IARE
INSTITUTE OF AERONAUTICAL ENGINEERING

Outcome Based Education (OBE) Manual
IARE - MT23

Department of Computer Science and Engineering

(M.Tech - Computer Science and Engineering)

Contents

OVERVIEW

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.

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

Higher Education Institutions are classified into two categories by the NBA

Tier-1: Institutions consist 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 consist 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 leadership positions and challenging them, and making them aware of the opportunities in 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 learning. Increased students' involvement allows them to feel responsible for their learning, and they should learn more through 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 a 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. The 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.

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

1.1 Vision and Mission of the Institution

Vision

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

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 the widespread community.

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 stakeholders.

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 play a pivotal role in the development of the worldwide 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 environment. 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 to be socially accountable. This accelerates the process of transfiguring the students into complete human beings, making the learning process relevant to life, and instilling in them a sense of courtesy and responsibility.

Core Values

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

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

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

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

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

1.2 Vision and Mission of the Department

Vision

The Vision of the department is to produce competent graduates suitable for industries and organizations at a global level, including research and development, with social responsibility.

Mission

To provide an open environment to foster professional and personal growth with a strong theoretical and practical background, having an emphasis on hardware and software development, making the graduates industry-ready with social ethics.

Further, the Department is to provide training and partner with Global entities in education and research.

DM1: To foster professional and personal growth.

DM2: Strong theoretical and practical background, having an emphasis on hardware and software development.

DM3: To provide training and partner with global entities in education and research

DM4: Making the graduates industry-ready with social ethics

Program Educational Objectives (PEOs)

Program Educational Objectives (PEOs) should be defined by the Head of the Department in consultation with the faculty members. PEOs are a promise by the department to the aspiring students about what they will achieve once they join the programme. PEO assessment is not made compulsory by the NBA as it is quite difficult to measure in the Indian context. NBA assessors usually do not ask for a PEO assessment. PEOs are about professional and career accomplishment after 4 to 5 years of graduation. PEOs can be written from different perspectives, like Career, Technical Competency, and Behaviour. While writing, the PEOs do not use technical terms as they will be read by prospective students who want to join the programme. Three to five PEOs are recommended.

Program Educational Objective – I: Design and Development of Solutions:

Design and develop computer software systems and products based on sound theoretical principles and appropriate software development skills.

Program Educational Objective – II: Success in Professional Career:

Demonstrate knowledge of technological advances through active participation in lifelong learning.

Program Educational Objective – III: Successful employment:

Accept to take up responsibilities upon employment in the areas of teaching, research, and software development.

Program Educational Objective – IV: Communication Skills and Leadership:
Exhibit technical communication, collaboration, and mentoring skills and assume roles as team members and as team leaders in an organization.

1.3 Mapping of program educational objectives to program outcomes and program-specific outcomes:

The following Figure 1 shows the correlation between the PEOs and the POs

PEO-I	PEO-II	PEO-III	PEO-IV
PO: 1, 2, 3, 4, 5, 6	**PO:** 1, 2, 3, 4, 5, 6	**PO:** 1, 2, 3, 5, 6	**PO:** 1,2,3,4,5,6

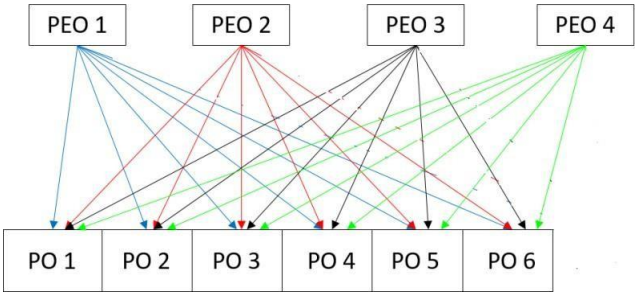


FIGURE 1: Correlation between the PEOs and the POs

2 Program Outcomes (POs)

A Program Learning Outcome is broad in scope and can be achieved at the end of the programme. POs are to be in line with the graduate attributes as specified in the Washington Accord. POs are to be specific, measurable, and achievable. The NBA has defined 3 POs, and the department has defined 3 more, and 6 POs are followed for the course. In the syllabus book given to students, there should be a clear mention of course objectives and course outcomes, along with the CO-PO course articulation matrix for all the courses.

M. Tech (CSE) - PROGRAM OUTCOMES (PO's)	
Upon completion of M.Tech Computer Science and Engineering, the students will be able to::	
PO1	Independently carry out research/investigation and development work to solve practical problems.
PO2	Write and present a substantial technical report/document.
PO3	Demonstrate a degree of mastery in computer science and engineering emerging areas such as data science, cybersecurity, and application development
PO4	Apply advanced-level knowledge, techniques, skills, and modern tools in the field of computer science and engineering and its allied areas.
PO5	Function effectively as a member or leader in diverse teams to carry out development work, and produce solutions that meet the specified needs with frontier technologies in multidisciplinary environments.

PO6	Engage in lifelong learning for continuing education in doctoral-level studies and pro-professional development.

