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# DESIGN AND IMPLEMENTATION OF AN NEP 2020-ALIGNED OUTCOME-BASED CURRICULUM: A CASE STUDY INTEGRATING SKILLS, COMPETENCIES, AND EXPERIENTIAL LEARNING

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## Abstract

The National Education Policy 2020 necessitates a paradigmatic shift in higher and technical education in India from linear, content-driven instructional models toward adaptive, competency-based, and multidisciplinary learning ecosystems. This transition foregrounds holistic learner development through the integration of arts, humanities, languages, values, and well-being practices with science, technology, engineering, and mathematics, thereby advancing a STEAM-oriented educational paradigm. However, a critical challenge persists in operationalizing these policy-level directives into coherent, course-level curriculum architectures that effectively respond to the complexity of contemporary skill requirements and rapidly evolving technological landscapes.

Addressing this gap, the present study adopts a case-based, design-oriented research approach to develop and validate an NEP 2020-aligned Outcome-Based Curriculum (OBC) framework for undergraduate engineering education. The framework conceptualizes curriculum design as a multi-layered, dynamic system, integrating Program Educational Objectives, Program Outcomes, Programme Specific Outcomes, Course Outcomes, and Session Outcomes into a hierarchically aligned and recursively connected structure. This architecture enables constructive alignment across cognitive, psychomotor, and affective domains, while embedding feedback loops for continuous refinement and outcome attainment.

The proposed model incorporates experiential, workflow-based, and technology-enabled learning processes, including micro-projects, complex engineering problems, laboratory-based inquiry, seminar-driven knowledge construction, and self-directed learning modules. These elements collectively foster higher-order cognitive capabilities, design thinking, systems integration skills, and digital competencies, aligning curriculum delivery with the demands of Industry 4.0 and knowledge-driven economies. The framework is further supported by outcome-based teaching–learning and assessment mechanisms, integrating formative, diagnostic, and summative evaluation strategies within a credit-based flexible learning structure.

Methodologically, the study employs a multi-phase iterative design, comprising policy analysis, stakeholder consultation, outcome mapping, pilot implementation, and qualitative validation. The framework is aligned with accreditation standards of the National Board of Accreditation and guidelines of the All India Council for Technical Education, ensuring both regulatory compliance and global comparability. Findings from the pilot implementation indicate that the proposed model enhances learner engagement, outcome attainment, interdisciplinary integration, and employability-oriented skill development, while demonstrating adaptability across institutional contexts.

The study contributes a complexity-informed and scalable curriculum design model that bridges the persistent gap between policy intent and pedagogical practice. The case study of a 3D Printing course illustrates the operationalization of the framework at the micro-curricular level, including detailed outcome mapping, curriculum structuring, and assessment design. The proposed approach redefines curriculum design as a dynamic, feedback-driven, and competency-oriented system, offering a future-ready pathway for engineering education aligned with the transformative vision of NEP 2020.

**Keywords:** Outcome-based education, NEP 2020, engineering curriculum, technical education, continuous assessment, experiential learning, 3D printing, micro projects, NBA accreditation, credit-based learning.

## 1. Introduction

The evolution of higher and technical education in India has been driven by the dual imperatives of quality enhancement and industry relevance, particularly in the context of rapidly changing technological and socio-economic landscapes. Within this ecosystem, the curriculum serves as a foundational and strategic document that guides all key stakeholders—including students, educators, evaluators, and industry—by defining the knowledge domains, skill sets, and competencies expected from graduates. Consequently, any meaningful reform aimed at preparing engineering graduates for industry readiness, innovation, and twenty-first century skill requirements must be systematically embedded within curriculum design and delivery.

A contemporary curriculum must extend beyond the traditional specification of theoretical content and incorporate structured, outcome-driven learning opportunities that promote practical competence, creativity, and problem-solving abilities. In this regard, the inclusion and documentation of theory session outcomes, laboratory session outcomes, micro-projects, seminar topics, complex engineering problems, assignments, and curated learning resources for each course are essential. The allocation of appropriate assessment weightage to these components ensures their effective implementation and integration within the learning process. Such a structured approach fosters hands-on learning, workflow-based problem-solving, and the application of digital tools, thereby enabling students to progressively develop competencies aligned with intended course outcomes. Simultaneously, it provides educators with a clear framework to design instructional/learning strategies, continuous assessment mechanisms, and learner-centered pedagogical practices.

