IARE

INSTITUTE OF AERONAUTICAL ENGINEERING

EDUCATION FOR LIBERATION

WRITING AND USING LEARNING OUTCOMES

At Program and Course Level that Align with NBA

NAAC ACCREDITATION A++ GRADE

nirf INDIA RANKINGS 2024

ENGINEERING RANK 151-200

INNOVATION RANK 11-50

NBA NATIONAL BOARD OF ACCREDITATION

Contents

Contents

PREAMBLE

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

OBE enhances the traditional methods and focuses on what the Institute provides to students. It shows the success by making or demonstrating outcomes using statements" able to do" in favour of students. OBE provides clear standards for observable and measurable outcomes.
National Board of Accreditation (NBA) is an authorized body for the accreditation of higher education institutions in India. NBA is also a full member of the Washington Accord. NBA accredited program and not the institutions.

Higher Education Institutions are classified into two categories by NBA

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

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

Four levels of outcomes from OBE are
1.Program Educational Objectives (PEOs)
2.Program Outcomes (POs)
3.Program Specific Outcomes (PSOs)
4.Course Outcomes (COs)

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

Benefits of OBE

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

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

India - OBE and Accreditation:

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

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

Institute Vision

To bring forth students, professionally competent and socially progressive, capable of working across cultures meeting the global standards ethically.

Institute Mission

To provide students with an extensive and exceptional education that prepares them to excel in their profession, guided by dynamic intellectual community and be able to face the technically complex world with creative leadership qualities.
Further, be instrumental in emanating new knowledge through innovative research that emboldens entrepreneurship and economic development for the benefit of wide spread community.

Department Vision

To build a strong community of dedicated graduates with expertise in the field of Aerospace science and engineering suitable for industrial needs having a sense of responsibility, ethics and ready to participate in aerospace activities of national and global interest.

Department Mission

The Aeronautical Engineering Department for M. Tech.- Aerospace is committed to,

- Fostering academic excellence and scholarly learning among students (M1).
- Promote innovations in the fields of Aerodynamics, Structural Design, Propulsion and Avionics systems (M2).
- Enhance national and globally competitive engineers for economic and social development (M3).

Quality Policy

Our policy is to nurture and build diligent and dedicated community of engineers providing a professional and unprejudiced environment, thus justifying the purpose of teaching and satisfying the stake holders.

A team of well qualified and experienced professionals ensure quality education with its practical application in all areas of the Institute.

Philosophy

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

Core Values

Excellence: All activities are conducted according to the highest international standards.
Integrity: Adheres to the principles of honesty, trustworthiness, reliability, transparency and ac- countability.
Inclusiveness: To show respect for ethics, cultural and religious diversity and freedom of thought.
Social Responsibility: Promotes community engagement, environmental sustainability, and global citizenship. It also promotes awareness of, and support for, the needs and challenges of the local and global communities.
Innovation: Supports creative activities that approach challenges and issues from multiple perspectives in order to find solutions and advance knowledge.

Outcome Based Education

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

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

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

Employability statement: This curriculum embeds the development of employability skills throughout the course and is designed to equip students with the ability to relate the knowledge and skills that they have learnt to real world contexts in which they work or may work in the future. The use of expert guest lecturers from industry is the important assets for students attending the program.

What does OBE address?

OBE addresses the following key questions:

What do we want the students to be able to do?
Have Knowledge, Develop Skills and be able to solve problems.

How can we help students best to achieve it?
Student Centric Learning

How will we know whether the students have achieved it?
Through various assessment schemes

How do we close the loop for further improvement? (Continuous Quality Improvement)?
Plan – Do – Check – Act.

OBE Implementation

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

♦Define Vision statements, Mission statements for the Institute and department
♦Define Program Educational Objectives
♦Program Outcomes and Program Specific Outcomes Statements
♦Role of Knowledge and Attitude Profiles (Wks)
♦Engineering Competencies (EC): Complex engineering problems solving and complex engineering activities
♦Define Course Outcomes
♦Map courses with Program Outcomes and Program Specific Outcomes
♦Define Course Outcomes with Bloom's Taxonomy for each course
♦Map topics with Course Outcomes
♦Prepare lecture-wise Course Lesson Plan – Schedule of instruction
♦Define pedagogical tools for course outcomes delivery
♦Define Self Learning and Term Work activities like Tutorial, Practical, seminar, Mini Project etc.,
♦Use Aakansha Learning Management Portal for course full stack
♦Use ESLO to measure the attainment of each CO through Direct/Indirect assessments
♦Track students' performance
♦Identify Gaps in the Curriculum and adopt suitable measures to bridge the Gap
♦Compare PO/PSO for last 3 academic years and propose remedial actions
♦Assess the attainment of Program Educational Objectives

OBE Outcomes and Profiles

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

♦Program Educational Objectives (PEO)
♦Program Outcomes (PO)
♦Program Specific Outcomes (PSO)
♦Knowledge and Attitude Profiles (WK)
♦Engineering Competencies (EC): Range of Complex Engineering Problems (CP) and
♦Range of Complex Engineering Activities (CA)
♦Learning Domains (LD)
♦Sustainable Development Goals (SDGs)

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

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

Planning and Development of Learning Outcomes Based Approach to Curriculum

The basic objective of the learning outcome-based approach to curriculum planning and development is to focus on demonstrated achievement of outcomes (expressed in terms of knowledge, understanding, skills, attitudes and values) and academic standards expected of a program of study. Learning outcomes specify what graduates completing a particular program of study are expected to know, understand and be able to do at the end of their program of study.

The expected learning outcomes are used to set the benchmark to formulate the course outcomes, program specific outcomes, program outcomes and engineering competencies. These outcomes are essential for curriculum planning and development, and in the design, delivery and review of academic programs. They provide general direction and guidance to the teaching-learning process and assessment of student learning levels under a specific program.

The overall objectives of the learning outcomes-based curriculum framework are to:

- Attain program outcomes, program specific outcomes and course outcomes that are expected to be demonstrated by the holder of a qualification.
- Enable prospective students, parents, employers and others to understand the nature and level of learning outcomes (knowledge, skills, attitudes and values) or attributes a graduate of a program should be capable of demonstrating on successful completion of the program of study.
- Maintain national standards and international comparability of learning outcomes and academic standards to ensure global competitiveness, and to facilitate student/graduate mobility.
- Provide higher education institutions an important point of reference for designing teaching-learning strategies, assessing student learning levels, and periodic review of programs and academic standards.

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

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

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

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

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

Skill on the other hand refers to the ability of using that information and applying it in a context. Knowledge refers to theory and skill refers to successfully applying that theory in practice and getting expected results. The table 1, shows the details of Knowledge, Skill and Competence with their sub - strand in education.

Table-1: Details of Knowledge, Skill, Competence and Deposition with their sub - strand in education.

Knowledge	Breadth	How broad is the learner's knowledge?
	Type	What characteristics and quality of knowing has the learner engaged in?
Skill	Range	What is the breadth of the physical, intellectual, social and other skills acquired by the learner?
	Selectivity	How does the learner select the skills learned to address a range of problems? What is the nature of the complexity of the problems and how does the learner engage with them?
Dispositions	Application of knowledge-skill pairs.	Outline the "know-why" component of the skilled application of knowledge and capture the nuances brought about by the contextual application of knowledge-skill pairs. There is often a character and quality of application inherent in the domain and context of application.
Competence	Autonomy and responsibility	How does the learner demonstrate the taking of responsibility personally and in groups? How does the learner deploy skills acquired in managing interactions with others and working on their own?
	Self- development	To what extent can the learner operate in new environments, acquire new knowledge and skills; and assimilate these to their existing body of knowledge and skills?
	Role in Context	Can the learner apply/deploy their knowledge and skills in a range of relevant contexts?

Competency-based approach.

A competency is the graduate's ability to apply knowledge, skills, and dispositions (called attitudes) to effectively complete tasks.

This philosophy and definition acknowledge cognitive (Thinking, and learning.) and metacognitive skills (knowledge and understanding), demonstrated use of knowledge and applied skills, and interpersonal skills that often work in concert.

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

Benefits of Competency-based approach are:

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

Competency = [Knowledge + Skills + Dispositions] in Task as shown in figure 1.

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

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

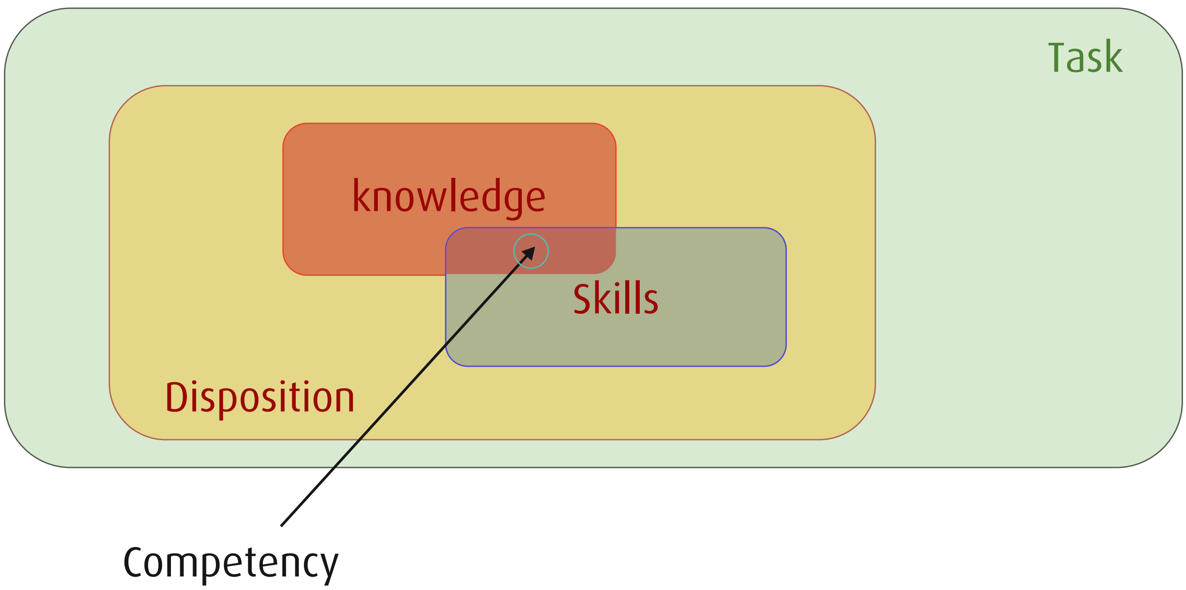

Figure 1: Bloom's Cognitive Skill List

Table-2: Bloom's levels

Definitions	I Remember	II Understand	III Apply	IV Analyze	V Evaluate	VI Create
Blooms Definition	Exhibit memory of previously learned materials by recalling facts, terms, basic concepts, and answers.	Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions,	Solve problems to 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	Present and defend opinions by making judgments. about information, validity of ideas, or quality of	Compile information together in a different way by combining elements in a new pattern or proposing alternative
Verbs	• Choose • Define • Find • How • Label • List • Match • Name • Omit • Recall • Relate • Select • Show • Spell • Tell • What • When • Where • Which • Who • Why	• Classify • Compare • Contrast • Demonstrate • Explain • Extend • Illustrate • Infer • Interpret • Outline • Relate • Rephrase • Show • Summarize • Translate	• Apply • Build • Choose • Construct • Develop • Experiment with • Identify • Interview • Make use of • Model • Organize • Plan • Select • Solve • Utilize	• Analyze • Assume • Categorize • Classify • Compare • Conclusion • Contrast • Discover • Dissect • Distinguish • Divide • Examine • Function • Inference • Inspect • List • Motive • Relationships • Simplify • Survey • Take • Part in • Test for • Theme	• Agree • Appraise • Assess • Award • Choose • Compare • Conclude • Criteria • Criticize • Decide • Deduct • Defend • Determine • Disprove • Estimate • Evaluate • Explain • Importance • Influence • Interpret • Judge • Justify • Mark • Measure • Opinion • Perceive • Prioritize • Prove • Recommend • Rule on • Select • Support • Value	• Adapt • Build • Change • Choose • Combine • Compile • Compose • Construct • Create • Delete • Design • Develop • Discuss • Elaborate • Estimate • Formulate • Happen • Imagine • Improve • Invent • Make up • Maximize • Minimize • Modify • Original • Originate • Plan • Predict • Propose • Solution • Solve • Suppose • Test • Theory

The inclusion of Bloom's levels illustrates in Table 2, the close linkage between knowledge-based and competency-based approaches.

On the lower skill levels, students are expected to “remember” or “understand” knowledge, which refers to more cognitive aspects of learning.

However, to reach the level “applying” or higher, assignments where students practice the use of knowledge in specific tasks provided by a teacher are required.

Architecture of the B. Tech curriculum

The architecture is proposed in Figure 2, as a guide for a model curriculum. Constructs on the left represent the traditional curriculum design view, (program – program outcome, course – course learning outcomes) and the right represent entities of competency models: Competency realm, area, competency, knowledge-skill pairs, and dispositions. Definitions for the terms are presented in Table 3.

The structure is divided into two levels. Level 1 includes the six major elements: Program, Program Learning Outcome, Competency Realm, Competency Area, Competency Statement, and Course.

Level 2 includes Course Learning Outcome and Competency which is further defined through three elements, namely Knowledge, Skill, and Disposition. Each Competency Area (CA) has a set of detailed competencies.

These competencies are defined using a combination of Competency Statement, Knowledge, Skills and Dispositions that one must have to demonstrate a specific competency under a Competency area.

These concepts allow a more detailed comparison of the learning objectives in a course, based on tasks assigned for students, and associated knowledge areas, skill levels, and dispositions. Level 2 aligns with the competency.