3 Relation between the Program Educational Objectives and the POs

A broad relationship between the program objectives and the program outcomes is given in the following Table below:

PEO's→ ↓ PO's		**(1) Design and Development of Solutions**	**(2) Success in Professional Career**	**(3) Successful employment**	**(4) Communication Skills and Leadership**
PO1	Independently carry out research/investigation, and development work to solve practical problems.	3	3	3	2
PO2	Write and present a substantial technical report/ document.	3	3	2	2
PO3	Demonstrate a degree of mastery in computer science and engineering, emerging areas such as data science, cybersecurity, and application development	3	3	2	2
PO4	Apply advanced-level knowledge, techniques, skills, and modern tools in the field of computer science and engineering and its allied areas.	3	3	2	2

PO5	Function effectively as a member or leader in diverse teams to carry out development work, and produce solutions that meet the specified needs with front-line technologies in multi-disciplinary environments.	3	3	2	2
PO6	Engage in lifelong learning for continuing education in doctoral-level studies and professional development.	2	3	3	3

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

- 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 the student's programme exit questionnaire, alumni survey, and employment survey.

4 Blooms Taxonomy

Bloom's taxonomy is considered the global language for education. Bloom's Taxonomy is frequently used by teachers in writing the course outcomes as it provides a readymade structure and list of action verbs. The stages ascend in complexity and what they demand of students. First, students need to simply remember information provided to them, but reciting something doesn't demonstrate having learned it, only memorization. With understanding comes the ability to explain the ideas and concepts to others. The students are then challenged to apply the information and use it in new ways, helping to gain a deeper understanding of previously covered material and demonstrating it moving forward. Questioning information is a vital part of learning, and both analysis and evaluation do just this. Analyzing asks a student to examine the information in a new way, and evaluation demands the student appraise the material in a way that lets them defend or argue against it as they determine. The final step in the revised taxonomy is creating, which entails developing a new product or point of view. How does this learned information impact your world? How can it be used to impact not just your education but the way you interact with your surroundings? By utilizing Bloom's Taxonomy, students are not going to forget the information as soon as the class ends - rather, they retain and apply the information as they continue to grow as students and in their careers, staying one step ahead of the competition.

4.1 Incorporating Critical Thinking Skills into Course Outcome Statements

Many faculty members choose to incorporate words that reflect critical or higher-order thinking into their learning outcome statements. Bloom (1956) developed a taxonomy outlining the different types of thinking skills people use in the learning process. Bloom argued that people use different levels of thinking skills to process different types of information and situations. Some of these are basic cognitive skills (such as memorization) while others are complex skills (such as creating new ways to apply information). These skills are often referred to as critical thinking skills or higher-order thinking skills.

Bloom proposed the following taxonomy of thinking skills. All levels of Bloom's taxonomy of thinking skills can be incorporated into expected learning outcome statements. Recently, Anderson and Krathwohl (2001) adapted Bloom's model to include language that is oriented towards the language used in expected learning outcome statements. A summary of Anderson and Krathwohl's revised version of Bloom's taxonomy of critical thinking is provided in Figure 3.

FIGURE 2: Revised version of Bloom's taxonomy

4.2 Definitions of the different levels of thinking skills in Bloom's taxonomy:

1. **Remember** –recalling relevant terminology, specific facts, or different procedures related to information and/or course topics. At this level, a student can remember something, but may not understand it.
2. **Understand** –the ability to grasp the meaning of information (facts, definitions, concepts, etc.) that has been presented.
3. **Apply** –being able to use previously learned information in different situations or in problem solving.
4. **Analyze** –the ability to break information down into its parts. Analysis also refers to the process of examining information to make conclusions regarding cause and effect, interpreting motives, making inferences, or finding evidence to support statements/arguments.
5. **Evaluate** –being able to judge the value of information and/or sources of information based on personal values or opinions.

6. **Create** –the ability to creatively or uniquely apply prior knowledge and/or skills to produce new and original thoughts, ideas, processes, etc. At this level, students are involved in creating their own thoughts and ideas.

4.3 List of Action Words Related to Critical Thinking Skills

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

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

The cognitive process dimensions- categories:

Lower Order of Thinking (LOT)			Higher Order of Thinking (HOT)		
Remember	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**
Interpreting Illustrating Classifying Summarizing Inferring (concluding) comparing explaining	Recognizing (identifying) Recalling (retrieving)	Executing Implementing	Differentiating Organizing Attributing	Checking (coordinating, detecting, testing, monitoring) Critiquing (judging)	Planning Generating Producing (constructing)

The Knowledge Dimension			
Concrete Knowledge→Abstract knowledge			
Factual	**Conceptual**	**Procedural**	**Metacognitive**
• Knowledge of terminologies • Knowledge of specific details and elements	• Knowledge of classifications and categories • Knowledge of principles and generalizations • Knowledge of theories, models and structures	• Knowledge of subject specific skills and algorithms • Knowledge of subject specific techniques and methods • Knowledge of criteria for determining when to use appropriate procedures	• Strategic Knowledge • Knowledge about cognitive task, including appropriate contextual and conditional Knowledge • Self- Knowledge

Action Verbs for Course Outcomes

Lower Order of Thinking (LOT)				Higher Order of Thinking (HOT)		
Definitions	**Remember**	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**
Bloom's Definition	Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.	Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas.	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 generalizations.	Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria.	Compile information together in a different way by combining elements in a new pattern or proposing alternative solution.
Verbs	• Choose • Define • Find • How • Label • List • Match • Extend	• Classify • Compare • Contrast • Demonstrate • Explain • Illustrate • Infer • Interpret	• Apply • Build • Choose • Construct • Develop • Interview • Make use of • Model	• Analyze • Assume • Categorize • Classify • Compare • Discover • Dissect • Distinguish	• Agree • Appraise • Assess • Award • Choose • Criticize • Decide • Deduct • Importance	• Adapt • Build • Solve • Choose • Combine • Invent • Compile • Compose • Construct

Action Verbs for Course Outcomes

Lower Order of Thinking (LOT)				Higher Order of Thinking (HOT)		
Definitions	**Remember**	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**
Verbs	• Name • Omit • Recall • Relate • Select • Show • Spell • Tell • What • When • Where • Which • Who • Why	• Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with • Illustrate • Infer • Interpret • Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with	• Organize • Plan • Select • Solve • Utilize • Identify • Interview • Make use of • Model • Organize • Plan • Select • Solve • Utilize • Identify	• Divide • Examine • Function • Inference • Inspect • List Motive • Simplify • Survey • Take part in • Test for Theme • Conclusion • Contrast	• Defend • Determine • Disprove • Estimate • Evaluate • Influence • Interpret • Judge • Justify Mark • Measure • Opinion • Perceive • Prioritize • Prove • Criteria • Criticize • Compare • Conclude	• Create • Design • Develop • Estimate • Formulate • Happen • Imagine • Improve • Make up • Maximize • Minimize • Modify • Original • Originate • Plan • Predict • Propose • Solution

5 Guidelines for Writing Course Outcome Statements:

Well-written course outcomes involve the following parts:

1. Action verb
2. Subject content
3. Level of achievement as per BTL
4. Modes of performing the task (if applicable)

5.1 Course Outcomes (COs)

A Course Outcome is a formal statement of what students are expected to learn in a course. When creating Course Outcomes remember that the outcomes should clearly state what students will do or produce to determine and/or demonstrate their learning. Course learning outcome statements re- fer to specific knowledge, practical skills, areas of professional development, attitudes, higher-order thinking skills, etc. that faculty members expect students to develop, learn, or master during a course.

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

5.2 Developing Course Outcomes

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

- Limit the course outcomes to 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.

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:

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

Course outcomes have three major characteristics

- They specify an action by the students/learners that is observable
- They specify an action by the students/learners that is measurable
- They specify an action that is done by the students/learners rather than the faculty members

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

5.3 Relationship of Course Outcome to Program Outcome

The Course Outcomes need to link to the Program Outcomes.

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 they will apply the knowledge or skill/how you will assess the learning)."

5.4 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

5.5 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 website 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 analyze 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.
- Analyze a character's motivation and portray that character before an audience.
- Differentiate among the 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 below provides three examples.

S No	Condition	Observable Behaviour	Standard
1	Given a list of drugs	The student will be able to classify each item as an amphetamine or a barbiturate	With at least 70% accuracy
2	Immediately following a fifteen-minute Discussion on a topic.	The student will be able to summarize in writing the major issues being discussed.	mentioning at least three of the five major topics.
3	Given an algebraic equation with one unknown.	The student will be able to correctly solve a simple linear equation	Within five minutes.

The following examples describe a course outcome that is not measurable as written, an explanation for why the course outcome is not considered measurable, and a suggested edit that improves the course outcome

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 Course Outcomes

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

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?

5.6 CO-PO Course Articulation Matrix (CAM) Mapping

The 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 can achieve the course learning objectives. The matrix can be used for any course and is a good way to evaluate a course syllabus.

Table 1 gives information about the action verbs used in the POs and the nature of POs, stating whether the POs are technical or non-technical. You need to understand the intention of each POs and the Bloom's level to which each of these action verbs in the POs corresponds. Once you have understood the POs, you can write the COs for a course and see to what extent each of those COs correlates with the POs.

TABLE 7: Process for mapping the values for the CO-PO Matrix

Type	POs	Action Verb(s) in POs	Bloom's level(s) for POs	Bloom's level(s) for COs
Technical	PO1	Apply	L3	Bloom's L1 to L4 for theory courses. Bloom's L1 to L5 for laboratory courses. Bloom's L1 to L6 for project work, experiential learning
	PO2	Build	L6	
		Discover	L4	
	PO3	Analyze	L4	
		Choose	L5	
	PO4	Illustrate	L2	
		Build	L6	
	PO5	Explain	L2	
		Develop	L3	
	PO6	Develop	L3	
		Solve	L6	

At the end, the POs can be calculated using various descriptors that you may define. The mapping of CO towards a PO is evaluated using descriptors such as High, Medium, Low, etc.

Observations:

1. The first five POs are purely technical, while the other POs are non-technical.
2. For the theory courses, while writing the COs, you need to restrict yourself to Bloom's Level 1 to Level 4. Again, if it is a programming course, restrict yourself to Blooms Level 1 to Level 3, but for the other courses, you can go up to Blooms Level 4.