However, traditional engineering curricula in India have largely been content-centric and examination-driven, with an overemphasis on rote learning and limited opportunities for experiential engagement, interdisciplinary learning, and skill development. This has often resulted in a gap between academic preparation and industry expectations, particularly in areas such as problem-solving, design thinking, collaboration, and digital competency. Recognizing these limitations, national bodies such as the National Institute of Technical Teachers' Training and Research (NITTTRs), the All India Council for Technical Education (AICTE), and the National Board of Accreditation (NBA) have increasingly advocated the adoption of Outcome-Based Education (OBE) as a guiding framework for curriculum design, delivery, and assessment (AICTE, 2020; NBA, 2021). OBE emphasizes clearly articulated learning outcomes at multiple levels, their constructive alignment with teaching-learning processes, and the use of systematic assessment mechanisms to ensure the attainment of desired graduate attributes/programme outcomes specified by NBA.

The NEP 2020 further strengthens this reform agenda by promoting flexible, multidisciplinary, and skill-integrated learning systems aligned with emerging frameworks such as the National Credit

Framework (NCrF) and the Academic Bank of Credits (ABC). These policy directions encourage higher education institutions to redesign curricula that support experiential learning, multiple entry–exit pathways, multidisciplinary engagement, and lifelong learning opportunities. Importantly, NEP 2020 advocates a transition from a narrow focus on STEM (Science, Technology, Engineering, and Mathematics) to a more holistic STEAM approach, integrating arts, humanities, languages, values, sports, and well-being practices such as yoga, thereby fostering the all-round development of learners. Within this evolving educational landscape, curriculum design assumes a transformative and strategic role in translating policy objectives into educational practices. It must respond not only to accreditation requirements but also to the demands of Industry 4.0, digital transformation, and global competitiveness. The framework proposed in this study addresses these challenges by operationalizing NEP 2020 principles through a systematic mapping of Program Outcomes (POs), Course Outcomes (COs), and Session Outcomes (SOs), supported by innovative teaching–learning strategies, experiential learning components, and diversified assessment mechanisms.

This paper presents the design philosophy, structural components, and implementation features of the proposed Outcome-Based Curriculum (OBC) framework through a case study of a 3D Printing course at the undergraduate engineering level. The study contributes to the ongoing discourse on reforming technical education by offering a scalable, skill-oriented, and policy-aligned curriculum model that bridges the gap between higher education, industry expectations, and global outcome-based standards, while simultaneously advancing the holistic and multidisciplinary vision articulated in NEP 2020.

## 2. Review of Literature

### 2.1 Outcome-Based Education (OBE)

Outcome-Based Education (OBE) has emerged as a paradigm shift in curriculum design, moving from content-centric instruction to competency-driven learning systems. The foundational work of William G. Spady [9] conceptualized education as a process organized around the demonstrable abilities and competencies that learners must exhibit upon completion, thereby reversing the traditional design logic from input-based to outcome-driven structures. In this framework, curriculum development follows a backward design approach, wherein learning outcomes are defined first, followed by the alignment of pedagogical strategies and assessment mechanisms to ensure their attainment.

The theoretical robustness of OBE is further reinforced by the principle of constructive alignment, proposed by John Biggs [3, 4], which emphasizes the systematic alignment between learning outcomes, teaching–learning activities, and assessment practices. This alignment ensures that student learning is intentional, measurable, and meaningful, rather than incidental. Additionally, global accreditation frameworks such as the Washington Accord [10] establish internationally recognized graduate attributes and professional competencies, thereby embedding OBE within a global quality assurance ecosystem.

The conceptual underpinnings of OBE are also grounded in classical educational taxonomies. The cognitive domain taxonomy developed by Benjamin S. Bloom [13] categorizes learning into hierarchical levels ranging from knowledge recall to higher-order thinking skills such as analysis, evaluation, and creation. Complementing this, the psychomotor taxonomy proposed by R. H. Dave [14] provides a structured framework for defining skill-based learning outcomes, particularly relevant in technical and engineering education. Together, these models provide a multi-dimensional foundation for designing outcome-oriented curricula that integrate knowledge, skills, and competencies.