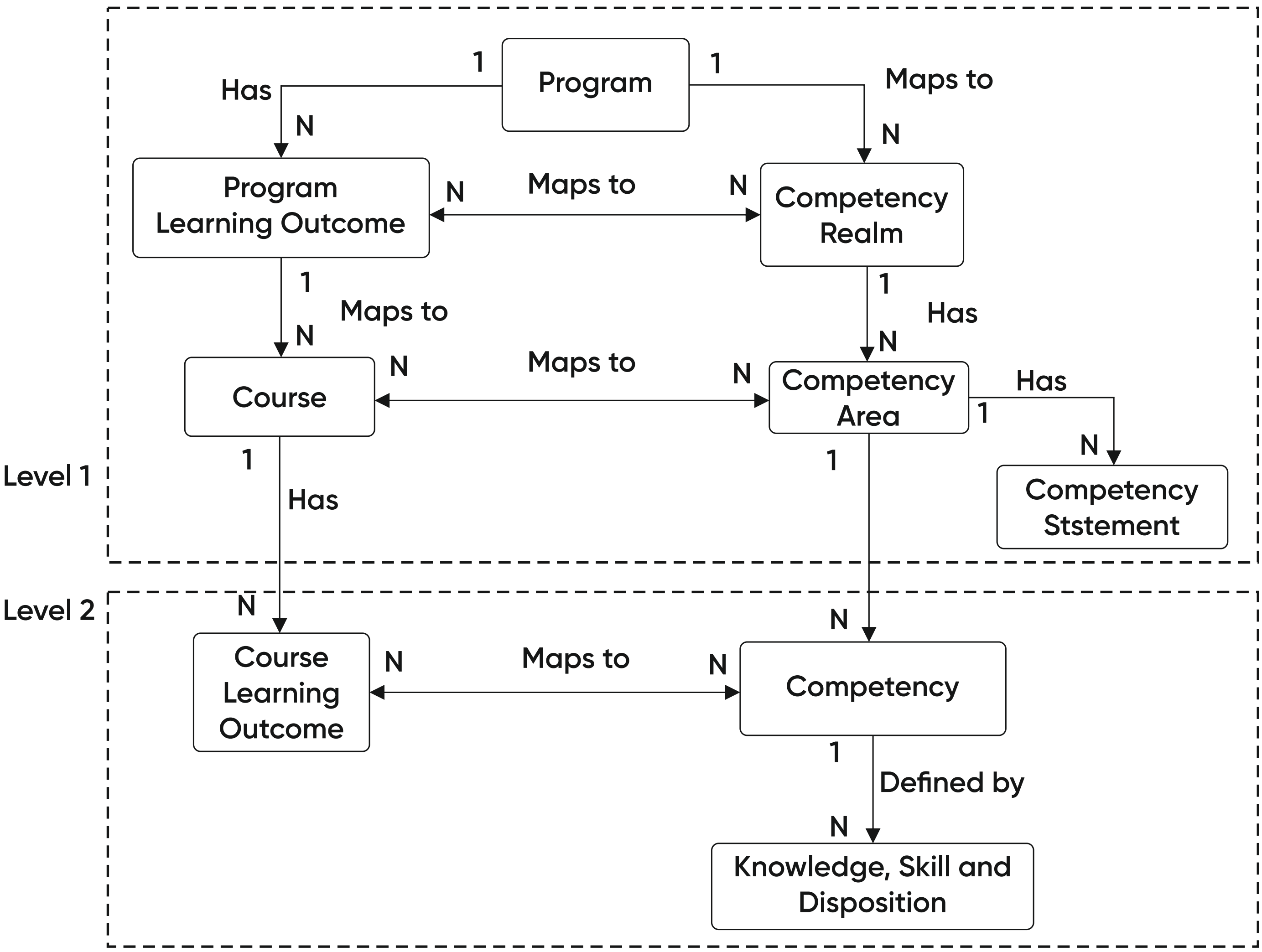

Figure 2: Curriculum structure of B. tech Program

Table 3: Definition of Terms Used in the Curriculum structure

Term Definition	Term Definition
Program	Program A major or a complete undergraduate degree program in IS.
Program Learning Outcomes	Defines what students are expected to know and be able to do on completing the program. They are similar to ABET Student Outcomes.
Competency Realm	Broad areas of study relevant to an IS graduate
Competency Area	A component of the Competency Realm
Competency Statement.	A high-level description of the capability to apply or use a set of knowledge and skills required to successfully perform broad work functions related to a Competency Area.
Course description	A description of what will be covered in the course. They are generally less broad than Program Learning Outcomes and broader than Course Learning Outcomes.
Course Learning Outcome	A detailed description of what a student must be able to do on completion of a course. When writing outcomes, it is helpful to use verbs that are measurable or that describe an observable action.
Competency	A detailed description of the capability to apply or use a set of knowledge, skills, and dispositions to successfully perform specific work tasks related to a Competency Area

Overview on Knowledge Levels (Familiarity, Usage and Assessment)

Course: Data Structures

1.Algorithm Analysis (Knowledge Level: Varies by topic)

a) Explain and compare the growth of functions: Logarithmic functions, Polynomials, Linearithmic, and exponential functions. (Familiarity)
b) Given a function, prove that it falls into a particular complexity class. (Usage)
c) Formally Define the Asymptotic Complexity notations (Big O, Big theta, and Big Omega). Distinguish between case analysis methods (best case, average case, and worst-case analysis). (Familiarity)
d) Calculate the running-time T(n) for a given function by calculating the number of processing steps. (Usage)
e) Find the asymptotic complexity of an algorithms as a function of problem size. (Usage)

2.Recursion (Knowledge Level: Varies by topic)

a) Identify the base case and the general case of a recursively defined problem. (Familiarity)
b) Write recursive functions to solve computational problems. (Usage)
c) Convert a recursive function to an iterative function and vice versa. (Usage)
d) Analyze the running-time for recursive functions by finding the depth of recursion, the tree method, and the master method of decreasing functions. (Usage)
e) Compare iterative and recursive solutions for a problem and select the best solution and be able to defend the selected solution based on nonfunctional attributes such as efficiency, simplicity, maintainability, code reuse, and others. (Assessment)

3. Abstract Data Types and Their Implementations (Knowledge Level: Varies by topic)

    3.1 Lists, Queue, and Stack:
        a) Explain the different representations (array and linked implementations) of the ADT and its manipulating operations. (Familiarity)
        b) Analyze and assess the impact of the ADT representation on the running-time complexity of the ADT operations and space requirements. (Usage)
        c) Implement (with templates) at least two representations (array, singly linked list, doubly linked list, circularly linked list) of at least one of the ADTs and use the implementation to solve a real-world problem. (Usage)

    3.2 Search tress: Binary Search trees BST, AVL trees, Red-black trees, and BTrees: (Knowledge Level: Varies by topic)
        a) Explain the different tree implementations and associated operations. (Familiarity)
        b) Analyze and assess the impact of the ADT implementation on the running-time complexity of the ADT operations and space requirements. (Usage)
        c) Implement at least one search tree. (Usage)
        d) Select a tree type that is best suited to solve a problem and be able to defend the selection. (Assessment)

    3.3 Heaps and Priority Queues (Knowledge Level: Usage)
        a) Implement the Heap ADT and its basic operations.
        b) Analyse the basic heap operations.
        c) Use the heap structure as an internal traversal method to develop efficient solutions to real world problems.

    3.4 Design and implement the Priority Queue ADT using various data structures (Array List, Linked List, and Heap) and evaluate the different implementations with respect to space and running-time efficiency. (Knowledge Level: Usage)

    3.5 Graphs and Graph Algorithms (Knowledge Level: Varies by topic)
        a) Depict various representation (adjacency list and adjacency matrix) given a picture or a description of the graph. (Familiarity)
        b) Compare the adjacency list and the adjacency matrix implementations of the Graph ADT according to the running-time complexity of the graph operations and space requirements. (Usage)
        c) Trace basic graph algorithms, including depth first traversal, breadth first traversal, minimum spanning trees (Prim's and Kruskal's), topological sort, and single-source and all-pairs shortest path (Dijkstra's and Bellman Ford's) for a given graph. (Usage)
        d) Choose the appropriate graph algorithms to solve a problem given a description of the problem. (Assessment)
        e) Analyze the impact of data structures on the complexity of graph algorithms and choose a data structure to store the edges and/or nodes for a given graph algorithm and be able to defend the selection. (Assessment)

    3.6 Hash Tables (Knowledge level: Usage)
        a) Design and implement two different versions of the hash table interface: Open addressing (Linear probing, Quadratic probing, Double hashing, Rehashing) and chaining.
        b) Analyze and assess the running-time complexity of basic hash table operations (insert, delete, and search)

4. Algorithm Design Strategies (Knowledge Level: Varies by topic)
    a) Differentiate between the strategies (greedy, divide-and-conquer, and dynamic programming) and identify a practical example to which the design strategy would apply. (Familiarity) b) Use divide-and-conquer to solve an appropriate problem. (Usage)

5. Sorting Algorithms: (Knowledge Level: Varies by topic)
   a) Implement, and analyze sorting algorithms including quadratic sorts, linearithmic sorts, and non-comparison linear sorts. (Usage)
   b) Select a sorting algorithm to solve a given problem based on running time and space efficiency and be able to defend the selection. (Assessment)

6.Implement and test projects that use data structures to solve real-world problems and satisfying a set of predefined functional requirements (pre/post conditions) and non-functional requirements (efficiency, robustness, codereuse, maintainability, and others). (Assessment)

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

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

Program Educational Objectives (PEO)

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

1.Excel in engineering practices in various industries.
2.Establish themselves as leaders in their professional careers.
3.Earn an advanced degree or professional certification.

Mapping program educational objectives to program outcomes shown in Fig 3, which ensures the curriculum aligns with key competencies, enabling students to develop the skills and knowledge required for professional success. Fig 4, gives the correlation between the PEOs and the PSOs

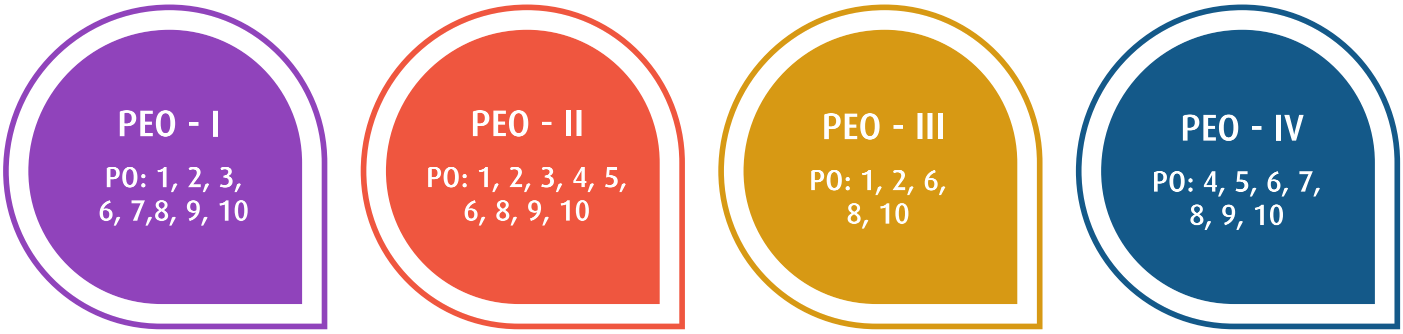

Fig 3: The correlation between the PEOs and POs

Fig 4: The correlation between the PEOs and the PSOs

Program Outcomes (POs)

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

The program must demonstrate that by the time of graduation the students have attained a certain set of knowledge, skills and behavioural traits, at-least to some acceptable minimum level. The minimum threshold value should not be less than 50% even to begin with; however, as the program progresses through its evolution, it is expected that this minimum threshold value would subsequently be raised to higher value. Specifically, it is to be demonstrated that all students of a batch to be accredited have acquired the following POs set by NBA as shown in Fig 7.

PO-1 Engineering Knowledge

Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop to the solution of complex engineering problems.

PO-2 Problem Analysis

Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)

PO-3 Design/Development of Solutions

Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5)

PO-4 Conduct Investigations of Complex Problems

Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8).

PO-5 Engineering Tool Usage

Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling recognizing their limitations to solve complex engineering problems. (WK2 and WK6)

PO-6 The Engineer and The World

Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7).

PO-7 Ethics

Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)

PO-8 Individual and Collaborative Team work

Function efectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.

PO-9 Communication

Communicate efectively and inclusively within the engineering community and society at large, such as being able to comprehend and write efective reports and design documentation, make efective presentations considering cultural, language, and learning diferences

PO-10 Project Management & Finance

Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multi disciplinary environments.

PO-11 Life-Long Learning

Recognize the need for, and have the preparation and ability for I) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change. (WK8)

Fig 5: Program Outcomes

Program Specific Outcomes

Program specific outcomes (PSOs) include subject-specific skills and generic skills, including transferable global skills and competencies, the achievement of which the students of a specific program of study should be able to demonstrate for the award of the degree. Program Specific Outcomes for each program, they are permitted upto 3 (three).

The program specific outcomes would also focus on knowledge, skills and competencies that prepare students for further study, employment, and citizenship. The evaluation of PSOs for a program is computed by gathering PSO attainment in all the courses comprising the program. The Fig 6, shows themes and specific strength of the departments for preparing Program specific Outcomes.

PSO- I

Ability to gather basic concepts of applied mathematics and programming as well as grasp the theoretical knowledge of computers to solve real life computational problems using efficient techniques.

PSO- II

Ability to acquire knowledge about the proficient use of programming languages and ICT tools to solve domain specific problems.

PSO- III

Ability to improvise existing tools and techniques to solve computationally intensive real-world problems.

PSO- IV

Ability to analyse a problem critically and designing system, component, or process for its solution using relevant techniques, resources, and tools of Information Technology.

PSO- V

Ability to acquire domain specific expertise through discipline specific elective and project works.

PSO- VI

Ability to understand different computing techniques, apply these to one's own work and develop methodology/solutions for the problems which are multi disciplinary in nature.

PSO- VII

Ability to have competency to take up higher studies, research and development activities and ability to recognize the need for and to engage in life-long learning

Fig 6 : Program Specific Outcomes

Program Specific Outcomes (PSOs) Program Specific Outcomes (PSOs) are statements that describe what the graduates of a specific engineering program should be able to do. A list of PSOs written for the department of Aeronautical Engineering is given below Table 4.

B. Tech (AE) - PROGRAM SPECIFIC OUTCOMES (PSO's)

Table 4: A list of PSOs for the department of Aeronautical Engineering

A graduate of the / Aeronautical Engineering / Program will demonstrate:	
PSO 1	Build the prototype of UAVs and aero-foil models for testing by using low speed wind tunnel towards research in the area of experimental aerodynamics
PSO 2	Focus on formulation and evaluation of aircraft elastic bodies for characterization of aero elastic phenomena.
PSO 3	Make use of multi physics, computational fluid dynamics and flight simulation tools for building career paths towards innovative startups, employability and higher studies

Relation between the Program Educational Objectives and the POs

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

Table 5: Relationship between the program educational objectives and the program outcomes

PEO's→ ↓ PO's		(1) Preparation & Learning Environment	(2) Core Competence	(3) Breadth	(4) Professionalism
Po1	Engineering Knowledge Breadth, depth and type of knowledge, both theoretical and practical	3	1	2	-
Po2	Problem Analysis Complexity of analysis	2	2	2	-
Po3	Design / Development of Solutions Breadth and uniqueness of engineering problems i.e., the extent to which problems are original and to which solutions have not previously been identified or codified	2	3	-	-
Po4	Conduct Investigations of Complex Problems Breadth and depth of investigation and experimentation	-	3	-	2
Po5	Engineering Tool Usage Level of understanding of the appropriateness of technologies and tools	-	2	-	2
Po6	The Engineer and the World Level of knowledge and responsibility for sustainable development	2	3	2	2
Po7	Ethics Understanding and level of practice	2	-	-	2
Po8	Individual and Collaborative Team work Role in and diversity of team	2	-	-	3
Po9	Communication Level of communication according to type of activities performed	2	1	2	3
Po10	Project Management and Finance Level of management required for differing types of activity	1	2	-	2
Po11	Life-Long Learning Duration and manner	1	1	2	1

Relationship between Program Outcomes and Program Educational Objectives
Key: 3 = High; 2 = Medium; 1= Low

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

Relation between the Program Educational Objectives and the PSOs

The relationship between Program Educational Objectives (PEOs) and Program Outcomes (POs) is crucial as it ensures that the educational goals are aligned with specific outcomes, equipping students with the skills and knowledge needed for their professional success. Broad relationship between the program objectives and the program outcomes is given in Table 6.

Table 6: Relationship between the program Educational objectives and the program specific outcomes

PEO's→ ↓ PO's		(1) Preparation & Learning Environment	(2) Core Competence	(3) Breadth	(4) Professionalism
Po1					
Po2					
Po3					

Relationship between Program Specific Outcomes and Program Educational Objectives
Key: 3 = High; 2 = Medium; 1= Low

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

Learning Domains (LD) - Blooms Taxonomy

Benjamin Bloom in 1956 developed a 3part model known as the Taxonomy of Learning Domains.
He splits learning into 3 different categories:
1. Cognitive domain (intellectual capability, i.e., knowledge, or 'think')
2. Affective domain (feelings, emotions and behaviour, i.e., attitude, or 'feel')
3. Psychomotor domain (manual and physical skills, i.e., skills, or 'do')

Bloom's Taxonomy is commonly used for the cognitive domain, Simpson's for the psychomotor domain, and Krathwohl's for the affective domain.

Bloom sees the domains as progressive; with the learner moving through the 6 stages of each domain as their knowledge, attitude and skills increase or develop. For the purpose of student assessment, these categories will be reclassified into twelve levels of LD. These levels are listed are shown in below Tables 8, 9 and 10.

9.1 Six levels of the Cognitive Domain

Bloom's taxonomy / Cognitive Domain is frequently used for writing learning outcomes as it provides a ready-made structure and list of verbs. These verbs are the key to writing learning outcomes.
since learning outcomes are concerned with what the students can do at the end of the learning activity, all of these verbs are active (action) verbs. as shown in Fig 7, and the justification is explained in Table 7.

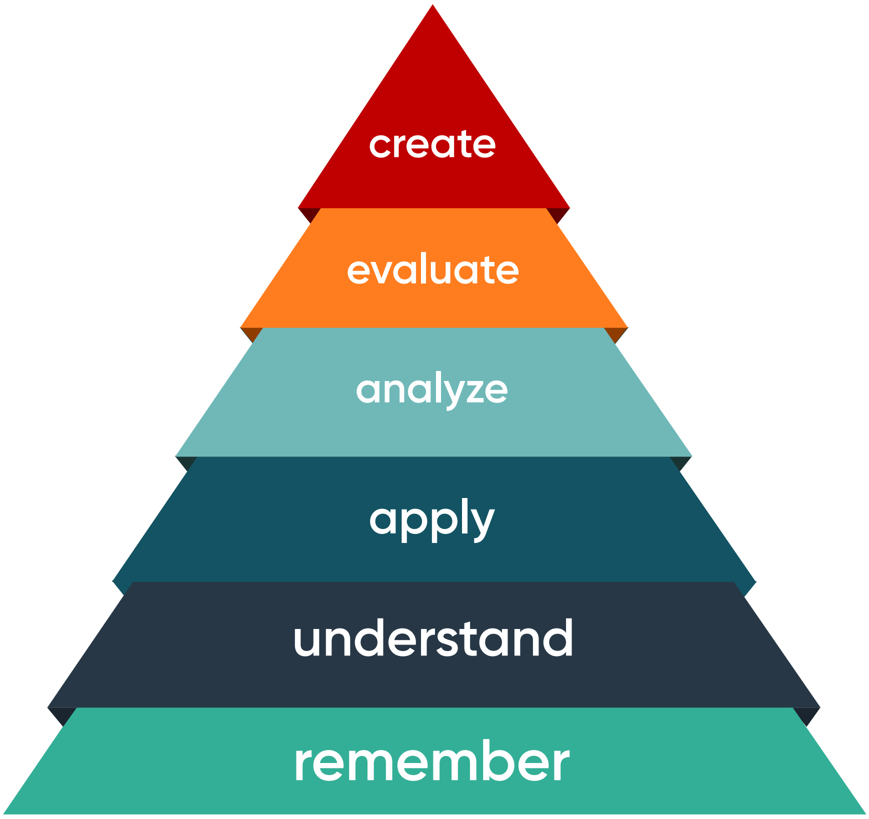

Fig 7: Six levels of the Cognitive Domain

Table 7: Justification of Cognitive Domain

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

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

Table 8: Cognitive domain levels

CLD	Category	Description
CLD1	Remember	Recognizing or recalling knowledge from memory. Remembering is when memory is used to produce definitions, facts, or lists, or recite or retrieve material.
CLD1	Understand	Constructing meaning from different types of functions be they have written or graphic messages activities like interpreting, exemplifying classifying, summarizing, inferring, comparing, and explaining.
CLD1	Apply	Carrying out or using a procedure through executing, or implementing. Applying related and refers to situations where learned material is used through products like models, presentations, interviews or simulations.
CLD1	Analyze	Breaking material or concepts into parts, determining how the parts relate or interrelate to one another or to an overall structure or purpose. Mental actions included in this function are differentiating, organizing, and attributing, as well as being able to distinguish between the components or parts. When one is analysing, he/she can illustrate this mental function by creating spreadsheets, surveys, charts, or diagrams, or graphic representations.
CLD1	Evaluate	Making judgments based on criteria and standards through checking and critiquing. Critiques, recommendations, and reports are some of the products that can be created to demonstrate the processes of evaluation. In the newer taxonomy evaluation comes before creating as it is often a necessary part of the precursory behaviour before creating something
CLD1	Create	Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing. Creating requires users to put parts together in a new way or synthesize parts into something new and different a new form or product. This process is the most difficult mental function in the new taxonomy.

These “action words” describe the cognitive processes by which thinkers encounter and work with knowledge:

- ❖ Remember
  - ✠ Recognizing
  - ✠ Recalling
- ❖ Understand
  - ✠ interpreting
  - ✠ exemplifying
  - ✠ classifying
  - ✠ summarizing
  - ✠ inferring
  - ✠ comparing
  - ✠ Explaining
- ❖ Apply
  - ✠ executing
  - ✠ Implementing
- ❖ Analyze
  - ✠ differentiating
  - ✠ organizing
  - ✠ Attributing
- ❖ Evaluate
  - ✠ checking
  - ✠ Critiquing
- ❖ Create
  - ✠ generating
  - ✠ planning
  - ✠ Producing

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

- ❖ Factual Knowledge
  - ✠ Knowledge of terminology
  - ✠ Knowledge of specific details and elements
- ❖ Conceptual Knowledge
  - ✠ Knowledge of classifications and categories
  - ✠ Knowledge of principles and generalizations
  - ✠ Knowledge of theories, models, and structures
- ❖ Procedural Knowledge
  - ✠ Knowledge of subject-specific skills and algorithms
  - ✠ Knowledge of subject-specific techniques and methods
  - ✠ Knowledge of criteria for determining when to use appropriate procedures
- ❖ Metacognitive Knowledge
  - ✠ Strategic Knowledge
  - ✠ Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge
  - ✠ Self-knowledge

9.2 Three levels (based on the original five categories) of the Affective Domain.

This domain is concerned with issues relating to the emotional component of learning and ranges from basic willingness to receive information to the integration of beliefs, ideas and attitudes. In order to describe the way in which things emotionally dealt.

Table 9: Cognitive domain levels

ALD	Category	Description
ALD7	Receiving	This refers to the learner's sensitivity to the existence of stimuli – awareness, willingness to receive, or selected attention.
	Responding	This refers to the learners' active attention to stimuli and his/her motivation to learn – acquiescence, willing responses, or feelings of satisfaction.
ALD8	Valuing	This refers to the learner's beliefs and attitudes of worth – acceptance, preference, or commitment. An acceptance, preference, or commitment to value.
	Organization	This refers to the learner's internalization of values and beliefs involving (1) the conceptualization of values; and (2) the organization of a value system. As values or beliefs become internalized, the leaner organizes them according to priority.
ALD9	Characterization	This refers to the learner's highest of internalization and relates to behaviour that reflects (1) a generalized set of values; and (2) a characterization or a philosophy about life. At this level, the learner is capable of practising and acting on their values or beliefs.

9.3 Three levels (based on the five original categories) of the Simpson's Psychomotor Domain.
The psychomotor domain is commonly used in areas of laboratory science subjects, engineering and physical education (Sports).

Table 10: Cognitive domain levels

PLD	Category	Description
PLD10	Perception	The ability to use sensory cues to guide motor activity. This ranges from sensory stimulation, through cue selection, to translation.
	Set	Readiness to act. It includes mental, physical, and emotional sets. These three sets are dispositions that predetermine a person's response to different situations (sometimes called mindsets).
PLD11	Guided Response	The early stages in learning a complex skill that includes imitation and trial and error. Adequacy of performance is achieved by practicing.
	Mechanism	This is the intermediate stage in learning a complex skill. Learned responses have become habitual and the movements can be performed with some confidence and proficiency.
PLD12	Complex / Overt Response	The skilful performance of motor acts that involve complex movement patterns. Proficiency is indicated by a quick, accurate, and highly coordinated performance, requiring a minimum of energy. This category includes performing without hesitation and automatic performance. For example, players often utter sounds of satisfaction or expletives as soon as they hit a tennis ball or throw a football because they can tell by the feel of the act what the result will produce.
	Adaptation	Skills are well developed and the individual can modify movement patterns to fit special requirements.
	Origination	Creating new movement patterns to fit a particular situation or specific problem. Learning outcomes emphasize creativity based on highly developed skills.

Understanding what "domain" we are trying to enable learners to achieve can help us to write appropriate educational objectives as well as consider how to evaluate the success of these objectives.
If we are essentially providing information; we would be assessing the learner's knowledge following teaching.
If we are encouraging students to consider a subject from multiple perspectives and to develop a professional attitude; we are assessing the affective domain. Assessing the affective domain is more difficult as personal belief systems differ, however in education the process learners go through to develop attitudes can be assessed.
If we are assessing learners' ability to perform tasks etc, we are assessing the skills domain; the "know how".

Knowledge and Attitude Profile (WK)

The list of WKs defines indicated volume of learning and attributes against which graduates must be able to perform. The list is used to extend and clarify the definition of the Program Outcomes.

In order to inculcate different dimensions of thinking mathematical, computational, design and creativeness among students in cognitive, affective and psychomotor domains, the curriculum is designed to cover the following nine knowledge and attitude profiles. These profiles reflect an indicated volume of learning and the work attitude against which graduates must be able to perform.

This list of WKs extracted verbatim from the 2024 NBA document are shown in Fig 8, and table 11 is representing their indicators of attainment.

WK1

A systematic, theory- based understanding of the natural sciences applicable to the discipline and awareness of relevant social sciences.

WK2

Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline.

WK3

A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.

WK4

Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.

WK5

Knowledge, including emcient resource use, environmental impacts, whole-life cost,reuse of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area.

WK6

Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.

WK7

Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development.

WK8

Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues.

WK9

Ethics, inclusive behavior and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability etc. with mutual understanding and respect, and of inclusive attitudes.

Fig 8: Knowledge and Attitude Profiles

Table 11: List of WKs extracted verbatim from the 2024 NBA and their indicators of attainment.

Wk	Attribute / Indicators of attainment
Wk1	**Application of Natural sciences**
	Applying concepts of natural sciences viz., physics, chemistry, social science, and discipline specialized engineering science fundamentals for solving respective problems / applications
Wk2	**Analytical skills -Numerical analysis, data analysis, statistics, modelling and Modern engineering & IT tools**
	The use of algorithms and numerical approximation techniques in mathematical analysis as applied to engineering problems.
	The knowledge and skills required to ask and answer a range of questions by analysing data including developing an analytical plan; selecting and using appropriate statistical techniques and tools; and interpreting, evaluating, and comparing results with other findings.
	An ability in data analysis implies knowledge in data awareness, cleaning, discovery, ethics, exploration, tools, and visualization.
	Development of an analytical, numerical, or empirical description of a real system
	Develop the models that can be mathematical or physical in nature and are created with the specific intent of describing, analysing, testing, demonstrating, and/or predicting behaviours, properties, or other characteristics of the system.
	The knowledge and skills to use computer systems to store and manipulate large quantities of information
	Identifies all relevant constraints and requirements and formulates an accurate description of the problem
	Use algorithms, computational tools, simulation and modelling techniques with data visualization for effective analysis.
Wk3	**Theory-based formulation**
	Gathers engineering knowledge from the open literature and discerns the most relevant
	Theoretical problem identification, model formulation and data collection
	Evaluates the analysis for accuracy and validity of assumptions made.
Wk4	**Engineering specialist knowledge**
	Applying engineering specialist knowledge for evaluation and validation of the assumptions made.
	Understanding of standards, innovation and critical analysis for accepted practices
	Apply engineering management principles to effectively implement economic decision-making.