3. For the laboratory courses, while composing COs, you need to restrict yourself between Blooms Level 1 to Level 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).

5.7 Tips for Assigning the values while mapping COs to POs

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

5.8 Method for Articulation

1. Identify the key competencies 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 vital 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 key competencies for CO – PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
4. Make a table with percentage of key competencies 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

$0–0 \leqq C \leqq 5\%$ - No correlation.

$1 - 5 < C \leqq 40\%$ - Low / Slight.

$2 - 40\% < C < 60\%$ - Moderate

$3 - 60\% \leqq C < 100\%$ - Substantial / High

6 Key Competencies for Assessing Program Outcomes:

PO	NBA statement / Vital features	No. of vital features
PO1	**Independently carry out research/investigation, and development work to solve practical problems** 1. Independence and Self-direction in solving practical problems 2. Scope definition and deliverables by referring to related literature 3. Work breakdown structure including resource identification, schedule, and implementation 4. Demonstrate the solution to the stakeholders	4
PO2	**Write and present a substantial technical report/document** 1. Clarity, Grammar/Punctuation, References. (Writing) 2. Speaking style and Subject content. (Presentation)	2
PO3	**Demonstrate a degree of mastery in computer science and engineering, emerging areas such as data science, cybersecurity, and application development** 1. Apply mathematical/statistical models to analyze critically various applications related to Data Science and Cybersecurity. 2. Leverage Machine Learning and Soft computing techniques for problem-solving in emerging areas such as data science, cybersecurity.	2

PO	NBA statement / Vital features	No. of vital features
PO4	**Apply advanced-level knowledge, techniques, skills, and modern tools in the field of computer science and engineering and its allied areas.** Identify, design, and develop solutions to real-time problems by using 1. Problem (domain) understanding and system definition 2. Solution/prototype development/implementation with programming constructs/tools 3. Information/data visualization and processing techniques 4. Advanced data structures, protocols, and techniques/algorithms 5. Identification/assessment of vulnerabilities of the system/network using security techniques/ algorithms	5
PO5	**Function effectively in multidisciplinary environments with the knowledge of frontier technologies by working cooperatively, creatively, and responsively as a member or leader in diverse teams.** During the classroom periods, in the hands-on labs, and in the design projects 1. Knowledge of advanced techniques. 2. Plan tasks and resources, manage risk and produce deliverables 3. Meeting deadlines and producing solutions 4. Work with all levels of people /Get along with others 5. Interpretation of results in related domains	5
PO6	**Engage in lifelong learning for continuing education in doctoral-level studies and professional development.** 1. Project management and professional certifications 2. Begin work on an advanced degree 3. Personal continuing education efforts with keeping current in CSE and advanced engineering concepts 4. Ongoing learning – stays up with industry trends/ new technology	4

7 Program Outcomes Attained through course modules:

Courses offered in Computer Science and Engineering Curriculum (IARE- MT23) and POs attained through course modules for I, II, III, and IV semesters.

Code	Subject	PO					
		1	2	3	4	5	6
I Semester M.Tech							
BCSD01	Mathematical Foundations of Computer Science	✓			✓	✓	✓
BCSD02	Advanced Data Structures	✓			✓	✓	✓
BCSD03	Data Science						
BCSD08	Soft Computing						
	Research Methodology and IPR	✓	✓	✓	✓	✓	
BCSD11	Advanced Data Structures Laboratory	✓		✓	✓	✓	
BCSD12	Data Science Laboratory	✓		✓	✓	✓	✓
II SEMESTER M.Tech							
BCSD13	Advanced Algorithms	✓		✓	✓	✓	✓
BCSD14	Advanced Computer Architecture	✓			✓	✓	
BCSD15	Cyber Security	✓			✓	✓	
BCSD20	Mining Massive Datasets	✓			✓	✓	
BCSD23	Advanced Algorithms Laboratory	✓	✓	✓	✓	✓	✓
BCSD24	Cyber Security Laboratory	✓	✓	✓	✓	✓	✓
BCSD25	Mini Project with Seminar	✓	✓	✓	✓	✓	✓
III SEMESTER M.Tech							
BCSD27	Quantum Computing	✓			✓	✓	
BCCD31	Energy from waste	✓				✓	
BCSD34	Phase-I Dissertation Work -II	✓	✓	✓	✓	✓	✓
IV SEMESTER M.Tech							
BCSD35	Phase-II Dissertation Work -III	✓	✓	✓	✓	✓	✓

8 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 frameworks 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.

8.1 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.

8.2 Alternate 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.

8.3 Semester End Examination (SEE)

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

8.4 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 work, giving solutions to research / industrial problems to the extent possible by the capabilities and limitations of the student. The results of the assessment of the individual projects and laboratory work can easily be conflated to provide the students with periodic reviews of their overall progress and to produce terminal marks and grading.

8.5 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 through thorough discussions in faculty and DAB meetings.

8.6 Programme Exit Survey

The programme exists in questionnaire form and is to be filled out 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, career 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.