### 2.2 Policy Drivers in India

In the Indian context, the transition toward outcome-based technical education has been significantly influenced by national regulatory and accreditation frameworks. The National Board of Accreditation (NBA) mandates the adoption of OBE principles for accredited engineering programs, requiring institutions to demonstrate measurable attainment of Program Outcomes through systematic assessment and continuous improvement processes [6]. This approach aligns Indian engineering education with international standards, facilitating global mobility and recognition of graduates.

Similarly, the All India Council for Technical Education (AICTE) has introduced comprehensive curriculum reforms through its Model Curriculum guidelines [3], emphasizing outcome orientation, skill integration, and industry relevance. A transformative milestone in this trajectory is the National Education Policy (NEP) 2020, which advocates a holistic restructuring of higher education systems through flexibility, multidisciplinary learning, and outcome-based education [1].

NEP 2020 further operationalizes these principles through enabling frameworks such as the National Credit Framework (NCrF) and the Academic Bank of Credits (ABC), which support learner mobility, credit accumulation, and multiple entry–exit pathways. These initiatives collectively aim to create a convergent educational ecosystem, where academic knowledge, vocational skills, and experiential learning are seamlessly integrated. From a systems perspective, these policy drivers represent a shift toward adaptive, modular, and learner-centric curriculum architectures capable of responding to evolving socio-economic and technological demands.

### 2.3 Curriculum Design and Pedagogy in Technical Education

Contemporary research in engineering education emphasizes that the successful implementation of OBE requires a holistic integration of curriculum design, pedagogy, and assessment systems, rather than isolated reforms. Institutions such as the NITTTR Bhopal have developed guidelines [7] that promote outcome mapping, learner-centered instructional strategies, and continuous assessment frameworks, aligned with the vision of NEP 2020.

Empirical studies highlight the effectiveness of active and experiential pedagogies, including project-based learning, problem-based learning, authentic assessment, and digital tool integration, in enhancing learning outcomes. These approaches facilitate deep learning, contextual application, and skill acquisition, which are critical for engineering practice. For instance, Kumar and Sharma [5] demonstrate that structured outcome-based frameworks significantly improve student engagement, participation, and continuous quality improvement processes, while Singh [8] reports that integrating NEP 2020 principles fosters interdisciplinary learning, skill development, and industry alignment.

Despite these advancements, a persistent challenge lies in translating macro-level policy directives into micro-level curriculum practices. While frameworks exist at the institutional and program levels, there is limited evidence on how outcome-based principles can be operationalized within individual courses and classroom/practice levels. Addressing this gap, recent work by Pradhan et al. [15] proposes an NEP 2020-aligned Outcome-Based Curriculum framework that integrates session-level outcomes, micro-projects, complex engineering problems, seminar components, and diversified assessment strategies to ensure the attainment of measurable learning outcomes. This approach represents a shift toward granular, course-level curriculum engineering, enabling more precise alignment between learning outcomes and instructional practices.

### 2.4 Research Gap in Existing Literature

Although OBE and competency-based education have been extensively explored in engineering education literature, their practical implementation at the course and session levels remains inadequately addressed. Existing studies predominantly focus on conceptual frameworks, accreditation compliance, and outcome assessment methodologies, with limited emphasis on operational models that integrate pedagogy, assessment, and curriculum design in a cohesive manner. Policy documents such as NEP 2020 and the National Credit Framework provide broad strategic directions, but they do not sufficiently elaborate on how these principles can be translated into actionable curriculum structures at the classroom level. Furthermore, while experiential and interdisciplinary learning are widely advocated, there is a lack of systematic models for embedding these elements through structured session outcomes, micro-projects, and workflow-based learning activities.

Another critical gap lies in the integration of digital competencies, workflow-based learning, and technology-enabled assessment mechanisms within outcome-based curricula. As engineering education increasingly aligns with Industry 4.0 and digital transformation paradigms, the absence of such integration limits the effectiveness of traditional OBE implementations. Therefore, there is a clear need for replicable, scalable, and context-sensitive curriculum models that demonstrate how NEP 2020-aligned OBE principles can be effectively operationalized at the course level while maintaining coherence across learning outcomes, pedagogy, and assessment.

### 2.5 Positioning of the Present Study

In response to the identified research gaps, the present study proposes and examines a complexity-aware, NEP 2020-aligned Outcome-Based Curriculum (OBC) framework that operationalizes outcome-based principles through structured and multi-layered curriculum components at the course level. Building upon the foundational work of Pradhan et al. (2025), the study advances the framework by incorporating session-level outcome mapping, experiential learning modules, workflow-based problem-solving, and integrated assessment mechanisms.

To demonstrate the practical applicability of the framework, the study presents a detailed case analysis of a 3D Printing course at the undergraduate engineering level. This course provides an ideal context due to its multidisciplinary nature, integration of digital design and manufacturing technologies, and alignment with Industry 4.0 competencies. Through this case study, the research illustrates how policy directives, pedagogical innovations, and outcome-based principles can be synthesized into a coherent and implementable curriculum model.

By bridging the gap between theoretical frameworks and practical implementation, this study contributes to the ongoing discourse on engineering education reform in India and offers a scalable, skill-oriented, and future-ready curriculum model aligned with both global OBE standards and the transformative vision of NEP 2020.

## 3. Research Methodology

This study adopts a case study–based and design-oriented research methodology to develop, implement, and evaluate an NEP 2020-aligned Outcome-Based Curriculum (OBC) framework for technical education. The methodology is designed not only to translate national policy directives and outcome-based education (OBE) principles into a practical, course-level curriculum model, but also to enhance alignment with contemporary skill requirements, digital competencies, and industry expectations.

The methodology is guided by the following key objectives:

- To operationalize NEP 2020 principles into a structured and implementable curriculum framework at the course level
- To ensure constructive alignment between learning outcomes, pedagogy, and assessment
- To integrate 21st-century skills, including problem-solving, digital literacy, innovation, and interdisciplinary thinking
- To develop a replicable and scalable curriculum model adaptable across technical institutions
- To incorporate continuous feedback and iterative refinement mechanisms for curriculum improvement

The research process follows a multi-stage, iterative design, comprising policy review, stakeholder consultation, curriculum mapping, pilot implementation, and validation through feedback. This approach ensures both theoretical rigor and empirical validation, enabling the framework to function as a dynamic and adaptive educational model.

### 3.1 Policy Review

The initial stage involved a comprehensive and systematic review of national policy and regulatory frameworks governing technical education in India, including the National Education Policy 2020, guidelines issued by the All India Council for Technical Education Model Curriculum, and accreditation manuals published by the National Board of Accreditation.

The objective of this stage was to identify structural, pedagogical, and assessment-related requirements necessary for aligning engineering curricula with OBE principles. Particular emphasis was placed on credit structures, outcome formulation, competency-based assessment, and experiential learning integration, including complex engineering problems, internships, micro-projects, and multidisciplinary learning. This stage also incorporated an analysis of emerging educational trends such as digital learning ecosystems and Industry 4.0 competencies, thereby strengthening the relevance of the framework in contemporary contexts.

### 3.2 Stakeholder Consultation

To ensure contextual relevance and practical applicability, structured stakeholder consultations were conducted involving subject experts, faculty members, and industry representatives. These consultations were facilitated through curriculum development workshops organized by National Institute of Technical Teachers’ Training and Research Bhopal.

Participants engaged in discussions on emerging industry trends, digital transformation, employability skills, and workflow-based learning approaches. Industry stakeholders provided insights into competency requirements, technological advancements, and professional expectations, while faculty members highlighted pedagogical constraints, assessment challenges, and implementation feasibility. This stage ensured that the proposed framework reflects a balanced integration of academic rigor, industry relevance, and skill orientation.

### 3.3 Curriculum Mapping

Following the preliminary stages, a systematic mapping of Program Educational Objectives (PEOs), Program Outcomes (POs), Programme Specific Outcomes (PSOs) and Course Outcomes (COs) was conducted. This process was guided by the revised taxonomy of educational objectives proposed by Benjamin S. Bloom, with a focus on higher-order cognitive skills such as analysis, evaluation, and creation.

The mapping framework was further aligned with the graduate attributes defined under the Washington Accord, as incorporated within the NBA accreditation system. Each course was structured to include Session Outcomes (SOs), enabling granular tracking of learning progression. Additionally, the methodology introduced enhanced mapping practices, including:

- Alignment of learning activities with specific skill domains (cognitive, psychomotor, and affective)
- Integration of workflow-based learning sequences
- Embedding of digital tool usage and simulation-based activities

Teaching-learning activities, laboratory work, assignments, self-learning components, complex engineering problems and micro-projects were systematically aligned with outcomes to ensure constructive alignment and measurable attainment.

### 3.4 Pilot Implementation

To evaluate the feasibility and effectiveness of the proposed framework, selected courses were redesigned and implemented on a pilot basis in affiliated institutions. The 3D Printing course was selected as a representative case due to its interdisciplinary nature and relevance to digital manufacturing and Industry 4.0 applications. The redesigned course incorporated:

- Clearly defined theory and laboratory session outcomes
- Industry-aligned micro-projects and assignments
- Hands-on laboratory activities and digital tool integration
- Problem-solving tasks based on real-world engineering scenarios

The pilot implementation emphasized experiential, workflow-based, and technology-enabled learning environments, enabling students to engage in design, prototyping, and iterative problem-solving processes. This stage provided critical insights into the operational feasibility, adaptability, and scalability of the framework.

### 3.5 Feedback and Validation

Following the pilot phase, structured feedback was collected from faculty members and students through focus group discussions and survey-based evaluation tools. Faculty feedback focused on curriculum clarity, alignment with accreditation requirements, and assessment feasibility, while student feedback emphasized engagement, skill development, and learning effectiveness.

The methodology incorporated a data-driven validation approach, involving:

- Identification of performance gaps and learning challenges
- Analysis of student engagement and outcome attainment levels

- Evaluation of assessment reliability and effectiveness

Based on these findings, iterative refinements were made to curriculum structure, assessment design, and instructional strategies, ensuring continuous improvement and adaptability of the framework.

### 3.6 Development of Detailed Course Curriculum Document

The final stage involved the preparation of a comprehensive and structured curriculum document based on the refined framework. The document includes:

- Course information and clearly defined outcomes (COs, SOs)
- Laboratory activities, micro-projects, assignments, and seminar topics
- Complex engineering problems and experiential learning components
- Assessment guidelines and outcome-mapping matrices (CO–PO linkage)

The document also incorporates enhanced features, such as:

- Skill mapping (technical, digital, and professional competencies)
- Rubric-based assessment frameworks
- Guidelines for integrating digital tools and emerging technologies

This structured documentation serves as a replicable, scalable, and adaptable template for institutions aiming to implement NEP 2020-aligned outcome-based curricula across diverse engineering disciplines. The proposed methodology advances existing approaches by introducing:

- A multi-layered and outcome-driven curriculum architecture
- Integration of policy alignment, skill development, and digital competencies
- A feedback-driven and iterative refinement model
- Emphasis on workflow-based and experiential learning design
- A scalable framework adaptable across disciplines and institutional contexts

Overall, the methodology provides a robust bridge between theoretical curriculum design and real-world educational implementation, ensuring alignment with both national policy mandates and global engineering education standards.

## 4. Proposed Outcome-Based Curriculum

The proposed Outcome-Based Curriculum (OBC) framework is operationalized through the design and implementation of a 3D Printing course, which serves as a representative model for integrating outcome-based education principles into technical curricula. The course is structured around six clearly defined Course Outcomes (COs) that focus on measurement principles, instrument selection, process understanding, and practical application in real-world contexts.

Each Course Outcome is systematically mapped to relevant Program Outcomes (POs) through a Course Articulation Matrix (CAM), thereby ensuring a measurable and transparent linkage between course-level learning and program-level competencies. This structured mapping facilitates quantifiable outcome attainment and continuous monitoring of student performance.

The curriculum incorporates a multi-dimensional assessment framework comprising Progressive Theory Assessment (PTA), Progressive Laboratory Assessment (PLA), Term Work and Self-Learning Activities (TWA), and a Course Evaluation Matrix (CEM). Progressive Theory Assessment includes class tests, quizzes, and mid-term examinations designed to evaluate students' conceptual understanding and application abilities in a continuous manner. Progressive Laboratory Assessment emphasizes process-oriented and product-based evaluation, supported by well-defined rubrics to ensure objectivity and consistency in laboratory performance assessment.

In addition, Term Work and Self-Learning Activities encompass micro-projects, complex engineering problems, assignments, seminar presentations, self-learning modules, and industrial visits, thereby promoting experiential, inquiry-based, and industry-aligned learning. The Course Evaluation Matrix further defines the weightage of each assessment component at the Course Outcome level, enabling systematic planning and alignment of teaching–learning activities with assessment strategies.

The curriculum design also incorporates detailed Theory Session Outcomes (TSOs) and Laboratory Session Outcomes (LSOs), which are explicitly mapped to the respective Course Outcomes. This layered outcome structure enables fine-grained tracking of learning progression at both theoretical and practical levels. Each laboratory activity is evaluated using structured rubrics designed to enhance assessment reliability, transparency, and constructive feedback mechanisms.

Overall, this comprehensive and structured mapping framework fosters transparency, objectivity, and student-centered learning, which are central principles of Outcome-Based Education and aligned with the vision of the National Education Policy 2020.

### 4.1 Assessment Philosophy

The proposed framework adopts a Criterion-Referenced Testing (CRT) approach, wherein student performance is evaluated against predefined learning standards and outcome criteria, rather than through relative comparison with peers. This approach ensures fairness, clarity, and alignment with outcome-based education principles.

The assessment strategy is designed to be holistic and continuous, integrating multiple dimensions of learning evaluation. It incorporates assessment for learning (formative assessment) to provide ongoing feedback and support student improvement, assessment as learning (self-reflective assessment) to encourage metacognitive development and learner autonomy, assessment of learning (summative assessment) to evaluate the achievement of learning outcomes at defined stages, and assessment before learning (diagnostic assessment) to identify prior knowledge and learning gaps.

Rubric-based evaluation is a mandatory component for assessing projects, internships, laboratory work, and presentations, ensuring consistency, transparency, and meaningful feedback. These rubrics are designed to evaluate both process and outcome dimensions, thereby supporting skill development alongside knowledge acquisition.

Furthermore, the integration of the Course Evaluation Matrix (CEM) enables instructors to systematically plan instructional delivery and assessment opportunities in alignment with the assigned weightages for each Course Outcome. This structured approach ensures constructive alignment between learning objectives, teaching strategies, and assessment practices, ultimately enhancing the effectiveness and credibility of the curriculum framework. The proposed curriculum framework represents a systematic shift from content-driven teaching to outcome-driven learning, ensuring that students acquire not only theoretical knowledge but also practical competencies, problem-solving skills, and industry-relevant capabilities.

### 4.2 Case Study: Curriculum document of '3D Printing' course of Undergraduate level

**A) Course Code :** xxx

**B) Course Title** **:**3D Printing

**C) Pre- requisite Course(s):**Computer Aided Modeling

**D) Rationale:** Additive manufacturing (AM) or Additive layer manufacturing (ALM) is the industrial production name for 3D Printing. 3D Printing is a process that makes solid objects from a digital model. It involves depositing material either metal, powdered plastic, or liquid in thin layers (2D) to get a 3D object. This course tries to develop understanding of the various 3D printing processes available tomake real object from digital model in the students. It also covers the software/hardware required, various materials used and details about printing process parameters.It also covers the post processing required and details about various printing process and parameters to make a quality 3D printed component.

**E) Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/laboratory/workshop/field/micro project session/student activity session/industry.

**After completion of the course, the students will be able to-**

**CO-1** Import and export CAD models in .STL file format and generate G-code for 3D printing.

**CO-2** Select appropriate 3D printing materials based on application requirements and process constraints.

**CO-3** Apply solid-based 3D printing processes to fabricate functional products.

**CO-4** Apply liquid-based 3D printing processes to fabricate products with required geometrical accuracy.

**CO-5** Apply powder-based 3D printing processes to manufacture components.

**CO-6** Perform post-processing operations and conduct quality inspection of 3D-printed components.

**F) Suggested Course Articulation Matrix (CAM):**

| **Course Outc** | **Programme Outcomes(POs)** | | | | | | | | | | | **ProgrammeSpecificOutcomes (PSOs)** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **PO-1** Engineering Knowledge | **PO-2** Problem | **PO-3** Design / Developmen | **PO-4** Conduct Investi | **PO-5** Engineering Tool Usag | **PO-6** The Engi | **PO-7** Ethics | **PO-8** Individual and Collab | **PO-9** Communication | **PO-10** Project Management and | **PO-11** Life-long Learning | **PSO-1** | **PSO-2** |

| **omes (COs** | | Analysis | t of Solutions | gations of Complex Problems | e | neer and The World | | orative Team Work | | Finance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO-1** | 3 | 3 | 3 | - | 3 | - | - | 1 | - | - | 2 | | |
| **CO-2** | 3 | 2 | - | - | - | - | 1 | - | - | - | 2 | | |
| **CO-3** | 3 | 3 | 2 | - | 3 | - | - | 1 | - | - | 2 | | |
| **CO-4** | 3 | 3 | 2 | - | 2 | - | - | 1 | - | - | 2 | | |
| **CO-5** | 3 | 3 | 2 | - | 2 | - | - | 1 | - | - | 2 | | |
| **CO-6** | 3 | 2 | 2 | - | 2 | - | - | 1 | - | - | 2 | | |

**Legend:** High (3),Medium (2),Low (1)and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional

**G) Teaching-Learning & Learning Scheme:**

| **Board of Study** | **Course Codes and Category** | **Course Titles** | **Teaching & Learning Scheme (Hours/Week)** | | | | | | **Assessment Scheme(Marks)** | | | | | | **Total Marks (TA+TWA+LA)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Classroom Instruction (CI)** | | **Lab Instruction (LI)** | **Term Work (TW) and Self Learning** | **Total Hours (CI+LI+TW+SL)** | **Total Credits (C)** | **Theory Assessment (TA)** | | **Term work &Self-Learning Assessment (TWA)** | | **Lab Assessment (LA)** | | |
| | | | **L** | **T** | | | | | **Progressive Theory Assessment (PTA)** | **End Theory Assessment (ETA)** | **Progressive Term Work Assessment** | **End Term Work Assessment (ETWA)** | **Progressive Lab Assessment (PLA)** | **End Laboratory Assessment (ELA)** | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3D Printing | 03 | - | 04 | 02 | 08 | 04 | 25 | 50 | 15 | 10 | 25 | 25 | 150 |

**Legend:**

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e., Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

TW: Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: 1 Credit = 30 Notional Hours

PTA: Progressive Theory Assessment in classroom (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.

Course Category: Basic Science Courses (BSC), Engineering Science Courses (ESC), Professional core courses (PCC), Professional Core Elective (PCE), Professional Open Electives (POE), Humanities and Social Science Courses (HSC), Project, Seminar, Internship (PSI), Mandatory NEP Courses (MNC)

**Note:** Separate passing is must for progressive and end semester assessment for both theory and practical.

**H) Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

### I) Theory Session Outcomes (TSOs) and Units:

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|---|---|
| *TSO 1a.* List the advantages of additive manufacturing processes over conventional manufacturing processes.<br>*TSO 1b.* Classify 3D Printing processes.<br>*TSO 1c.* Explain the given 3D Printing process.<br>*TSO 1d.* List typical steps involved in 3D printing of an object from digital model.<br>*TSO 1e.* List the applications of 3D Printing processes.<br>*TSO 1f.* Explain reverse engineering steps for 3D Printing.<br>*TSO 1g.* Explain CAD-CAM and related terminologies.<br>*TSO 1h.* Convert the given CAD file format into others.<br>*TSO 1i.* Transfer the given CAD data to CAM facilities.<br>*TSO 1j.* Explain the given STL interface terminology.<br>*TSO 1k.* Use the given alternative 3D printing interface.<br>*TSO 1l.* Generate STL file for the given CAD file.<br>*TSO 1m.* Repair the given STL file.<br>*TSO 1n.* Apply part orientation and support techniques for the given situation. | **Unit-1.0:Additive Manufacturing Introduction and CAD-CAM for 3D Printing**<br>1.1 Additive v/s Conventional Manufacturing processes.<br>1.2 Classification of 3D Printing Processes. Working principle of various 3D Printing processes- Fused Deposition Modeling (FDM), Stereo lithography (SLA), Selective Laser Sintering (SLS), Binder Jetting, Material Jetting, Direct Energy Deposition and Laminate Object Manufacturing.<br>1.3 Additive Manufacturing application domains: Aerospace, Electronics, Health Care, Defense, Automotive, