black trees, Splay trees, **Multiway Search Trees:** B-trees, 2-3 trees	No. of Lectures: 11
MODULE 4	**Digital Search Structures:** Digital Search trees, Binary tries and Patricia, Multiway Tries, Suffix trees, Standard Tries, CompressedTries	No. of Lectures: 9
MODULE 5	**Pattern matching:** Introduction, Brute force, the Boyer – Moore algorithm, Knuth-Morris-Pratt algorithm, Naïve String,Harspool, Rabin Karp	No. of Lectures: 8

TEXTBOOKS:

1.Fundamentals of data structures in C++ Sahni, Horowitz, Mehatha, Universities Press.

2.Introduction to Algorithms, TH Cormen, PHI

REFERENCE BOOKS:

1. Design methods and analysis of Algorithms, SK Basu, PHI.

2. Data Structures & Algorithm Analysis in C++, Mark Allen Weiss, Pearson Education.
3. Fundamentals of Computer Algorithms, 2nd Edition, Ellis Horowitz, Sartaj Sahni, Sanguthevar Rajasekaran, Universities Press.

ELECTRONIC RESOURCES:

1. https://nptel.ac.in/courses/106106131
2. https://onlinecourses.swayam2.ac.in/cec20_cs03/preview
3. https://ocw.mit.edu
4. https://www.geeksforgeeks.org/data-structures/
5. https://visualgo.net/en

23. COURSE PLAN:

S.No.	Topics to be covered	COs	Reference
1	Unit I: Heap Structures – Introduction & Priority Queue ADT	CO1	T1: 6.1, 6.2; T2: 6.1
2	Binary Heaps – structure, order property, array representation	CO1	T1: 6.2; T2: 6.1
3	Heap operations – insert, delete-min/max, build-heap ($\Theta(n)$)	CO1	T1: 6.3; T2: 6.2
4	Min-Heap vs Max-Heap usage applications	CO1	T1: 6.3; T2: 6.2
5	Applications of min and max heap	CO1	T1: 6.3; T2: 6.2
6	Leftist Heaps – mergeable heaps concept	CO1	T1: 6.4; T2: 19.1
7	rank, skew	CO1	T1: 6.4; T2: 19.1
8	Leftist Heaps – operations & complexity	CO1	T1: 6.4; T2: 19.1
9	Binomial Heaps – binomial trees,	CO1	T1: 6.5; T2: 19.2
10	meld, insert, delete-min	CO1	T1: 6.5; T2: 19.2

S.No.	Topics to be covered	COs	Reference
11	Fibonacci Heaps – structure & amortized analysis (overview)	CO1	T1: 6.6; T2: 19.3
12	Heaps – use-cases, design choices, comparisons	CO1	T1: 6.6; T2: 19.3
13	Unit II: Hashing – Intro; hash table models & load factor	CO2	T1: 5.1; T2: 11.1
14	Hash functions – Division & Multiplication methods	CO2	T1: 5.2; T2: 11.2
15	Hash functions – Mid-Square & Folding; uniformity	CO2	T1: 5.2; T2: 11.2
16	Collision handling – Chaining (lists, trees)	CO2	T1: 5.3; T2: 11.2
17	Open addressing – Linear/Quadratic probing	CO2	T1: 5.4; T2: 11.4
18	Double hashing; deletion challenges in open addressing	CO2	T1: 5.4; T2: 11.4
19	Performance: expected time, clustering; table sizing & rehash	CO2	T1: 5.5; T2: 11.5
20	Perfect hashing & practical design guidelines,hashes	CO2	T1: 5.6; T2: 11.5
21	Unit III: OBST – optimal search cost DP, freq tables	CO3	T1: 4.7; T2: 15.1
22	OBST – construction, correctness & example builds	CO3	T1: 4.7; T2: 15.1
23	AVL Trees – rotations, height bounds	CO3	T1: 4.4; T2: 13.2
24	AVL Trees – insertion/deletion; complexity	CO3	T1: 4.4; T2: 13.2
25	Red-Black Trees – properties & rotations	CO3	T1: 4.5; T2: 13.3
26	Red-Black Trees – insert/delete algorithms	CO3	T1: 4.5; T2: 13.3
27	Splay Trees – splaying operations & amortized ideas	CO3	T1: 4.6; T2: 13.4
28	Splay Trees – access/update sequences, use-cases	CO3	T1: 4.6; T2: 13.4
29	Multiway Trees – B-trees: node structure, invariants	CO3	T1: 4.8; T2: 18.1
30	B-trees – search, insert (split), delete (merge/borrow)	CO3	T1: 4.8; T2: 18.2

S.No.	Topics to be covered	COs	Reference
31	2-3 / 2-3-4 Trees – relation to RB trees; disk access model	CO3	T1: 4.9; T2: 18.3
32	Unit IV: Digital Search Structures – DST overview	CO4	T1: 7.1; T2: 12.1
33	Tries – standard (character) tries; prefix search	CO4	T1: 7.2; T2: 12.2
34	Binary Tries – bitwise tries, integer keys	CO4	T1: 7.3; T2: 12.3
35	Patricia (radix) Tries – path compression	CO4	T1: 7.3; T2: 12.3
36	Multiway Tries – memory layout, fanout choices	CO4	T1: 7.4; T2: 12.4
37	Compressed Tries – space-efficient representations	CO4	T1: 7.4; T2: 12.4
38	Suffix Trees – concepts & applications	CO4	T1: 7.5; T2: 12.5
39	Suffix Trees – construction ideas & queries	CO4	T1: 7.5; T2: 12.5
40	Design trade-offs across digital search structures	CO4	T1: 7.6; T2: 12.6
41	Unit V: Pattern Matching – problem setup & metrics	CO5	T1: 8.1; T2: 32.1
42	Naïve & Brute-Force methods; baseline analysis	CO5	T1: 8.2; T2: 32.2
43	Knuth–Morris–Pratt (KMP) – prefix (LPS) function	CO5	T1: 8.3; T2: 32.3
44	Boyer–Moore – bad-char & good-suffix heuristics	CO5	T1: 8.4; T2: 32.4
45	Horspool variant; practical tuning & ASCII/Unicode issues	CO5	T1: 8.4; T2: 32.4
46	Rabin–Karp – rolling hash, multi-pattern search	CO5	T1: 8.5; T2: 32.5
47	Algorithm selection & comparisons recap & case studies	CO5	T1: 8.6; T2: 32.6
48	recap & case studies	CO5	T1: 8.6; T2: 32.6

24. PROGRAM OUTCOMES & PROGRAM SPECIFIC OUTCOMES:

PO No.	NBA Statement / Vital Features	No. of Vital Features
PO1	**An ability to independently carry out research /investigation and development work to solve practical problems.** 1. Research problems in Computer Science and Engineering 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 collection, analyses, and interpretation systematically. 5. Innovative approaches are applied to engineering problem-solving. Results are validated against established theories and standards.	6
PO 2.	**An ability to 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. Research findings are communicated to both technical and non-technical audience.	6
PO 3.	**Students should be able to demonstrate advanced proficiency in Computer Science and allied emerging areas of Engineering.** i. In-Depth Technical Knowledge ii. Advanced Problem-Solving and Algorithmic Skills. iii. Hands-On Practical Expertise iv. Research and Innovation Aptitude v. Interdisciplinary Integration	5

PO 4.	**Students should be able to identify, analyze, and effectively solve complex real-world problems by applying advanced computing concepts, while considering solutions from a global perspective** i. Ability to break down multifaceted problems into manageable parts and develop effective solutions using advanced computing techniques. ii. Analytical Thinking and Critical Reasoning iii. Advanced Computing Knowledge. iv. Capability to understand and model complex systems, considering interdependencies and dynamic behaviors within global contexts. v. Global and Societal Awareness. vi. Aptitude for developing novel approaches and innovative solutions to address complex challenges. vii. Ability to work effectively in diverse teams and integrate knowledge from multiple disciplines to solve global problems. viii. Skill in clearly presenting problem analyses, solutions, and their implications to technical and non-technical global audiences	**8**
PO 5.	i. **An ability to acquire and apply advanced technical knowledge, professional skills, and modern computing tools to develop sustainable solutions** 1. Ability to continuously learn and apply cutting-edge technical knowledge in computing and related fields. ii. Proficiency with Modern Computing Tools. iii. Capability to design and implement solutions that are environmentally, economically, and socially sustainable. iv. Understanding of professional ethics and responsibility in creating technology solutions with long-term positive impact. v. Integration of Multidisciplinary Knowledge. vi. Adaptability and Lifelong Learning	**6**
PO 6.	**An Ability to recognize the significance of lifelong learning and actively pursue continuous professional development by adapting technologies in emerging areas.** i. Self-Directed Learning. ii. Skill in quickly learning and integrating new technologies and tools as they emerge in the field. iii. Capability to assess the relevance and impact of new technologies and decide on their applicability. iv. Continuous Professional Development Planning. v. Ability to engage with professional communities, attend workshops, and collaborate to stay updated.	**6**

	vi. Habit of regularly reflecting on personal growth, learning experiences, and professional competencies to improve continuously.	

25. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes		Strength	Proficiency Assessed by
PO1	Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and engg. specialization to the solution of complex engineering problems.	5	CIE/PPT/ Objective / quiz /SEE/ Assignments/ Viva-Voce/
PO2	Problem analysis: Identify, formulate, research literature, and analyze engineering problems to arrive at substantiated conclusions using first principles of mathematics, natural, and engineering sciences.	1	CIE/PPT/ Objective / quiz /SEE/ Assignments/ Viva-Voce/
PO3	Design/development of solutions: Design solutions for complex engineering problems and design system components, processes to meet the specifications with consideration for the public health and safety, and the cultural, societal, and environmental considerations.	5	CIE/PPT/ Objective / quiz /SEE/ Assignments/ Viva-Voce/
PO4	Conduct investigations of complex problems: Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	5	CIE/PPT/ Objective / quiz /SEE/Assignments/ Viva-Voce/
PO5	Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.	1	CIE/PPT/ Objective / quiz /SEE/ Assignments/ Viva-Voce/

PO6	The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.	4	CIE/PPT/ Objective / quiz /SEE/ Assignments/ Viva-Voce

26. MAPPING OF EACH CO WITH PO(s)

Course Outcomes (COs)	PO(s)					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Y		Y	Y		Y
CO2	Y		Y	Y		Y
CO3	Y		Y	Y		Y
CO4	Y	Y	Y	Y	Y	
CO5	Y		Y	Y		Y

27. JUSTIFICATIONS FOR CO – PO / PSO MAPPING - DIRECT:

Course Outcomes (COs)	POs	Justification for mapping (Students will be able to)	No. of key competencies
CO 1	PO1	1. identify practical computational problems and determine suitable applications of advanced heap structures for efficient optimization. 2. design and apply advanced heap methodologies to evaluate their efficiency in solving optimization problems, fostering a research-oriented approach. 3. analyze algorithmic performance and trade-offs of various heap structures, enhancing analytical reasoning and understanding of optimization	**1,2,4**
	PO3	1. identify optimization and priority-based problems suitable for advanced heap solutions. 2. implement and evaluate appropriate heap structures for solving specific optimization problems. 3. analyze performance metrics to evaluate the effectiveness of heap implementations.	**1,2,3**

	PO4	1.break down complex optimization problems and solve them using advanced heap structures. 2.evaluate heap implementations to enhance analytical reasoning and performance assessment. 3 apply heap structures and optimization techniques to solve real-world problems, demonstrating advanced computing skills.	**1,2,3**
	PO6	1.independently study advanced heap structures, fostering self-directed learning. 2. quickly learn and apply emerging heap-based technologies to solve optimization problems.	**1,2**
CO 2	PO 1	1. evaluate the strengths and weaknesses of different hashing methods and collision resolution techniques, making informed decisions to improve data retrieval performance. 2.use for developing innovative hashing functions or more efficient collision handling methods to enhance system performance, solving problems like optimization and latency reduction.	**4,5**
	PO 3	1. gain a deep understanding of hashing algorithms, data structures, and collision resolution techniques, which are fundamental to efficient data storage and retrieval systems. 2. apply algorithmic reasoning to handle collisions, improve search efficiency, and enhance overall system performance. 3. use for implementation and experimentation with different hashing and collision resolution methods, students develop practical skills in designing and optimizing real-world data retrieval systems.	**1,2,3**
	PO4	1. decompose data retrieval challenges into manageable parts, applying advanced computing techniques to optimize hashing and collision resolution. 2.use analytical skills to evaluate and optimize hashing methods and collision strategies, ensuring efficient performance. 3.analyze the course advanced knowledge of algorithms and data structures to solve real-world retrieval problems. 4. understand and model data retrieval systems, considering interdependencies and dynamic behaviors in real-world contexts. **5.** develop novel solutions for optimizing data retrieval systems.	**1,2,3,4,6,8**

		6. clearly present problem analyses and solutions, communicating technical concepts to both technical and non-technical audiences.	
	PO6	1.independently explore and deepen their understanding of hashing and collision resolution techniques, fostering continuous learning. 2. develop the ability to quickly adapt to and implement emerging tools and technologies in data retrieval and optimization.	**1,2**
CO 3	PO 1	1.analyze data characteristics and explore multiple algorithms to identify efficient search structures, reflecting real-world research practices. 2. design strategies to manage data growth and optimize performance using systematic analysis and evaluation methods. **3.**assess trade-offs in time, space, and operations, applying analytical reasoning to select optimal structures. 4.innovate by developing or modifying search algorithms to enhance efficiency, demonstrating creativity in practical problem-solving.	**2,4,5**
	PO3	1.Design and implement balanced search structures develops students' advanced algorithmic and problem-solving skills, enabling them to handle large-scale data efficiently. 2. perform hands-on implementation and performance optimization, they gain practical expertise and demonstrate proficiency in core and emerging areas of computer science, aligning directly with the PO attributes.	**2,3**
	PO4	1.design balanced search structures, students analyze complex data-related problems and apply advanced computing and algorithmic concepts to enhance efficiency and scalability. 2.strengthens their analytical thinking, critical reasoning, and computational proficiency, enabling them to develop optimized solutions applicable to real-world, globally relevant challenges.	**2,3**
	PO6	1.Construct balanced search structures requires self-directed learning to understand evolving data structures and algorithms. 2. analyze and adopt new tools or techniques for handling large datasets, evaluate their applicability and impact,	**1,2,34**

		3.update their knowledge—thereby fostering lifelong learning and professional growth aligned with the PO attributes.	
CO4	PO1	1.evaluate digital search structures by analyzing their time and space efficiency, thereby developing students' skills in data collection, comparison, and analytical evaluation. 2. promote critical reasoning by requiring students to analyze and compare search structures, assess trade-offs, and select the most efficient one, enhancing analytical and decision-making skills. 3.develop their problem-solving skills by encouraging their to optimize or modify search structures, aligning with research-oriented development and method improvement.	**3,4,5**
	PO2	1.document their assessment clearly, improving their technical writing ability. 2. collect, analyze, and integrate performance data effectively into their reports 3.organize reports logically using proper sections, tables, and figures for clarity.	**1,2,3**
	PO 3	1 develop hands-on skills in implementing and evaluating search structures, enhancing practical proficiency in data storage and retrieval.	**3**
	PO4	1.develop analytical and critical reasoning by requiring evaluation and comparison of digital search structures for efficiency. 2.apply advanced computing concepts such as indexing, hashing, and data retrieval algorithms to optimize database performance. 3. promotes awareness of global computing needs by applying efficient data storage and retrieval techniques relevant to modern, large-scale applications.	**2,3,5**
	PO5	1.encourages independent exploration and assessment of advanced search structure self-directed learning. 2. adapt and apply new database search techniques and tools as technologies evol 3.develops the ability to evaluate modern search methods and determine their suit specific applications. 4. continuous improvement by motivating students to stay updated with emerging management and retrieval technologies.	**1,2,3,4**

CO5	PO1	1. identify text processing problems suited for pattern matching. 2 compare algorithms to enhance analytical reasoning. 3.explore optimized or hybrid algorithms for better solutions.	**1,4,5**
	PO3	1.enhance understanding of different pattern matching algorithms, strengthening technical knowledge in text processing. 2.apply analytical and algorithmic thinking to compare and select efficient pattern matching techniques for real-world problems.	**1,2**
	PO4	1.enhance understanding of different pattern matching algorithms, strengthening technical knowledge in text processing. 2. apply analytical and algorithmic thinking to compare and select efficient pattern matching techniques for real-world problems. **3.**develop analytical and critical reasoning by requiring students to compare and evaluate the efficiency and suitability of different pattern matching algorithms. 4. gain advanced computing knowledge by understanding and applying various pattern matching algorithms used in modern text processing and analysis.	**2,3**
	PO6	1 encourage independent exploration and assessment of advanced search structure self-directed learning. 2 learn and apply new database search techniques and tools as technologies evolv 3 develop the ability to evaluate modern search methods and determine their suit specific applications. 4 utilize continuous improvement by motivating students to stay updated with en management and retrieval technologies. .	**1,2,3,4**

28. TOTAL COUNT OF KEY COMPETENCIES FOR CO – (PO, PSO) MAPPING:

Course Outcomes	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
	6	**6**	**5**	**8**	**6**	**6**
CO1	3		3	3		2
CO2	2		3	5		2
CO3	3		2	2		4
CO4	3	3	1	3	4	
CO5	3		2	2		4

29. PERCENTAGE OF KEY COMPETENCIES FOR CO – (PO):

Course Outcomes	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
	6	**6**	**5**	**8**	**6**	**6**
CO1	50.00		60.00	37.50		33.33
CO2	33.33		60.00	62.50		33.33
CO3	50.00		40.00	25.00		66.67
CO4	50.00	50.00	20.00	37.50	66.67	
CO5	50.00		40.00	25.00		66.67

30. COURSE ARTICULATION MATRIX (PO – PSO MAPPING):

CO’S and PO’S, CO’S and PSO’S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

0 - 0≤ C≤ 5% – No correlation, 2 - 40 % <C < 60% –Moderate

1-5 <C≤ 40% – Low/ Slight 3 - 60% ≤ C < 100% – Substantial /High

Course Outcomes	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
	6	**6**	**5**	**8**	**6**	**6**
CO1	2		2	1		1
CO2	1		2	3		1
CO3	2		1	1		3
CO4	2	2	1	1	3	
CO5	2		1	1		3
Total	9	2	7	7	3	8
Average	1.8	2	1.4	1.4	3	2

31. ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE	✓	Seminars	-
Objective / quiz	✓	Viva-Voce/PPT	✓	MOOCS	-
Assignments	✓	Project	-		

31. ASSESSMENT METHODOLOGY INDIRECT:

✓	Course End Survey (CES)

33. RELEVANCE TO SUSTAINABILITY GOALS:

Python, as a versatile and powerful programming language, can play a significant role in advancing various SDGs.

x	1		
x	2		
✓	3		Algorithms model the spread of diseases and predict outbreaks, aiding in public health planning and response. This includes managing resources and optimizing responses to health crises.
✓	4		Algorithms power educational platforms that raise awareness about sustainability issues, providing tools and resources for individuals and organizations to contribute to sustainability goals.
x	5		
x	6		

x	7	AFFORDABLE AND CLEAN ENERGY	
x		DECENT WORK AND ECONOMIC GROWTH	
x	9	INDUSTRY, INNOVATION AND INFRASTRUCTURE	
x	10	REDUCED INEQUALITIES	
x	11	SUSTAINABLE CITIES AND COMMUNITIES	
x	12	RESPONSIBLE CONSUMPTION AND PRODUCTION	
x	13	CLIMATE ACTION	
x	14	LIFE BELOW WATER	

x	15	LIFE ON LAND	
x	16	PEACE, JUSTICE AND STRONG INSTITUTIONS	
x	17	PARTNERSHIPS FOR THE GOALS	

Signature of Course Coordinator **HOD**
Name & Designation