8.7 Alumni Survey

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

8.8 Employer Survey

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

8.9 Course Expert Committee

The course expert team is responsible for exercising the central domain of expertise in developing and renewing the curriculum and assessing its quality and effectiveness to the highest professional standards. Inform the Academic Committee of the 'day-to-day' matters that 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 reviews the full stack content developed by the respective course coordinator.

8.10 Programme Assessment and Quality Improvement Committee (PAQIC)

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

8.11 Department Advisory Board (DAB)

The Departmental Advisory Board plays an important role in the development of the department. Department-level Advisory Board will be established to provide guidance and direction for the 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 the curriculum and Industry requirements and give necessary feedback or advice to be taken to improve the curriculum.

8.12 Faculty Meetings

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

8.13 Professional Societies

The importance of professional societies like IEEE, IETE, ISTE, etc, is 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.

9 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 employers. The weightage in CO attainment of Direct and Indirect assessments is illustrated in the Table.

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%

9.1 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 the delivery of course content are listed in the Table.

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

S No	Courses	Components	Frequency	Max. Marks	Evidence
1	Core / Elective	Continuous Internal Examination	Twice in a semester	25	Answer script
		Alternative Assessment Tools (AAT)	Twice in a semester	5	Video / Quiz / assignment
		Semester End Examination	Once in a semester	70	Answer script
2	Laboratory	Conduction of experiment	Once in a week	4	Work sheets
		Observation	Once in a week	4	Work sheets
		Result	Once in a week	4	Work sheets
		Record	Once in a week	4	Work sheets
		Viva	Once in a week	4	Work sheets
		Internal laboratory assessment	Once in a semester	10	Answer script
		Semester End Examination	Once in a semester	70	Answer script
3	Project Work	Presentation	Twice in a semester	30	Presentation
		Semester End Examination	Once in a semester	70	Thesis report
4	Comprehensive Examination	Written examination (objective type)	Once in a semester	50	Online assessment
		Oral examination	Once in a Semester	50	Viva

9.2 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 the Table.

TABLE 12: Tools used in Indirect assessment

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

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

Indirect Tools: (Non-measurable (surveys) in terms of marks and w.r.t. CO) Assessment done at the institute level.

10 PO - Assessment Tools and Processes

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

1. Direct method
2. Indirect method

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

TABLE 13: Attainment of POs

	Assessment	Tools	Weight
POs Attainment	Direct Assessment	CO attainment of courses	80%
	Indirect Assessment	Student 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.

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

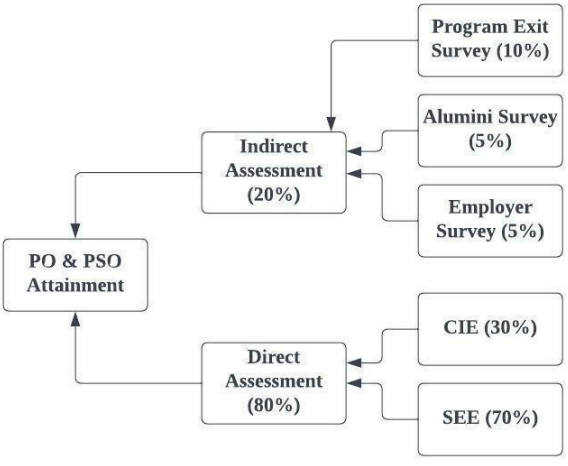


FIGURE 3: The evaluation process of POs' attainment through course outcome attainment

11 Course Description:

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

The "Course Description" contains the following:

- Course Overview
- Prerequisite(s)
- Marks Distribution
- Content delivery / Instructional methodologies
- Evaluation Methodology
- Course Objectives
- Course Outcomes
- Program Outcomes
- How Program Outcomes are assessed
- Mapping of each CO with PO(s)
- Justification for CO – PO mapping- direct
- Total count of key competencies for CO – PO mapping
- Percentage of key competencies for CO – PO
- Course articulation matrix (PO mapping)
- Assessment methodology-direct
- Assessment methodology-indirect
- Syllabus
- List of Text Books / References / Websites
- Course Plan

Appendix A

Sample Course Description

INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

COURSE DESCRIPTION

Department	**Computer Science and Engineering**				
Course Title	**Advanced Algorithms**				
Course Code	BCSD13				
Program	M.Tech				
Semester	II				
Course Type	Core				
Regulation	MT23				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	3	-	3	-	-
Course Coordinator	Dr S Janardhana Rao, Associate Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	BCSD02	I	Advanced Data Structures

II COURSE OVERVIEW:

This course typically aims to equip students with a deep understanding of fundamental algorithmic techniques, their analysis, and their applications in solving complex computational problems. This course includes graph theory, flow networks, and linear programming. Gain an understanding of a wide range of advanced algorithmic problems and their application to real-world problems.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Advanced Algorithms	60 Marks	40 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

√	PowerPoint Presentations	√	Chalk & Talk	√	Assignments	**x**	MOOC
x	Open-Ended Experiments	x	Seminars	**x**	Mini Project	**x**	Videos
x	Others						

V EVALUATION METHODOLOGY:

Theory Course: Each theory course will be evaluated for a total of 100 marks, out of which 40 marks will be for Continuous Internal Assessment (CIA) and 60 marks for Semester End Examination (SEE). **Semester End Examination (SEE):** The SEE shall be conducted for 60 marks of a 3-hour duration. The syllabus for the theory courses shall be divided into FIVE modules, and each module carries equal weightage in terms of the marks distribution. The question paper pattern shall be as defined below. Two full questions with either 'or' choice will be drawn from each unit. Each question carries 12 marks. There could be a maximum of two / three subdivisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50%	To test the objectiveness of the concept
30%	To test the analytical skill of the concept
20%	To test the application skill of the concept

Continuous Internal Assessment (CIA):

For each theory course, the CIA shall be conducted by the faculty/teacher handling the course. CIA is conducted for a total of 40 marks, with 30 marks for Continuous Internal Examination (CIE), 05 marks for Assignment, and 05 marks for Alternative Assessment Tool (AAT). Two CIE Tests are Compulsory, and the sum of the two tests, along with the scores obtained in the assignment and AAT, shall be considered for computing the final CIA of a student in a given course. The CIE Tests/Assignment /AAT shall be conducted by the course faculty with due approval from the HOD. Advance notification for the conduct of the Assignment/AAT is mandatory, and the responsibility lies with the concerned course faculty.

Outline for Continuous Internal Assessments (CIA - I and CIA - II) and SEE

Activities	CIE-1	CIE-2	SEE	Total Marks
Continuous Internal Examination (CIE)	10 Marks	10 Marks		20 Marks
Assignment / Quiz	5 Marks	5 Marks		10 Marks
Alternative Assessment Tool (AAT)	5 marks	5 marks		10 marks
Semester End Examination (SEE)	-	-	60 Marks	60 Marks
Total	-	-	**100 Marks**	

Continuous Internal Examination (CIE):

Two CIE exams shall be conducted at the end of the 9th and 17th weeks of the semester, respectively. The CIE exam is conducted for 25 marks of 2 hours duration, consisting of 5 one-mark compulsory questions in part A and 4 questions in part B. The student has to answer any 4 out of 5 questions, each carrying 5 marks. Marks are awarded by taking an average of the marks scored in two CIE exams.

Technical Seminar and Term Paper:

Two seminar presentations are conducted during the I year, I semester, and II semester. For the seminar, a student under the supervision of a concerned faculty member shall identify a topic in each course and prepare a term paper with an overview of the topic. The evaluation of the Technical seminar and term paper is for a maximum of 5 marks. Marks are awarded by taking

the average of the marks scored in two Seminar Evaluations.

VI COURSE OBJECTIVES:

The students will try to learn

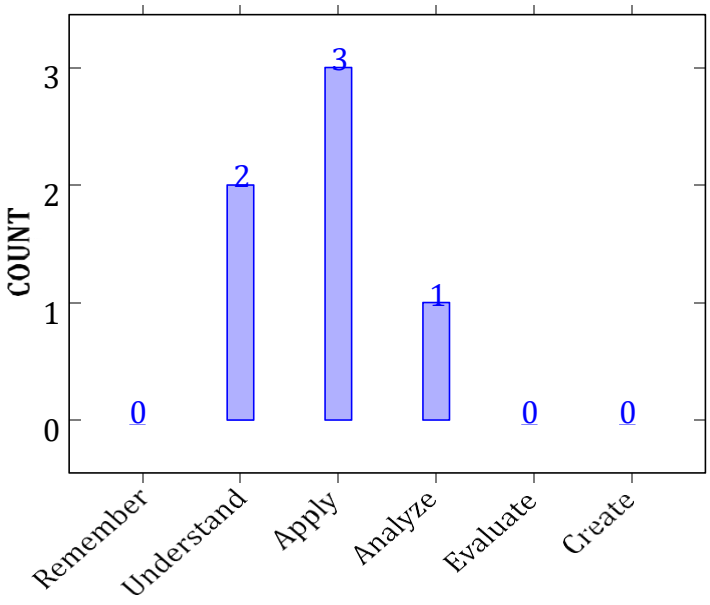
I	The advanced methods of designing and analyzing algorithms.
II	The student should be able to choose appropriate algorithms and use it for a specific problem.
III	Students should be able to understand different classes of problems concerning their computational difficulties.

VII COURSE OUTCOMES:

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

CO 1	Make use of appropriate tools and methods to analyze algorithms for optimized solutions.	Understand
CO 2	Select appropriate data structures for solving complex algorithmic problems effectively.	Apply
CO 3	Apply dynamic programming and greedy techniques to design efficient algorithms for solving optimization challenges	Apply
CO 4	Develop solutions for network flow problems using flow network models and techniques.	Apply
CO 5	Build solutions to real-world problems using a variety of shortest path and linear programming algorithms	Apply
CO 6	Analyze classification of problems into P, NP, NP-Hard, and NP-Complete classes using principles of complexity theory and algorithmic models.	Analyze

COURSE KNOWLEDGE COMPETENCY LEVEL



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VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Independently carry out research/investigation, and development work to solve practical problems.
PO 2	Write and present a substantial technical report/document
PO 3	Demonstrate a degree of mastery in computer science and engineering, emerging areas such as data science, cybersecurity, and application development
PO 4	Apply advanced-level knowledge, techniques, skills, and modern tools in the field of computer science and engineering and its allied areas.
PO 5	Function effectively as a member or leader in diverse teams to carry out development work, and produce solutions that meet the specified needs with frontier technologies in multidisciplinary environments
PO 6	Engage in lifelong learning for continuing education in doctoral-level studies and professional development.

IX HOW PROGRAM OUTCOMES ARE ASSESSED:

PROGRAM OUTCOMES		Strength	Proficiency Assessed by
PO 1	Independently carry out research/investigation, and development work to solve practical problems.	-	CIE/SEE/AAT
PO 3	Demonstrate a degree of mastery in computer science and engineering, emerging areas such as data science, cybersecurity, and application development	-	CIE/SEE/AAT
PO 4	Apply advanced-level knowledge, techniques, skills, and modern tools in the field of computer science and engineering and its allied areas.	-	CIE/SEE/AAT

X MAPPING OF EACH CO WITH PO(s),PSO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	√	-	√	√	-	-
CO2	√	-	-	-	-	-
CO3	√	-	√	√	-	-
CO4	√	-	-	√	-	-
CO5	√	-	-	√	-	-
CO6	√	-	√	√	-	-

XI JUSTIFICATIONS FOR CO – (PO, PSO) MAPPING -DIRECT:

Course Outcomes	PO'S	Justification for mapping (Students will be able to)	No. of Key competencies matched.
CO1	PO 1	Analyze the running time and space complexity of the given algorithms using techniques such as recurrences, potential functions, properties of probability by applying the mathematical principles, engineering principles, and scientific principles	3
	PO 3	Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	4
	PO 4	Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change	4
CO2	PO 1	Use research-based knowledge and research Methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide a valid conclusion problem	3
CO3	PO 1	Utilize appropriate tree traversal techniques for solving graph problems to integrate mathematical principles and computer science methodologies	3
	PO 3	By making use of tree traversal techniques, one can use them to perform research as their career path.	5
	PO 4	Understand the given traversal techniques to develop the solution for graph problems and the interpretation of results.	5
CO4	PO 1	Finding the solution to complex engineering problems and extending the efficiencies of the same problem using different algorithms in engineering disciplines.	3
CO5	PO 1	Choose (Pick) greedy algorithms for finding solutions of minimization and maximization problems to support the study of their own engineering discipline and methodologies..	3
	PO 4	Use research-based knowledge and research Methods include design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	5

CO6	**PO 1**	Apply the knowledge of dynamic programming algorithms for calculating an optimized solution of complex Engineering problems by understanding mathematical principles and computer science methodologies	**3**
	PO 3	Make use of modern computer tools for creating innovative career paths, to be an entrepreneur, and a desire for higher studies. ,	**6**
	PO 4	Understand the given problem and choose an appropriate technique of dynamic programming algorithms for solving the given problem from the provided Information and data to reach substantiated conclusions by the interpretation of results	**5**

Note: For Key Attributes, refer **Annexure - I**

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

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
	3	10	10	11	1	5
CO 1	3	-	4	4	-	-
CO 2	3					
CO 3	3	-	5	5	-	-
CO 4	3	-	-		-	-
CO 5	3	-	5		-	-
CO 6	3	-	6	5	-	-

.

XIII PERCENTAGE OF KEY COMPETENCIES FOR CO – (PO, PSO):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
	3	10	10	11	1	5
CO 1	100	-	40	36.36	-	-
CO 2	100	-	-		-	-
CO 3	100	-	50	45.45	-	-
CO 4	100	-	-		-	-
CO 5	100	-	50		-	-
CO 6	100	-	60	45.45	-	-

XIV COURSE ARTICULATION MATRIX (PO – PSO MAPPING):

CO'S and PO'S and CO'S and PSO'S on the scale of 0 to 3, **0** being **no correlation**, **1** being the **low correlation**, **2** being **medium correlation** and **3** being **high correlation**. *0* - 0 ≤ C≤ 5% – No correlation

1 -5 <C≤ 40% – Low/ Slight

2 - 40 % <C < 60% –Moderate

3 - 60% ≤ C < 100% – Substantial /High

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	-	2	1	-	-
CO 2	3	-	-		-	-
CO 3	3	-	2	2	-	-
CO 4	3	-	-		-	-
CO 5	3	-	2			
CO 6	3	-	2	2	-	-
TOTAL	**18**	**-**	**8**	**5**	**-**	**-**
AVERAGE	**3**	**-**	**2**	**1.6**	**-**	**-**

XV ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	√	SEE Exams	√	Assignments	√
Quiz	-	Tech - Talk	-	Certification	-
Term Paper	√	Seminars	√	Student Viva	-
Laboratory Practices	-	5-minute Video / Concept Video	-	Open-Ended Experiments	-
Micro Projects	-	-	-	-	-

XVI ASSESSMENT METHODOLOGY INDIRECT:

√	Early Semester Feedback	√	End Semester OBE Feedback
-	Assessment of Activities / Modeling and Experimental Tools in Engineering by Experts		

XVII SYLLABUS:

MODULE I	**ROLE OF ALGORITHMS IN COMPUTING**

	Role of algorithms in computing, Analyzing algorithms, Designing Algorithms, growth of Functions, Divide and Conquer - The maximum-subarray problem, Strassen's algorithms for matrix multiplication, the Substitution method for solving recurrences, The recurrence-tree method for solving recurrences, The master method for solving recurrences, Probabilistic analysis and random analysis

MODULE II	**REVIEW OF DATA STRUCTURES**
	Review of Data Structures- Elementary Data Structures, Hash Tables, Binary Search Trees, and Red-Black Trees.
MODULE III	**ELEMENTS OF DYNAMIC PROGRAMMING**
	Elements of dynamic programming, - Matrix-chain multiplication, Longest common subsequence, Greedy Algorithms - Elements of the greedy strategy, Huffman codes, Amortized Analysis - Aggregate analysis, The accounting method, The potential method, Dynamic tables.
MODULE IV	**FLOW NETWORKS**
	Flow-Networks: Maxflow-min-cut theorem, Ford-Fulkerson Method to compute maximum flow, Edmond-Karp maximum-flow algorithm.
MODULE V	**SHORTEST PATH IN GRAPHS**
	Shortest Path in Graphs: Floyd-Warshall algorithm and introduction to dynamic programming paradigm. More examples of dynamic programming. Linear Programming: Geometry of the feasibility region and Simplex algorithm NP-completeness: Examples, proof of NP-hardness and NP-completeness.

TEXTBOOKS

1. Cormen, Leiserson, Rivest, Stein, "Introduction to Algorithms". The MIT Press, 4th edition, 2022.
2. Aho, Hopcroft, Ullman "The Design and Analysis of Computer Algorithms", Pearson Education, 7th edition, 2018..

REFERENCE BOOKS:

1. Kleinberg and Tardos," Algorithm Design", Pearson Education, 2 nd edition, 2016.

WEB REFERENCES

1. https://www.personal.kent.edu/ rmuhamma/Algorithms/algorithm.html

XVIII COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

S.No	Topics to be covered	CO's	Reference
	OBE DISCUSSION		
1	Course Description on Outcome-Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO), and CO-PO Mapping	-	https://lms.iare.ac.in/index?route=course/details&course_id=354

CONTENT DELIVERY (THEORY)			
2	Role of algorithms in computing,	CO 1	T1: 1.1-1.5
3	Analyzing algorithms	CO 1	T1: 3.2-3.5
4	Designing Algorithms	CO 1	T1: 3.5-3.7
5	Growth of Functions	CO 1	T1: 4.1-4.2
6	Divide and Conquer	CO 1	T1: 4.2-4.3
7	The maximum-subarray problem	CO 1	T1: 4.3-4.4
8	Strassen's algorithms for matrix multiplication	CO 1	T1:5.1-5.2
9	The substitution method for solving recurrences	CO 1	T1:5.2,5.5
10	The recurrence-tree method for solving recurrence	CO 1	T1: 6.1-6.2
11	The master method for solving recursions	CO 1	T1: 6.1-6.2
12	Probabilistic analysis, and random analysis	CO 1	T1: 7.1-7.2
13	Review of Data Structures	CO 2	T1: 7.1-7.2
14	Elementary Data Structures	CO 2	T1: 7.4-7.5
15	Hash Tables	CO 2	T1: 7.4-7.5
16	Binary Search Trees	CO 2	T2: 7.6-8.1
17	and Red Black Trees.	CO 2	T2: 7.6-8.1
18	Elements of dynamic programming	CO 3	T1: 8.2-8.5
19	Matrix-chain multiplication,	CO 3	T1:9.1-9.2
20	Longest common subsequence	CO 3	T1: 9.1-9.2
21	Greedy Algorithms	CO 3	R1:8.4,8.10
22	Elements of the greedy strategy	CO 3	R1:8.4- 10
23	Huffman codes,	CO 3	R1:8.4
24	Amortized Analysis	CO 3	R1: 8.14-8.16
25	Aggregate analysis	CO 3	R1: 8.14-8.16
26	The accounting method	CO 3	R1: 8.16,8.17
27	The potential method	CO 3	R1:8.22
28	Dynamic tables.	CO 3	R1:8. 27
29	Flow-Networks:	CO 4	R1:8. 28

30	Maxflow-min-cut theorem,	CO 4	T2: 2.1-2.2
31	Ford-Fulkerson Method to compute maximum flow	CO 4	T2:2.2-2.4
32	Shortest Path in Graphs	CO 5	T2: 2.1-2.4
33	Floyd-Warshall algorithm and introduction to dynamic programming paradigm.	CO 5	T2:3.1-2.1
34	More examples of dynamic programming.	CO 5	T2: 2.5
35	Linear Programming	CO 5	T2: 2.5
36	Geometry of the feasibility region and Simplex algorithm	CO 5	T2: 2.5,13.4
37	NP-completeness	CO 5	T2: 2.5,13.4
38	Examples,	CO 5	T2: 2.5-2.6
39	proof of NP-hardness and NP-completeness.	CO 5	T2: 13.3

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