Knowledge of resource use, Environmental impacts, Net-zero carbon support Engineering design and operations and Constraints and Boundaries

Wk5

- Demonstrates originality in developing design solutions that incorporate social values and local considerations of sustainable development impacts.
- Use of modern modelling and computational tools for system design / component design / process design for problem analysis and re-use of sources for improving efficiency / optimization
- Evaluates the feasibility of alternative solutions in all relevant contexts which, as appropriate to the problem, may include: technical, sustainability, suitability for implementation, economic, aesthetic, ethical, health and safety, societal, environmental and cultural.
- Identifying major sources of emissions, including energy production, transportation, industry, and agriculture.
- Implementing measures to reduce emissions, such as improving energy efficiency, transitioning to renewable energy, and adopting low-carbon technologies
- Investing in projects that remove carbon from the atmosphere, such as reforestation, carbon capture and storage, and renewable energy initiatives.
- Waste minimization and resource reuse compliance with environmental regulations and impact assessment
- Undertakes analysis to confirm the robustness of the proposed solution in the light of uncertain and/or incomplete information and data.
- Describes the preferred solution and presents the findings in a coherent written form and defends those findings orally.
- Technical Constraints, Budgetary Limitations, Time Constraints and Secondary impacts

Knowledge of engineering practice (technology), In the practice areas in the engineering discipline

Wk6

- Identifies the range of current tools and resources available, selects one or more suitable tools and/or appropriate resources, and justifies the selection including considerations of the limitations of the tools available.
- Applies such tools to simulate behaviour or model outcomes that might resolve a complex engineering problem, checks the results for validity, evaluates results and recognises the limitations on those results.
- Integration of Measurement Systems for process parameters with engineering design in the practice areas.

Knowledge of the role of engineering in society, Issues in engineering practice in the discipline and Professional responsibility to public safety and sustainable development.

Wk7

- Identifies risks, develops and evaluates risk management strategies to minimize the likelihood of significant consequences (such as injury or loss of life, major environmental damage, or significant economic loss) occurring in unusual or unexpected circumstances.

Identifies the relevant steps to be undertaken to address cultural or community concerns.

Identifies hazards and justifies relevant strategies and systems to reasonably assure public health and safety (including as appropriate to the discipline, safety in construction/fabrication, operation, maintenance, deconstruction/disposal, failing-safe and occupational health and safety).

Identifies and justifies specific actions required for environmental protection in the event of failure.

Undertakes life-cycle analysis to determine the sustainability of any proposed outcomes

Evaluates the impacts of any relevant legislation or regulations and justifies relevant steps to be taken to ensure compliance

Advanced student project work involves students developing sustainable design solutions.

Wk8

Engagement with selected knowledge in the current research literature of the discipline, Awareness of the power of critical thinking, Creative approaches to evaluate emerging issues

Reviews the open research literature

Identifies the needs for research or investigation.

Understanding of appropriate codes of practice and industry standards awareness of quality issues

Identifies appropriate research or investigation methodologies.

Designs and executes valid forms of research, experimentation or measurement

Use creative ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modelling techniques

Ability to apply qualitative and quantitative methods for evaluating emerging complex engineering problems.

Draws valid conclusions and justifies those conclusions

Calibrates / validates the data collection methods and equipment.

Analyses the data including considering sources of error.

Engineering ethics; Respect; diversity, and inclusivity; Honouring all – Laws, Regulations and Codes

Wk9	
	Demonstrates an understanding of the moral responsibilities of a professional engineer including: the need to self-manage in an orderly and ethical manner, to balance obligations to the interests of employers and clients, and to uphold standards in the engineering profession.
	Identifies and justifies ethical courses of action when confronted with complex situations that might arise in the work of a professional engineer.
	Identifies and justifies the use or otherwise of new technologies, such as but not limited to, Generative AI.
	Evaluates the ethical dimensions of professional practice (diversity and inclusivity) and demonstrates ethical behaviour.
	High degree of trust and integrity for professional obligations in an organization
	Comprehends how legislative, regulatory, contract law, other common law and professional obligations apply and manages own activities to comply.

ENGINEERING COMPETENCE (EC) PROFILES

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

Engineering competence can be described using a setoff attribute corresponding largely to the program outcomes (POs), but with different emphases. For example, at the professional level, the ability to the responsibility in the real-life situation is essential. Unlike the program outcomes, engineering competence is more than a set of attributes that can be demonstrated individually.

Competence must be assessed holistically ***TWELVE*** elements of engineering competences for a global benchmarking are mentioned in Table 12.

Table 12: Engineering Competence Profiles

EC	Attributes	Descriptors for Rubric Design	Category
EC1	Depth of knowledge required	Ensures that all aspects of an engineering activity are soundly based on fundamental principles - by diagnosing, and taking appropriate action with data, calculations, results, proposals, processes, practices, and documented information that may be ill-founded, illogical, erroneous, unreliable or unrealistic requirements applicable to the engineering discipline	CP
EC2	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	CP
EC3	Design and development of solutions	Support sustainable development solutions by ensuring functional requirements, minimize environmental impact and optimize resource utilization throughout the life cycle, while balancing performance and cost effectiveness.	CA
EC4	Range of conflicting requirements	Competently addresses complex engineering problems which involve uncertainty, ambiguity, imprecise information and wide-ranging or conflicting technical, engineering and other issues.	CP
EC5	Infrequently encountered issues	Conceptualises alternative engineering approaches and evaluates potential outcomes against appropriate criteria to justify an optimal solution choice.	CP
EC6	Protection of society	Identifies, quantifies, mitigates and manages technical, health, environmental, safety, economic and other contextual risks associated to seek achievable sustainable outcomes with engineering application in the designated engineering discipline.	CA
EC7	Range of resources	Involve the coordination of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies) in the timely delivery of outcomes	CA
EC8	Extent of stakeholder involvement	Design and develop solution to complex engineering problem considering a very perspective and taking account of stakeholder views with widely varying needs.	CP
EC9	Extent of applicable Codes, Legal and Regulatory	Meet all level, legal, regulatory, relevant standards and codes of practice, protect public health and safety in the course of all engineering activities.	CP
Ec10	Interdependence	High level problems including many component parts or sub-problems, partitions problems, processes or systems into manageable elements for the purposes of analysis, modelling or design and then re-combines to form a whole, with the integrity and performance of the overall system as the top consideration.	CP
Ec11	Continuing Professional Development (CPD) and lifelong learning	Undertake CPD activities to maintain and extend competences and enhance the ability to adapt to emerging technologies and the ever-changing nature of work.	CA
Ec12	Judgement	Recognize complexity and assess alternatives in light of competing requirements and incomplete knowledge Require.	CA

The engineering competence profiles are stated generically and are applicable to all engineering disciplines. The application of a competence profile may require application in different regularly, disciplinary, occupational or environment contexts.

Complex Engineering Problems need to think broadly and systematically and see the big picture
- Complex problems
- Difficult decision
- Uncertain strategy
- Confusion idea
- Contentious Product
- Interactable change

The differences between technical problems and complex engineering problems based on various criteria is shown in Table 13.

Table 13: Differences between technical problems and complex engineering problems

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

12. Guidelines for writing Course Outcome Statements

A Course Outcome is a formal statement of what students should able to know, do and value by the end of the course.

When creating Course Outcomes remember that the outcomes should clearly state what students will do or produce to determine and/or demonstrate their learning.

The CO statement is intended or desired learning gains, faculty members expect the students to develop, learn master during the course in terms of:

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

It contains the measurable action verbs, the substance/content to be learned, and the targeted competency level.

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

12.1 Developing Course Outcomes

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

- ❖ 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.
- ❖ Focus on 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 (basic e.g., “upon completion of this course students will be able to list the names of the 28 states and 8 union territories ” versus “one objective of this course is to teach the names of the 28 states and 8 union territories”).
- ❖ 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 missions.
- ❖ Include various ways for students to show success (outlining, describing, modelling, depicting, etc.) rather than using a single statement such as “at the end of the course, students will know“as the stem for each expected outcome statement.
- ❖ The keywords used to define COs are based on Bloom's Taxonomy.

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 are they able to be performed by the students?

Course outcome statements on the course level describe:
1.What faculty members want students to know at the end of the course and
2.What faculty members want students to be able to do at the end of the course?

Course outcomes have three major characteristics
1.They specify an action by the students/learners that is observable
2.They specify an action by the students/learners that is measurable
3.They specify an action that is done by the students / learners rather than the faculty members.

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

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

STUDENTS SHOULD BE ABLE TO + BEHAVIOR + RESULTING EVIDENCE

For example, you can use the following template to help you write an appropriate course level learning outcome.
"Upon completion of this course students will be able to (knowledge, concept, rule or skill you expect them to acquire) by (how will they apply the knowledge or skill/how will you assess the learning)."
Characteristics of Effective Course Outcomes:
Well written course outcomes:

- Describe what you want your students to learn in 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 behaviours.
- Are assessable through one or more indicators (papers, quizzes, projects, presentations, journals, portfolios, etc.)
- Are realistic and achievable.
- Use simple language

Examples of Effective Course Outcomes

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

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

A more detailed model for stating learning objectives requires that objectives have three parts: a condition, an observable behaviour, and a standard. The table 14 provides three examples.
Relationship of Course Outcome to Program Outcome

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

Table 14: Examples for writing effective course outcomes

S.No	Learning Objective	Condition	Observable Behaviour	Standard
1	Students will be able to solve algebraic equations	Given a set of algebraic equations	Solve linear and quadratic algebraic equations	Correctly solve 90% of equations presented in the exercise
2	Students will be able to write an essay	After reading a provided article	Write a well-organized argumentative essay	The essay must have a clear thesis, supporting arguments, and a conclusion, with minimal grammatical errors
3	Students will be able to conduct a scientific experiment.	With a laboratory kit and procedure manual	Set up and conduct an experiment	Conduct the experiment according to the procedure with no major errors, and record accurate data
4	Students will be able to use proper punctuation in writing.	Given a short story to edit	Identify and correct punctuation errors in the text	Correct all punctuation errors with 95% accuracy
5	Students will be able to use critical thinking to solve problems.	Given a complex case study	Analyse the problem and propose a solution	Provide a solution that addresses at least three key issues with logical reasoning.
6	Students will be able to present a research project.	During a class presentation	Present findings to the class using visual aids	The presentation must be clear, within 10 minutes, and answer at least 3 questions from the audience.
7	Students will be able to perform basic first aid.	Given a first aid kit and a simulation scenario	Apply the correct first aid techniques to a simulated injury	Provide first aid for the scenario in accordance with standard first aid protocols, with no critical steps omitted.
8	Students will be able to use a spreadsheet program.	Using a computer with spreadsheet software	Create and format a spreadsheet with formulas	The spreadsheet must include at least 3 formulas and be formatted according to provided specifications.
9	Students will be able to recognize historical events.	Given a list of historical events and dates	Match events to the correct dates and locations	Correctly match 85% of the events with their corresponding dates and locations.
10	Students will be able to participate in group discussions.	In a small group setting	Contribute relevant ideas and respond to peers' comments	Contribute at least 3 relevant ideas and respond to at least 2 peers during the discussion.

The following table 15, is the example describe a Course Outcome that is not measurable as written, an explanation for why the Course Outcome is not considered measurable, and a suggested edit that improves the Course Outcome.

Table 15: Course Outcome which is not measurable

Original Course Outcome	Evaluation of language used in this Course Outcome	Improved Course Outcome
Explore in depth the literature on an aspect of teaching strategies	Exploration is not a measurable activity but the quality of the product of exploration 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

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

12.2 Write Your Course Outcomes!

One of the first steps you take in identifying the expected learning outcomes for your course is identifying the purpose of teaching the course. By clarifying and specifying the purpose of the course, you will be able to discover the main topics or themes related to students' learning. Once discovered, these themes will help you to outline the expected learning outcomes for the course. Ask yourself:

- ❖ 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?

13 CO-PO Course Articulation Matrix Mapping

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

Observations:

1.The first five POs are purely of technical in nature, while the other POs are non-technical.
2.For the theory courses, while writing the COs, you need to restrict yourself between Blooms Level LD1 to Level LD 4. Again, if it is a programming course, restrict yourself between Blooms Level LD 1 to Level LD 3 but for the other courses, you can go up to Blooms Level LD 4.
3.For the laboratory courses, while composing COs, you need to restrict yourself between Blooms Level LD 1 to Level LD 5.
4.Only for Mini-project and Main project, you may extend up to Blooms Level 6 while composing COs.
5.For a given course, the course in-charge has to involve all the other Professors who teach that course and ask them to come up with the CO-PO mapping. The course in-charge has to take the average value of all of these CO-PO mappings and finalize the values or the course in-charge can go with what the majority of the faculty members prefer for. Ensure that none of the Professors who are handling the particular course discuss with each other while marking the CO-PO values.
6.If you want to match your COs with non-technical POs, then correlate the action verbs used in the course COs with the thumb rule given in the table and map the values. (Applies only for mapping COs to non-technical Pos).

13.1 Tips for Assigning the values while mapping COs to POs/PSOs.

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

13.2 Method for Articulation

1. Identify the Indicators of Attainment of POs / PSOs to each CO and make a corresponding mapping table with assigning √ mark at the corresponding cell. One observation to be noted is that the first five POs are purely of technical in nature, while the other POs are non-technical.
2. Justify each CO - PO/PSO mapping with a justification statement and recognize the number of Indicators of Attainment (IA) features mentioned in the justification statement that are matching with the given Key Attributes for Assessing Program Outcomes. Use a combination of words found in the COs, POs//PSOs and your course syllabus for writing the justification.
3. Make a table with number of Indicators of Attainment for CO – PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
4. Make a table with percentage of Indicators of Attainment for CO – PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
5. Finally, Course Articulation Matrix (CO - PO / PSO Mapping) is prepared with COs and POs and COs and PSOs on the scale of 0 to 3, 0 being no correlation (marked with ("-") , 1 being the low/slight correlation, 2 being medium/moderate correlation and 3 being substantial/high correlation based on the following strategy which is shown Table 16 .

Table 16: Method for Articulation

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

14. Indicators of Attainment for Assessing Program Outcomes

Table 17: Indicators of attainment of WKs for assessing program specific outcomes.

Po1	**Engineering Knowledge: Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop to the solution of complex engineering problems**
	Applying concepts of natural sciences viz., physics, chemistry, social science, and discipline specialized engineering science fundamentals for solving respective problems / applications
	The use of algorithms and numerical approximation techniques in mathematical analysis as applied to engineering problems
	Development of an analytical, numerical, or empirical description of a real system
	The knowledge and skills required to analyse data (data awareness, cleaning, discovery, ethics, exploration, tools, and visualization) including developing an analytical plan; selecting and using appropriate statistical techniques and tools; and interpreting, evaluating, and comparing results with other findings
	Ability to use statistical principles to summarize data and draw conclusions from it
	Identifies all relevant constraints and requirements and formulates an accurate description of the problem
	Develop the models that can be mathematical or physical in nature and are created with the specific intent of describing, analysing, testing, demonstrating, and/or predicting behaviours, properties, or other characteristics of the system

The knowledge and skills to use computer systems to store and manipulate large quantities of information

Use algorithms, computational tools, simulation and modelling techniques with data visualization for effective analysis.

Gathers engineering knowledge from the open literature and discerns the most relevant

Theoretical problem identification, model formulation and data collection

Evaluates the analysis for accuracy and validity of assumptions made.

Applying engineering specialist knowledge for evaluation and validation of the assumptions made.

Understanding of standards, innovation and critical analysis for accepted practices

Apply engineering management principles to effectively implement economic decision-making.

Po2

Problem Analysis: Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)

Applying concepts of natural sciences viz., physics, chemistry, social science, and discipline specialized engineering science fundamentals for solving respective problems / applications

The use of algorithms and numerical approximation techniques in mathematical analysis as applied to engineering problems

Development of an analytical, numerical, or empirical description of a real system

The knowledge and skills required to analyse data (data awareness, cleaning, discovery, ethics, exploration, tools, and visualization) including developing an analytical plan; selecting and using appropriate statistical techniques and tools; and interpreting, evaluating, and comparing results with other findings

Ability to use statistical principles to summarize data and draw conclusions from it

Identifies all relevant constraints and requirements and formulates an accurate description of the problem

Develop the models that can be mathematical or physical in nature and are created with the specific intent of describing, analysing, testing, demonstrating, and/or predicting behaviours, properties, or other characteristics of the system

The knowledge and skills to use computer systems to store and manipulate large quantities of information

Use algorithms, computational tools, simulation and modelling techniques with data visualization for effective analysis.

Gathers engineering knowledge from the open literature and discerns the most relevant

Theoretical problem identification, model formulation and data collection

- Evaluates the analysis for accuracy and validity of assumptions made.
- Applying engineering specialist knowledge for evaluation and validation of the assumptions made.
- Understanding of standards, innovation and critical analysis for accepted practices
- Apply engineering management principles to effectively implement economic decision-making.

Design / Development of Solutions: Design creative solutions for complex engineering problems and design/develop systems /components/ processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5).

Po3

- Demonstrates originality in developing design solutions that incorporate social values and local considerations of sustainable development impacts.
- Use of modern modelling and computational tools for system design / component design / process design for problem analysis and re-use of sources for improving efficiency / optimization.
- Evaluates the feasibility of alternative solutions in all relevant contexts which, as appropriate to the problem, may include: technical, sustainability, suitability for implementation, economic, aesthetic, ethical, health and safety, societal, environmental and cultural.
- Investing in projects, implementing measures, identifying and reducing major sources of emissions such as improving energy efficiency, transitioning to renewable energy, and adopting low-carbon technologies
- Waste minimization and resource reuse compliance with environmental regulations and impact assessment.
- Describes the preferred solution and presents the findings including technical constraints, budgetary limitations, time constraints and secondary impacts in a coherent written form and defends those findings orally.

Conduct Investigations of Complex Problems: Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8).

Po4

- Reviews the open research literature and identifies the needs for investigation methodologies.
- Understanding of appropriate codes of practice and industry standards awareness of quality issues
- Designs and executes valid forms of research, experimentation or measurement.
- Use creative ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modelling techniques and including considering sources of error

Ability to apply qualitative and quantitative methods for evaluating emerging complex engineering problems.

Draws valid conclusions and justifies those conclusions.

Calibrates / validates the data collection methods and equipment.

Engineering Tool Usage: Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling recognizing their limitations to solve complex engineering problems. (WK2 and WK6)

Po5

The use of algorithms and numerical approximation techniques in mathematical analysis as applied to engineering problems

Development of an analytical, numerical, or empirical description of a real system

The knowledge and skills required to analyse data (data awareness, cleaning, discovery, ethics, exploration, tools, and visualization) including developing an analytical plan; selecting and using appropriate statistical techniques and tools; and interpreting, evaluating, and comparing results with other findings

Ability to use statistical principles to summarize data and draw conclusions from it

Identifies all relevant constraints and requirements and formulates an accurate description of the problem

Develop the models that can be mathematical or physical in nature and are created with the specific intent of describing, analysing, testing, demonstrating, and/or predicting behaviours, properties, or other characteristics of the system

The knowledge and skills to use computer systems to store and manipulate large quantities of information

Use algorithms, computational tools, simulation and modelling techniques with data visualization for effective analysis

Identifies the range of current tools and resources available, selects one or more suitable tools and/or appropriate resources, and justifies the selection including considerations of the limitations of the tools available.

Applies such tools to simulate behaviour or model outcomes that might resolve a complex engineering problem, checks the results for validity, evaluates results and recognises the limitations on those results.

Integration of measurement systems for process parameters with engineering design in the practice areas.

The Engineer and The World: Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7).

Po6

- Applying concepts of natural sciences viz., physics, chemistry, social science, and discipline specialized engineering science fundamentals for solving respective problems / applications
- Demonstrates originality in developing design solutions that incorporate social values and local considerations of sustainable development impacts.
- Use of modern modelling and computational tools for system design / component design / process design for problem analysis and re-use of sources for improving efficiency / optimization.
- Evaluates the feasibility of alternative solutions in all relevant contexts which, as appropriate to the problem, may include: technical, sustainability, suitability for implementation, economic, aesthetic, ethical, health and safety, societal, environmental and cultural.
- Investing in projects, implementing measures, identifying and reducing major sources of emissions such as improving energy efficiency, transitioning to renewable energy, and adopting low-carbon technologies
- Waste minimization and resource reuse compliance with environmental regulations and impact assessment.
- Describes the preferred solution and presents the findings including technical constraints, budgetary limitations, time constraints and secondary impacts in a coherent written form and defends those findings orally.
- Identifies risks, develops and evaluates risk management strategies to minimize the likelihood of significant consequences (such as injury or loss of life, major environmental damage, or significant economic loss) occurring in unusual or unexpected circumstances.
- Identifies hazards and justifies relevant strategies and systems to reasonably assure public health and safety (including as appropriate to the discipline, safety in construction/fabrication, operation, maintenance, deconstruction/disposal, failing-safe and occupational health and safety).
- Identifies and justifies specific actions required for environmental protection in the event of failure and to address cultural or community concerns.
- Advanced student project work involves students developing sustainable design solutions and undertakes life-cycle analysis and ensures relevant regulations and legislations for compliance.

Ethics: Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)

Po6

- Demonstrates an understanding of the moral responsibilities of a professional engineer including need to self-manage in an orderly and ethical manner, to balance obligations to the interests of employers and clients, and to uphold standards in the engineering profession.
- Identifies and justifies ethical courses of action when confronted with complex situations that might arise in the work of a professional engineer.
- Identifies and justifies the use or otherwise of new technologies, such as but not limited to, Generative AI.

Evaluates the ethical dimensions of professional practice (diversity and inclusivity) and demonstrates ethical behaviour.

High degree of trust and integrity for professional obligations in an organization.

Comprehends how legislative, regulatory, contract law, other common law and professional obligations apply and manages own activities to comply.

Individual and Collaborative Team work: Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams (No WK) (WK 9)

Po8

Manages own activities with honesty and integrity and in an orderly manner to meet deadlines

In group situations students are guided to develop empathy for others and to adopt inclusive behavior and language.

Contributes constructively to team decision making, earns the trust and confidence of other team members.

Students have opportunities to contribute to a diverse range of team-based settings.

Provides leadership in a team environment by making informed decisions, keeping the team motivated and accepting and delegating responsibility.

Critically evaluates the effectiveness of their individual and overall team performance.

Communication: Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences (WK-1 & WK-9)

Po9

Applying natural sciences, concepts of physics, chemistry, social science, Engineering science fundamentals and engineering science discipline specialization addressing engineering problems / applications WK1

Presents a range of written reports and other documentation relevant to the engineering discipline that convey information effectively and respectfully to both technical and diverse audiences.

Presents work verbally in a clear, appropriate and articulate manner, using visual aids appropriately in a range of contexts.

Comprehends and responds appropriately to written and verbal instructions and appropriately instructs or briefs others in group exercises.

Produces engineering specifications or design

Documentation that satisfies the requirements of the design brief.

Critically evaluates the effectiveness and appropriateness of their own communication methods

Body Language: Pay attention to your body language and that of others. Are you maintaining eye contact? Are you nodding or showing engagement? Are others responding positively?

Tone of Voice: Reflect on how your tone may have influenced the conversation. Was it open and inviting, or dismissive?

Project Management and Finance: Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multidisciplinary environments (No -WK).

Po10

- Selects and justifies appropriate forms of contract for delivery of work by consultants or contractors.
- Use of Engineering management principles for Economic decision-making
- Selects and applies relevant systems or techniques for managing quality, reliability and risk in the context of engineering projects.
- Selects and applies relevant project management techniques to the planning and execution of future work
- Estimates the capital and on-going costs of engineering work
- Team Leadership and Collaboration
- Multidisciplinary Integration
- Work Application and Adaptation
- Identification of Stakeholders
- Understanding Stakeholder Needs and Expectations
- Involvement and Participation
- Building Relationships
- Feedback Mechanisms
- Monitoring and Evaluation
- Reporting and Accountability
- Sustainability and Long-Term Engagement

Life-Long Learning: Recognize the need for, and have the preparation and ability for
i) independent and life-long learning
ii) adaptability to new and emerging technologies and
iii) critical thinking in the broadest context of technological change. (WK8)

Po11	
	Curiosity and a desire for lifelong learning.
	Self-knowledge
	Growth mindset.
	Reviews the open research literature.
	Identifies the needs for research or investigation.
	Understanding of appropriate codes of practice and industry standards awareness of quality issues
	Identifies appropriate research or investigation methodologies.
	Designs and executes valid forms of research, experimentation or measurement.
	Use creative ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modelling techniques.
	Ability to apply qualitative and quantitative methods for evaluating emerging complex engineering problems
	Draws valid conclusions and justifies those conclusions
	Calibrates/validates the data collection methods and equipment.
	Analyses the data including considering sources of error

Indicators of Attainment for Assessing Program Specific Outcomes: (Department)

Table 18: Indicators of attainment of WKs for assessing program specific outcomes
(To be Prepared by respective department)

PSO Number	PSO Statement / Indicators of attainment (IA)	Number of IAs
PSO 1		
PSO 2		
PSO 3		

15. Adopting United Nation's Sustainable Development Goals Engineering Program

The Engineering Programs are vital for achieving sustainable development while addressing socio-economic issues and challenges envisaged in United Nation's Sustainable Development Goals i.e. UNSDGs are shown in figure 9.

Figure 9: United Nation's Sustainable Development Goals (UNSDGs)

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

The CEP solving and CEAs play a pivotal role in developing innovative solutions that address societal challenges, fostering sustainable development. Thus, the analysis of a complex engineering problem needs to include consideration for sustainable development in the light of UN SDGs. Prospective sustainable solution resulting from a CEP-solving activity or CEA can be related to specific SDG(s).

It is pertinent to mention that is not mandatory for an HEI to map all 17 SDGs with its engineering program. Only those SDGs may be mapped which are covered in CEP solving activities, CEAs, semester projects, open-ended labs, capstone projects or co-and-extra-curricular activities with holistic consideration for sustainable development.

The documentation or any deliverable of the activity will stand as evidence of the addressal of the respective SDG. For example, embedding renewable energy concepts, such as solar and wind power, into class / lab CEPs / CEAs and final year/ capstone projects can align them with the targets set of for SDG-7. Similarly, focusing on cutting -edge technologies like the Internet of Things (IoT) and smart grids in class / lab projects and final-year projects can work for SDG-9. By addressing CEPs / CEAs aligned with specific SDGs, engineers can contribute significantly to global efforts to build a more sustainable and equitable word.

The effectiveness of the incorporation of SDG targets in class / lab projects or CEPs / CEAs can be further enhanced by encouraging the students to:

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

16. Correlation Matrix POs – ECs – WKs – SDGs

A correlation matrix has been established to link Program Outcomes (POs) with the corresponding engineering competencies, knowledge and attitude profiles, as well as the targeted UN Sustainable Development approved by NBA is shown in table 19.

Table 19: Correlation Matrix PLOs – ECs – WKs – SDGs

Pos	Ecs**	Wks	SDGs (Proposed)
Po1 Engineering Knowledge: Breadth, Depth and Type of Knowledge, both Theoretical and Practical	EC 1: Depth of knowledge required	WK-1: Natural Sciences and Awareness of Relevant Social Sciences WK-2: Mathematics and Computing WK-3: Engineering Fundamentals WK-4: Engineering SpecialistKnowledge	SDG-9
Po2 Problem Analysis: Complexity of Analysis	EC 4: Range of conflicting requirements EC 2: Depth of analysis required EC 10: Interdependence	WK-1: Natural Sciences and Awareness of relevant Social Sciences WK-2: Mathematics & Computing WK-3: Engineering Fundamentals WK-4: Engineering SpecialistKnowledge	Selected SDGs from SDG -1 to 17 (relevance as per curriculum)
Po3 Design / Development of Solutions: Breadth and Uniqueness of Engineering Problem i.e. the extent to which problems are original and so which solutions have not previously been identified or codified	EC 4: Range of conflicting requirements EC 5: Infrequently encountered issues EC 8: Extent of stakeholder involvement in design and development of solutions	WK-5: Engineering Design and Operations	SDG - 1, 2, 3, 6, 10, 11, 12, 13, 14 (relevance as per curriculum)

Po4 Investigation: Breadth and Depth of Investigation and Experimentation	EC 5: Infrequently encountered issues EC 7: Range of resources	WK-8: Research literature	SDG - 9
Po5 Total Usages: Level of Understanding of Appropriateness of Technologies and Tools	EC 2: Depth of analysis required EC 5: Infrequently encountered issues	WK-2: Mathematics and computing WK-6: Engineering Practices	SDG - 9
Po6 The Engineer and the World: Level of Knowledge and Responsibility for Sustainable Development.	EC 6: Protection of Society EC 9: Extent of applicable Codes, Legal and Regulatory	WK-1: Natural sciences and awareness of relevant social sciences WK-5: Engineering design and operations WK 7: Engineering in Society	Selected SDGs from SDG - 1 to 17 (relevance as per curriculum)
Po7 Ethics: Understanding and Level of Practice	EC 9: Extent of applicable Codes, Legal and Regulatory	WK-9: Ethics, Inclusive behaviour and conduct	SDG - 5, 10, 16
Po8 Individual and Collaborative Team Work Role in and Diversity of Team	EC 8: Extent of stakeholder involvement in design and development of solutions	WK 9: Ethics inclusive behaviour and conduct	SDG - 5, 10, 16
Po9 Communication: Level of Communication According to Type of Activities Performed.	EC 8: Extent of stakeholder involvement in design and development of solutions	WK-1: Natural sciences and awareness of relevant social sciences WK-9: Ethics inclusive behaviour and conduct	SDG - 5, 10, 16
Po10 Project Management and Finance: Level of Management Required for Differing Types of Activity	EC 10: Interdependence EC 7: Range of resources EC 12: Judgement	WK-2: Mathematics & Computing WK-5: Engineering design and operation	SDG - 9
Po11 Lifelong Learning: Duration and Manner	EC 11: Continuing Professional Development (CPD) and lifelong hearing. EC 12: Judgement	WK-8: Research literature	SDG - 9, 13

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

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

Program Outcomes and Program Specific outcomes Attained through course modules:

Courses offered in Aeronautical Engineering Curriculum (IARE- BT23) and POs/PSOs attained through course modules for I, II, III, IV, V, VI, VII and VIII semesters.

17. Methods for measuring Learning Outcomes and Value Addition:

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

i)Continuous Internal Assessment (CIA)
ii)Alternate Assessment Tools (AAT)
iii)Semester end examination (SEE)
iv)Laboratory and project work
v)Course exit survey
vi)Program exit survey
vii)Alumni survey
viii)Employer survey
ix)Course expert committee
x)Program Assessment and Quality Improvement Committee (PAQIC)
xi)Department Advisory Board (DAB)
xii)Faculty meetings
xiii)Professional societies

The above assessment indicators are detailed below.

17.1 Continuous Internal Assessment (CIA)

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

17.2Alternate Assessment Tools (AAT)

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

17.3 Semester End Examination (SEE)

The semester end examination is conducted for all the courses in the department. Before the Semester end examinations course reviews are conducted, feedback taken from students and re- medial 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 sub- mitted to the Departmental Academic Council (DAC) and to the Principal for taking necessary actions to better the course for subsequent semesters.

17.4 Laboratory and Project Works

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

17.5 Course Exit 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 for the entire faculty. Based on this, alterations or changes to the course objectives are undertaken by thorough discussions in faculty and DAC meetings.

17.6 Programme Exit Survey

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

17.7Alumni Survey

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

17.8 Employer Survey

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

17.9 Course Expert Committee

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.

17.10 Program Assessment and Quality Improvement Committee (PAQIC)

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

17.11 Department Advisory Board (DAB)

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

17.12Faculty 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.

17.13 Professional Societies

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

18. CO - Assessment processes and tools:

Course outcomes are evaluated based on two approaches namely direct and indirect assessment methods. The direct assessment methods are based on the Continuous Internal Assessment (CIA) and Semester End Examination (SEE) whereas the indirect assessment methods are based on the course end survey and program exit survey provided by the students, Alumni and Employer. The weightage in CO attainment of Direct and Indirect assessments are illustrated in Table 20.

Table 20: The weightage in CO attainment of Direct and Indirect assessments

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

18.1 Direct Assessment:

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

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

Table 21: The direct assessment tools used to assess the impact of delivery of course content

S No	Courses	Components	Frequency	Max. Marks	Evidence
1	Core / Elective	Continuous Internal Examination	Twice in a semester	20	Answer script
		Alternative Assessment Tools(AAT)	Twice in a semester	20	Video / Quiz / assignment
		Semester End Examination	Once in a semester	60	Answer script
2	Laboratory	Conduction of experiment	Once in a week	5	Work sheets
		Observation	Once in a week	5	Work sheets
		Result	Once in a week	5	Work sheets
		Record	Once in a week	5	Work sheets
		Viva	Once in a week	10	Work sheets
		Internal laboratory assessment	Once in a semester	10	Answer script
		Semester End Examination	Once in a semester	60	Answer script

3	Project Work	Presentation	Twice in a semester	40	Presentation
		Semester End Examination	Once in a semester	60	Thesis report

18.2 Indirect Assessment:

Course End Survey - In this survey, questionnaires are prepared based on the level of understanding of the course and the questions are mapped to Course Outcomes. The tools and processes used in indirect assessment are shown in Table 22.

Table 22: Tools and processes used in indirect assessment of course outcomes.

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.

19. PO- Assessment tools and Processes

The institute has methods shown in table 23 for assessing attainment of Pos. They are,

1.Direct method
2.Indirect method

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

Table 23: The methods for assessing attainment of Program Outcomes.

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

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

18.1 PO Direct Attainment is calculated using the following rubric:

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

The figure 10, represents the evaluation process of POs attainment through course outcome attainment.

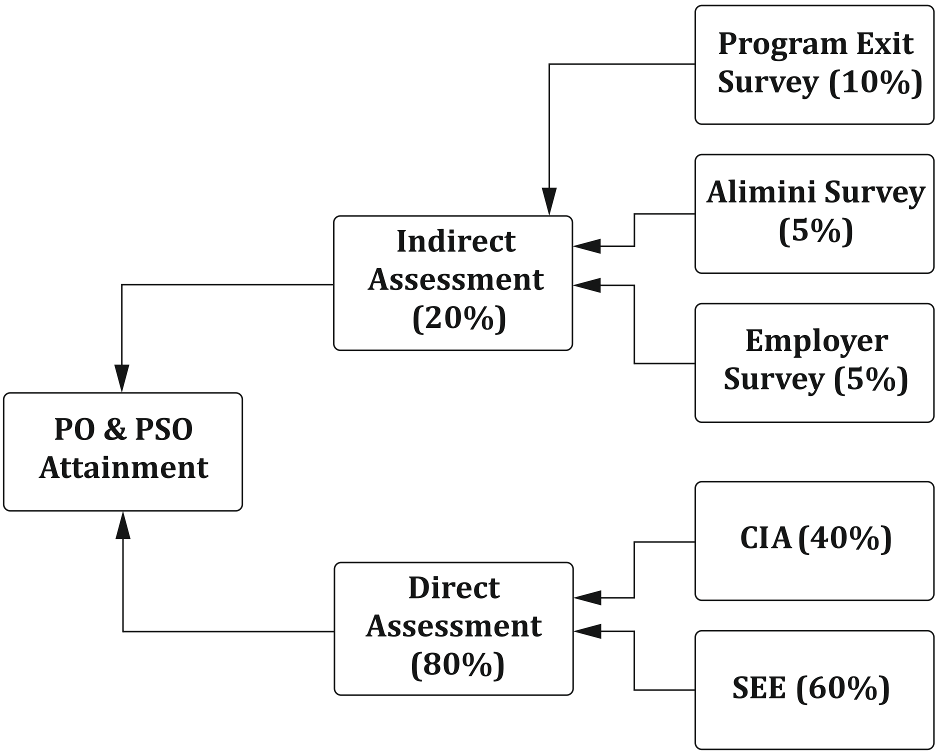

Fig 10: Evaluation process of POs attainment

Course Outline Description- (Appendix-A)

Check List	Please tick (✓)
1. General Information about the Course	☐
2. Teaching Learning Scheme	☐
3. A. Course Outcomes	☐
B. Cognitive Levels	☐
4. Content and Context of the Course	☐
5. Complex Engineering Problem Solving	☐
6. A. Assessment Methods – Direct	☐
B. Assessment Methods – Indirect	☐
7. Content Delivery / Instructional Methodologies	☐
8. Engineering Competencies (ECs) Focused	☐
9. Employability Skills	☐
10. Relevance to Sustain ability goals	☐
11. A. Mapping between COs and POs / PSOs	☐
B. Indicators of Attainment with COs to POs and PSOs	☐
C. Course Articulation Matrix of COs to Pos	☐
D. Level of Contribution of the COs to POs and PSOs	☐
12. Syllabus	☐
13. Tentative Schedule of Instructions	☐
14. Specific Goals for the Course	☐
15. History of Changes	☐

Course Outline Description

SECTION 1: General Information about the Course	
Course Title	Data Structures
Course Code	ACSD08
Course Start	Third Semester
Course Type	Core
Regulation	IARE - BT 23
Prerequisite Courses	1. Object-Oriented Programming (ACSD01) 2. Essentials of Problem Solving (ACSD05)
Department	Computer Science and Engineering
Number of Credits	3 Credit hours
Academic Year	2024-25
Method(s) of Instruction	Theory and laboratory
Course Coordinator's Name	Dr. B Padmaja, Professor of Computer Science and Engineering IARE10209 b.padmaja@iare.ac.in
Prior Learning Assessment and Recognition (PLAR)	Students interested in PLAR pathways for open learning can register one semester prior to the start of semester. Students will receive the necessary contact information one semester in advance.
Open Learning Faculty Member Information	Open Learning Faculty (OLF) is available to assist students. Students will receive the necessary contact information at the start of the course.
Course Webpage	https://akanksha.iare.ac.in/index?route=course/details&course_id=1242
Course Description	This course introduces the fundamental concepts of data structures and explores the different implementations (array-based and linked representations) of these data structures. Topics include recursion, fundamental data structures (including stacks, queues , linked lists, hash tables, trees, and graphs), and algorithmic analysis. Includes analysing algorithms' running-time complexity and space requirements, searching and sorting techniques. Course includes laboratory component for lab-based exercises. Key notions of object-oriented programming with a view for efficiency, maintainability, and code-reuse, are emphasized. The Java programming language will be used to demonstrate the concepts discussed in lecture, and students will demonstrate these skills by solving real-world problems in the Java language.
Course Objectives	The students will try to learn: a. The concepts of data structures b. Implementation of various ADTs (abstract data types) such as lists, stack, queue, tree and graph structures c. Real life use of various data structures d. Methods to analyse, learn and compare different algorithms e. Applications, advantages and limitations of various data structures.
Text and Reference Books	Text Books 1. Michael T. Goodrich, Roberto Tamassia, Michael H. Goldwasser, Data Structures and Algorithms in Java", 6th edition, John Wiley & Sons Inc., 2014, ISBN-13: 978-1118771334 2. Mark Allen Weise, "Data Structures and Algorithm Analysis in Java", 3rd edition, Pearson education, 2012, ISBN-13: 978-0273752110 Reference Books

	1. S. Lipschutz, "Data Structures", Tata McGraw Hill Education, 1st edition, 2014, ISBN-13: 978-1259029967 2. D. Samanta, "Classic Data Structures", PHI Learning, 2 nd edition, 2004, ISBN: 812033731X, 9788120337312 .
Learning Resources	Course full stack is made available in IARE learning management portal – Akansha, which includes lecture notes, tutorial question bank, definition and terminology, tech-talk topics, assignments, Model question papers (2 sets), complex engineering problem solving statements, power point presentations (PPTs) and ELRV lecture recordings at: • https://www.youtube.com/watch?v=wtcPOIiOGeY&list=PLzkMouYverAJBXkAe4S6SEDdjKLbxo2du • https://www.youtube.com/playlist?list=PLzkMouYverAI9IvTTpixG2GL2jpT8HQsW
Supplemental Materials	Readings, Videos, and Links 1. https://ece.uwaterloo.ca/~dwharder/aads/Lecture_materials/ 2. https://ocw.mit.edu/courses/6 -006-introduction-to-algorithms-spring-2020/pages/lecture-notes/ 3. https://www.cise.ufl.edu/~sahni/cop5536/presentations.htm 4. https://cds.iisc.ac.in/courses/ds286/ 5. https://www.cise.ufl.edu/~sahni/cop3530/powerpoint.htm
Learning and Teaching Strategies	Online material will provide the foundation of the learning resources, requiring the students to log in and engage regularly throughout the sixteen weeks of the course. There will be a mix of suggested readings, discussions and video content containing embedded digital content and undertake the assessment tasks.

SECTION 2: Teaching Learning Scheme

At least 48 lecture hours of scheduled teaching and learning activities (TLA) will be delivered in person, with the remaining hours for scheduled and self-scheduled teaching and learning activities delivered either in person or online.

Notional Study Time: 90 Hours (Lecture hours: 48, Tutorial hours: 8, Scheduled revision session hours: 2, Guided independent study hours: 15, Homework / Programming assignment hours: 10, Course project / Preparation for complex problem-solving hours: 15)

TLA Code	Teaching and Learning Activities	Number	Duration (Hours)	Total Workload
TLA 1	Lectures	48	01	48
TLA 2	Tutorials	08	01	08
TLA 3	Case Study			
TLA 4	Problem Solving			
TLA 5	Demonstration			
TLA 6	Scheduled revision sessions	02	01	02
TLA 7	Guided independent study: Directed viewing of video materials / PPTs			15
TLA 8	Independent private study			
TLA 9	Laboratory Exercises	0	0	0
TLA 10	Homework assignments / Programming assignments			10
TLA 11	Placement / work based learning or Specific practical training	0	0	0
TLA 12	Presentation / Seminar Preparation			

TLA 13	Course Project / Preparation for Complex Problem Solving			15
TLA 14	Technical visit			
TLA 15	Field activities	0	0	0
			Total study hours	90
			Expected total study hours	90

SECTION 3A: Course Outcomes		
After successfully completing this course, the student will be able to:		
Outcome Number	Course Outcomes	Learning Domain
CO1	Outline common data structures and fundamental algorithms, and familiarise with the associated terminology.	Understand
CO2	Illustrate Abstract Data Types (ADT) in terms of their data structures (strings, stacks, queues, linked lists, hash tables, trees and graphs).	Understand
CO3	Develop programs to implement common algorithms for sorting and searching data.	Apply
CO4	Compare common algorithms for sorting and searching data.	Analyse
CO5	Apply collision resolution techniques to resolve collisions within the hash table.	Apply
CO6	Choose the appropriate data structure to solve real-world problems and to defend the selection.	Apply

SECTION 3B: Cognitive Levels	
Blooms Taxonomy Level	Cognitive Level in Percentage (%)
Remember	0
Understand	32
Apply	52
Analyze	16
Evaluate	0
Create	0

SECTION 4: Content and Context of Data Structures

CO1 Outline common data structures and fundamental algorithms and familiarise with the associated terminology.

Make the student to understand data Structure vs files. They should made to know that data structure is often referred to data storage in main memory (RAM) and data storage representation in secondary storage is referred to as file structure or database. T each learners about common formats used for data storage and transfer between systems. They should understand the structure of common file data formats such as JavaScript Object Notation (JSON), comma separated values (CSV) and extensible markup language (XML).

Familiarise with the common data structures and with appropriate terminology for the most common data structures. Algorithms manipulate that data in these structures in various ways, such as searching for a data item and sorting a set of data elements.

- Array:
  - A collection of elements identified by index or key.
  - Fixed size, fast access time (O(1) for accessing elements).
  - Examples: Lists in Python / Arrays in C / C++ / Java.
  - Use cases: Storing data in contiguous memory for quick access, such as in numerical computations.
- Linked List:

	○ A linear collection of elements where each element (node) points to the next one. ○ Dynamic size, slower access (O(n) to find an element), but efficient for insertions and deletions (O(1)). ○ Types: ▪ Singly Linked List: Each node points to the next. ▪ Doubly Linked List: Each node points to both the next and previous node. ○ Use cases: Efficient insertion/deletion in dynamic scenarios (e.g., implementing stacks and queues). • Stack: ○ Follows Last In, First Out (LIFO) principle. ○ Operations: push (add), pop (remove), peek (view top element). ○ Use cases: Undo functionality, depth-first search (DFS). • Queue: ○ Follows First In, First Out (FIFO) principle. ○ Operations: enqueue (add), dequeue (remove), front (view front element). ○ Use cases: Task scheduling, breadth-first search (BFS), buffering. • Tree: ○ A hierarchical structure with a root node and child nodes. ○ Binary Tree: Each node has at most two children. ○ Binary Search Tree (BST): Left child is less; right child is greater than the parent. ○ Use cases: Efficient searching, sorting, hierarchy representation. • Hash Table: ○ A collection of key-value pairs, optimized for fast lookups, insertions, and deletions. ○ Operations: insert, delete, search with O (1) average time complexity. ○ Use cases: Database indexing, caching, implementing associative arrays. • Graph: ○ A collection of nodes (vertices) and edges (connections between nodes). ○ Types: ▪ Directed: Edges have direction. ▪ Undirected: Edges have no direction. ▪ Weighted: Edges have weights (values). ○ Use cases: Representing networks, social media connections, dependency structures.
CO2	Illustrate Abstract Data Types (ADT) in terms of their data structures (strings, stacks, queues, linked lists, hashing, trees and graphs).
	Teach learners how to create and manipulate language-specific built-in abstract structures for storing collections of values. These should include simple and multi-dimensional arrays, sets (unique values) and tuples (unchangeable values). Learners should also know how to use hash table (map) structures to store data as key/value pairs. For each of the above data structures, learners must know how to add, locate, remove and update data anywhere within the structure. Learners must know how to create both a singly and doubly linked list abstract data structure from first principles. They must also know how to add, locate, remove and update elements anywhere within the structure. Learners must know how to create a binary search tree abstract data structure from first principles. They should be able to traverse it and add, locate, remove and update elements at any point within it. Learners should know how to apply these abstract data structures by writing code containing stacks, queues, deques and heaps, using both linked lists and appropriate built-in structures. Learners should know how to add, locate, remove and update elements at any point within them.
CO3	Develop programs to implement common algorithms for sorting and searching data.
	Teach learners how recursion works and how recursive functions are structured. They should be capable of applying recursion to common problems. Examples might include factorial or Fibonacci sequence calculations, as well as string operations such as reversal and character counting. Learners must know how to sort collections of data, both in ascending and descending order, using a variety of different sorting algorithms. They must know how to code common sorting algorithms such as bubble sort, selection sort, merge sort, shell sort, radix sort and quicksort. They should understand how each works and demonstrate their application.

	Learners must know how to search through data. They should know how to perform linear searches of unsorted data. Learners should also know how to perform the more efficient binary searches on sorted data. They should do this using both iteration and recurs ion. They should also use binary tree structure searching capabilities. You should also make learners aware of the effects of sorting data before searching within it. You should teach learners how to find the largest and smallest values in a given list of values. Learners critically review their program code with a view to increasing its efficiency. This not only tells them how well the code is working, but also offers them insights into any improvements they should apply.
CO4	Compare common algorithms for sorting and searching data.
	Learners should know how linear searching becomes less efficient as the volume of data increases. They should also know that, while binary searching can solve the problem for large data sets, the additional overhead of initial sorting of data can reduce th is. Although learners do not need to derive the time and space complexity of algorithms and data structures, they should understand what these terms mean and know the different time complexities of accessing, searching, inserting and deleting elements within a rrays, stacks, queues, singly and doubly linked lists, hash tables, and binary trees. Learners should also know the different time complexities of the different sorting algorithms (bubble sort, selection sort, merge sort and quicksort). You can use common notation, such as Big O, to describe these. To consolidate their understanding, you should give learners a range of problems to solve that cover the range of algorithms and data structures taught during the course. You should also encourage learners to write multiple versions of their code using diff erent algorithms and/or data structures and compare their efficiency. There are opportunities for learners to work in groups to discuss, analyse and formulate a solution to a given problem. Learners could then produce independent solutions and compare and contrast.
CO5	Apply collision resolution techniques to resolve collisions within the hash table.
	Learners are required to know Hashing and usage of hash functions to generate hash values. The hash value is used to create an index for the keys in the hash table. The hash function may return the same hash value for two or more keys. When two or more keys have the same hash value, a collision happens. To handle this collision, use Collision Resolution Techniques (linear probing, quadratic probing and chaining). Make the students to know that, a hash table is a data structure that holds information in an associative manner. Data access becomes very speedy if we know the index of the needed data. As a result, regardless of data size, it becomes a data structure with incredibly fast insertion and search operations. Hash Tables are arrays that use the hash technique to generate an index from which an element can be entered or located. You should make the students understand the Hashing's irreversibility and constant time access properties that have made possible to find applications in a variety of domains. The following are some examples of hashing applications, including password secu rity, password verification, tokenization, programming language data structures and compilers, blockchain, machine learning feature hashing, and many others! Learners should be made to learn the usage and working of the function called "hash function" to convert data of any arbitrary size to a fixed -size value and storing it in a data structure called "hash table" at the value produced by hash functions. Hash c odes, digests, hash values, and hashes are all terms for the values returned by this function. You should teach learners, when is it not advisable to use Hashing / Hash Tables? • In general, hashing provides great time complexity for operations like as Insert, Search, and Delete. • Because hash tables take up more memory, it's better to use arrays for smaller applications. • Some operations, such as iterating through entries when the keys are inside a defined range, identifying the entry with the largest/smallest key, and so on, are not supported by hash tables. Arrays are preferable in certain situations.
CO6	Choose the appropriate data structure to solve real -world problems and to defend the selection.
	You should make the learners to choosing the right data structure and algorithm

	• When designing an application, the choice of data structures and algorithms directly impacts performance. • For example, a hash table is ideal when fast lookups are needed, but a binary search tree might be better if the dataset needs to be kept ordered. • Similarly, an algorithm like quick sort is fast for general use cases, but in some scenarios, merge sort might be preferred due to its stability and predictable performance. • Usage of hash tables design and implement two different versions of the hash table interface: Open addressing (Linear probing, Quadratic probing, Double hashing, Rehashing) and chaining. • Analyze and assess the running-time complexity of basic hash table operations (insert, delete, and search). Understanding complexity analysis in terms of time complexity and space complexity is crucial for evaluating the efficiency of algorithms. Big-O notation (e.g., O(n), O(log n), $O(n^2)$) is used to describe the worst-case scenario for an algorithm's performance, helping developers choose the most efficient solution. • Time Complexity: Describes the amount of time an algorithm takes to complete as a function of the input size. • Space Complexity: Describes the amount of memory an algorithm uses.

SECTION 5: Complex Engineering Problem Solving
Programs, complex problem solving and programming projects There is one piece of assessed coursework, involving a mixture of theoretical work and programming. We encourage to use the data structures and algorithms in different languages — although they can use a single language, depending on the level of their ability. Programming assignments are a mandatory part of the course. Homework programs will concentrate on implementing fundamental programming concepts and techniques. Projects will be large scale programs implementing the Abstract Data Types discussed in class. P rogramming Projects will be worth significantly more points than homework programs. All programs are individual assignments. Programming exams/hack-a-thons will also be conducted. Student are required to complete these tasks during the class period with no assistance. Data Structures and Algorithms for External Storage: Considering the differences in access characteristics between main memory and external storage devices such as disks, several algorithms for sorting files of externally stored data such as indexed files and B -trees, that are well suited for storing and re trieving information on secondary storage devices will be discussed.

SECTION 6A: Assessment Methods – Direct			
Item	Evaluation Components	Week in / out	Marks
AAT: 1 - 1	Tech-Talk	Week – 2 / 5	05
AAT: 1 - 2	Hack-a-thon	Week – 4 / 7	05
AAT: 2 - 1	Complex Engineering Problem Solving	Week – 9 / 12	05
AAT: 2 - 2	Hack-a-thon	Week – 12 / 15	05
CIE - 1	2 hours - Answer 4 out of 5 questions	Week - 9	10
CIE - 2	2 hours - Answer 4 out of 5 questions	Week - 17	10
SEE	3 hours - Answer 1 from each module	Week - 18	60
		Total Marks	100
Department's Late Submission Policy: 1. 1 – 24 hours: 25% of the mark will be deducted 2. > 24 hours: Not accepted			
SECTION 6B: Assessment Methods –Indirect			
Course End Survey (End Semester OBE Feedback)			✓

SECTION 7: Content Delivery / Instructional Methodologies Please tick (√) relevant engineering competency profile covered							
✓	Power Point Presentations	✓	Chalk and Talk	✓	MOOC	✓	AAT

SECTION 8: Engineering Competencies (ECs) Focused Please tick (√) relevant engineering competency profile covered			
EC Number	Attributes	Profiles	(√)
EC1	Depth of knowledge required (CP)	Ensures that all aspects of an engineering activity are soundly based on fundamental principles - by diagnosing, and taking appropriate action with data, calculations, results, proposals, processes, practices, and documented information that may be ill-founded, illogical, erroneous, unreliable or unrealistic requirements applicable to the engineering discipline	✓
EC2	Depth of analysis required (CP)	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	✓
EC3	Design and development of solutions (CA)	Support sustainable development solutions by ensuring functional requirements, minimize environmental impact and optimize resource utilization throughout the life cycle, while balancing performance and cost effectiveness .	✓
EC4	Range of conflicting requirements (CP)	Competently addresses complex engineering problems which involve uncertainty, ambiguity, imprecise information and wide - ranging or conflicting technical, engineering and other issues.	-
EC5	Infrequently encountered issues (CP)	Conceptualizes alternative engineering approaches and evaluates potential outcomes against appropriate criteria to justify an optimal solution choice.	-
EC6	Protection of society (CA)	Identifies, quantifies, mitigates and manages technical, health, environmental, safety, economic and other contextual risks associated to seek achievable sustainable outcomes with engineering application in the designated engineering discipline.	-
EC7	Range of resources (CA)	Involve the coordination of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies) in the timely delivery of outcomes	-
EC8	Extent of stakeholder involvement (CP)	Design and develop solution to complex engineering problem considering a very perspective and taking account of stakeholder views with widely varying needs.	✓
EC9	Extent of applicable codes, legal and regulatory (CP)	Meet all level, legal, regulatory, relevant standards and codes of practice, protect public health and safety in the course of all engineering activities.	-
EC10	Interdependence (CP)	High level problems including many component parts or sub-problems, partitions problems, processes or systems into manageable elements for the purposes of analysis, modelling or design and then re-combines to form a whole, with the integrity and performance of the overall system as the top consideration.	✓
EC11	Continuing professional development (CPD) and lifelong learning (CA)	Undertake CPD activities to maintain and extend competences and enhance the ability to adapt to emerging technologies and the ever-changing nature of work.	✓
EC12	Judgement (CA)	Recognize complexity and assess alternatives in light of competing requirements and incomplete knowledge. Require judgement in decision making in the course of all complex engineering activities.	-

SECTION 9: Employability Skills
Example: Communication skills / Programming skills / Project based skills
Studying Data Structures equips the students with a range of employability skills that are highly valued in industries. Employability Skills: • Problem-solving skills for designing efficient solutions. • Logical and analytical thinking for data organization. • Proficiency in programming languages like C / C++ / Java / Python. • Optimization skills for time and space complexity. • Knowledge of scalable and robust system design. • Teamwork and collaboration in software development. • Adaptability to learn and apply advanced data structures. Project Management: • Planning and organizing project timelines and tasks. • Allocating resources efficiently. • Collaborating and communicating with team members. • Identifying and mitigating project risks. • Testing and validating system performance.

SECTION 10: Relevance to Sustainability goals
Brief description about the course and its correlation with Sustainability Development Goal (SDGs).

SDG Goals		Correlation with SDG
4	QUALITY EDUCATION	Quality Education: This subject will prepare students for modern technological challenges, improving educational tools, and promoting skills essential for global development.
8	DECENT WORK AND ECONOMIC GROWTH	Decent Work and Economic Growth: Prepares students for careers in technology-driven industries, boosting employability and fostering innovation in the digital economy.
9	INDUSTRY, INNOVATION AND INFRASTRUCTURE	Industry, Innovation, and Infrastructure: Supports the development of efficient algorithms and systems crucial for advancing technological infrastructure and innovation.
11	SUSTAINABLE CITIES AND COMMUNITIES	Sustainable Cities and Communities: Enables the creation of smart city technologies (e.g., optimized traffic systems, resource management) using graph and tree structures.
17	PARTNERSHIPS FOR THE GOALS	Partnerships for the Goals: Facilitates collaboration in data-driven research and global educational initiatives through scalable and efficient data processing.

SECTION 11A: Mapping between COs and POs / PSOs														
Course Outcomes	Program Outcomes (POs)											Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	1	2	3
CO1	✓	✓	✓	-	-	-	-	-	-	-	✓	✓	-	-
CO2	✓	✓	✓	✓	✓	-	-	-	-	-	✓	✓	-	✓
CO3	✓	✓	✓	✓	✓	-	-	-	-	-	✓	✓	✓	✓
CO4	✓	✓	✓	✓	✓	-	-	-	-	-	✓	✓	✓	✓
CO5	✓	✓	✓	✓	✓	-	-	-	-	-	✓	✓	✓	✓
CO6	✓	✓	✓	✓	✓	✓	-	-	-	-	✓	✓	✓	✓

Outcomes		WKS and Indicators of attainment and Justification for mapping (students will be able to)																																									IAs Count
COs	POs	WK 1	WK 2								WK 3			WK 4			WK 5						WK 6			WK 7				WK 8							WK 9						
		a	a	b	c	d	e	f	g	h	a	b	c	a	b	c	a	b	c	d	e	f	a	b	c	a	b	c	d	a	b	c	d	e	f	g	a	b	c	d	e	f	
CO 1	PO 1	•	•	•	•	•	•		•			•	•	•																													10
	PO 2	•	•	•	•	•	•		•			•	•	•																													10
	PO 3																•	•	•			•																					4
	PO 11																													•	•	•			•	•							5
	PSO 1	•	•	•			•		•			•	•	•																													8
CO2	PO 1	•	•	•	•	•	•		•			•	•	•																													10
	PO 2	•	•	•	•	•	•		•			•	•	•																													10
	PO 3																•	•	•			•																					4
	PO 4																													•	•	•			•	•							5
	PO 5		•	•	•	•	•		•														•	•	•																		9
	PO 11																													•	•	•			•	•							5
	PSO 1	•	•	•			•		•			•	•	•																													8
	PSO 3		•	•			•		•			•	•	•									•	•	•																		10
CO3	PO 1	•	•	•	•	•	•		•			•	•	•																													10
	PO 2	•	•	•	•	•	•		•			•	•	•																													10
	PO 3																•	•	•			•																					4
	PO 4																													•	•	•			•	•							5
	PO 5		•	•	•	•	•		•														•	•	•																		9
	PO 11																													•	•	•			•	•							5
	PSO 1	•	•	•			•		•			•	•	•																													8
	PSO 2		•	•			•		•			•	•	•									•	•	•																		10
	PSO 3		•	•			•		•			•	•	•									•	•	•																		10
CO4	PO 1	•	•	•	•	•	•		•			•	•	•																													10
	PO 2	•	•	•	•	•	•		•			•	•	•																													10
	PO 3																•	•	•			•																					4
	PO 4																													•	•	•			•	•							5
	PO 5		•	•	•	•	•		•														•	•	•																		9
	PO 11																													•	•	•			•	•							5

	PSO 1	•	•	•			•		•			•	•	•																													8
	PSO 2		•	•			•		•			•	•	•									•	•	•																		10
	PSO 3		•	•			•		•			•	•	•									•	•	•																		10
CO 5	PO 1	•	•	•	•	•	•		•			•	•	•																													10
	PO 2	•	•	•	•	•	•		•			•	•	•																													10
	PO 3																•	•	•			•																					4
	PO 4																													•	•	•			•	•							5
	PO 5		•	•	•	•	•		•														•	•	•																		9
	PO 11																													•	•	•			•	•							5
	PSO 1	•	•	•			•		•			•	•	•																													8
	PSO 2		•	•			•		•			•	•	•									•	•	•																		10
	PSO 3		•	•			•		•			•	•	•									•	•	•																		10
CO 6	PO 1	•	•	•	•	•	•		•			•	•	•																													10
	PO 2	•	•	•	•	•	•		•			•	•	•																													10
	PO 3																•	•	•			•																					4
	PO 4																													•	•	•			•	•							5
	PO 5		•	•	•	•	•		•														•	•	•																		9
	PO 6	•															•	•	•			•				•	•		•														8
	PO 11																													•	•	•			•	•							5
	PSO 1	•	•	•			•		•			•	•	•																													8
	PSO 2		•	•			•		•			•	•	•									•	•	•																		10
	PSO 3		•	•			•		•			•	•	•									•	•	•																		10

SECTION 11B: Indicators of Attainment with COs to POs and PSOs

Course Outcomes	Percentage of Indicators of Attainments (IA) with POs and PSOs														
	PO												PSO		
	1	2	3	4	5	6	7		8	9	10	11	1	2	3
CO1	67	67	67	-	-	-	-		-	-	-	71	53	-	-
CO2	67	67	67	71	82	-	-		-	-	-	71	53	-	90
CO3	67	67	67	71	82	-	-		-	-	-	71	53	90	90
CO4	67	67	67	71	82	-	-		-	-	-	71	53	90	90
CO5	67	67	67	71	82	-	-		-	-	-	71	53	90	90
CO6	67	67	67	71	82	80	-		-	-	-	71	53	90	90

SECTION 11C: Course Articulation Matrix of COs to POs			
0 No Contribution (0-5%)	1 Low (≥5 - <40%)	2 Moderate (≥40 - <60%)	3 High (≥60%)
-			

Course Outcomes	Program Outcomes (POs)											Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	1	2	3
CO1	3	3	3	-	-	-	-	-	-	-	3	2	-	-
CO2	3	3	3	3	3	-	-	-	-	-	3	2	-	3
CO3	3	3	3	3	3	-	-	-	-	-	3	2	3	3
CO4	3	3	3	3	3	-	-	-	-	-	3	2	3	3
CO5	3	3	3	3	3	-	-	-	-	-	3	2	3	3
CO6	3	3	3	3	3	3	-	-	-	-	3	2	3	3
Total	18	18	18	15	15	3	-	-	-	-	18	12	12	15
Average	3	3	3	3	3	3	-	-	-	-	3	2	3	3

SECTION 11D: Level of Contribution of the COs to POs and PSOs

Number	Programme Outcomes	Proficiency Assessed by	Contribution Level (from 1 to 3)
PO 1	Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop to the solution of complex engineering problems.	CIE / SEE / AAT:1 – 2 Assignments / Open-ended problems	3
PO 2	Identify, formulate, review research literature and analyse complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4).	CIE / SEE / AAT:1 – 2 Hack-a-thon	3
PO 3	Design creative solutions for complex engineering problems and design / develop systems / components/ processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5)	CIE / SEE / AAT:2 – 1 Complex Engineering Problem Solving	3
PO 4	Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8)	CIE / SEE / AAT:2 – 1 Complex Engineering Problem Solving	3
PO 5	Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling recognizing their limitations to solve complex engineering problems. (WK2 and WK6).	CIE / SEE / AAT:2 – 2 Hack-a-thon	3
PO 6	Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7)	CIE / SEE / AAT:2 – 2 Hack-a-thon	3
PO 11	Recognize the need for, and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change. (WK8)	CIE / SEE / AAT:2 – 1 Complex Engineering Problem Solving	3

PSO 1	Understand, design and analyze computer programs in the areas related to Algorithms, System Software, Web design, and big data, Artificial Intelligence, Machine Learning and Networking.	AAT: 1 – 1 Tech-Talk	2
PSO 2	Focus on improving software reliability, network security or information retrieval systems.	AAT: 2 – 1 Complex Engineering Problem Solving	3
PSO 3	Make use of modern computer tools for creating innovative career paths, to be an entrepreneur and desire for higher studies.	AAT: 2 – 1 Complex Engineering Problem Solving	3

SECTION 12: Course Content	
MODULE - I	INTRODUCTION TO DATA STRUCTURES, SEARCHING AND SORTING
	Basic concepts: Introduction to data structures, classification of data structures, operations on data structures, Algorithm Specification, Recursive algorithms, Data Abstraction, Performance analysis - time complexity and space complexity, Introduction to Linear and Non Linear data structures, Searching techniques: Linear and Binary search, Uniform Binary Search, Interpolation Search, Fibonacci Search; Sorting techniques: Bubble, Selection, Insertion, and Quick, Merge, Radix and Shell Sort and comparison of sorting algorithms.
MODULE - II	LINEAR DATA STRUCTURES
	Stacks: Stack ADT, definition and operations, Implementations of stacks using array, applications of stacks, Arithmetic expression conversion and evaluation; Queues: Primitive operations; Implementation of queues using Arrays, applications of linear queue, circular queue and double ended queue (deque).
MODULE - III	LINKED LISTS
	Linked lists: Introduction, singly linked list, representation of a linked list in memory, operations on a single linked list; Applications of linked lists: Polynomial representation and sparse matrix manipulation. Types of linked lists: Circular linked lists, doubly linked lists; Linked list representation and operations of Stack, linked list representation and operations of queue.
MODULE - IV	NON-LINEAR DATA STRUCTURES
	Trees: Basic concept, binary tree, binary tree representation, array and linked representations, binary tree traversal, binary tree variants, threaded binary trees, application of trees, Graphs: Basic concept, graph terminology, Graph Representations - Adjacency matrix, Adjacency lists, graph implementation, Graph traversals – BFS, DFS, Application of graphs, Minimum spanning trees – Prims and Kruskal algorithms.
MODULE - V	BINARY TREES AND HASHING
	Binary search trees: Binary search trees, properties and operations; Balanced search trees: AVL trees; Introduction to M - Way search trees, B trees; Hashing and collision: Introduction, hash tables, hash functions, collisions, applications of hashing.

SECTION 13: Tentative Schedule of Instructions		
Week Number	Topics	Duration (Hours)
1	1.1 Introduction to data structures 1.2 Classification of data structures, operations on data structures 1.3 Recursive algorithms and performance analysis	3
2	2.1 Searching techniques: linear search, binary search 2.2 Uniform binary search, interpolation search 2.3 Fibonacci search	3
3	3.1 Sorting techniques: bubble sort, selection sort 3.2 Insertion sort 3.3 Quick sort, comparison between sorting techniques	3
4	4.1 Merge sort 4.2 Radix sort 4.3 Shell sort and comparison between sorting techniques	3
5	5.1 Stack ADT, definition and operations 5.2 Implementations of stacks using arrays 5.3 Applications of stacks	3
6	6.1 Arithmetic expression conversion and evaluation 6.2 Queues: primitive operations, applications of queue 6.3 Implementation of queues using arrays	3
7	7.1 Circular queue – operations and its implementation 7.2 Double ended queue (deque) – operations and its implementation 7.3 Linked lists: introduction, operations, advantages and disadvantages	3
8	8.1 Singly linked list, operations on a single linked list 8.2 Applications of linked lists - polynomial representation 8.3 Sparse matrix manipulation	3
9	9.1 Types of linked lists: circular linked lists 9.2 Doubly linked lists 9.3 Linked list representation and operations of stack and queue	3
10	10.1 Trees basics, binary tree representation, array and linked representations 10.2 Binary tree traversal, binary tree variants 10.3 Threaded binary trees, application of trees	3
11	11.1 Graphs: basic concept, graph terminology 11.2 Graph representations - adjacency matrix, adjacency lists 11.3 Graph implementation	3
12	12.1 Graph traversals – Breadth First Search (BFS) 12.2 Graph traversals – Depth First Search (DFS) 12.3 Applications of graph	3
13	13.1 Minimum spanning trees (MST) – Kruskals algorithm 13.2 Prim's algorithm, examples 13.3 Applications of MST	3
14	14.1 Binary search trees (BST) - properties and applications 14.2 Balanced search trees, operations 14.3 Implementation of BST	3
15	15.1 Introduction to AVL trees 15.2 Introduction to m-way search trees 15.3 B-trees, applications of B-trees	3
16	16.1 Hashing: introduction, hash tables, hash functions 16.2 Collisions – collision resolution techniques 16.3 Applications of hashing	3
	Total	48

SECTION 14: Specific Goals for the Course	
The following table shows the knowledge and skills covered by the unit outcomes:	
Knowledge	Skills
Learners should understand: • built-in data structures • abstract data structures • the implementation of static abstract data structures • the implementation of dynamic abstract data structures • how to compare different search algorithms • how to compare different sorting algorithms • how to construct tree and tree traversal s • graph representation and traversal (BFS and DFS) • priority queue is an abstract data type that performs operations on data elements per their priority. • hashing technique in data structures to map keys and values into a hash table.	Learners can: • produce code to access, add, remove and update data within built-in collection structures • produce code that creates singly linked list data structures from first principles • produce code to access, add, remove, and update data in a singly linked list • produce code that creates doubly linked list data structures from first principles • produce code to access, add, remove, and update data in a doubly linked list • produce code that uses binary search tree data structures from first principles • produce code to access, add, remove, and update data by traversing a binary search tree • produce code to implement stacks, queues, deques, and heap structures, using both the linked list and array or list structures • produce recursive functions or methods to solve a variety of problems • produce code that uses sorting algorithms • produce code that uses searching algorithms • produce code to locate the largest and smallest items in a collection of values • select the best search algorithm based on time and space complexity • select the best sort algorithm based on time and space complexity • construct minimal spanning tree using Prims and Kruskal algorithms • find the shortest path between source and destination using Dijkstra's algorithm • basic operations on hash tables like, Search, Insert, update and remove.

Administrative Information

SECTION 15: History of changes		
Regulations	Description of change	BOS Date
R 16	From R15 JNTUH, Hyderabad to R16 IARE regulations with change in V module • Module - V: Pattern Matching and Tries is replaced with Binary Trees and Hashing • Data Structures and algorithms are implemented using C programming language	24.07.2016
R 18	Changes from R16 to R18 regulation • Credit weightage is reduced from 4 to 3. • Module I: Performance analysis - time complexity and space complexity, Asymptotic Notation -Big O, Omega, and Theta notations are introduced • Module – IV: Minimum spanning trees – Prims and Kruskal algorithms are introduced • Data Structures and algorithms are implemented using C programming language.	16.07.2018
UG 20	Changes from R18 to UG 20 regulation • Data Structures and related algorithms are studied using object-oriented programming using Python.	17.11.2020
BT 23	Incorporated the following additions in BT 23 regulations • Module – I: Uniform Binary Search, Interpolation Search, Radix and Shell Sort • Data Structures and related algorithms are studied using object oriented programming using Java.	21.08.2023

Course Outline Approvals	
Course Coordinator Name: Signature: Date:	Head of the Department Name: Signature: Date:
Dean of Outcome Based Teaching and Learning Name: Signature: Date:	Dean of Academics Name: Signature: Date:

Find out more:
www.iare.ac.in

Institute of Aeronautical Engineering
(Autonomous)
Dundigal, Hyderabad - 500 043, Telangana, India
Ph - 040-29705852, 29705853, 29705854
Call +91 8886234501, 8886234502

Enquiries: support@iare.ac.in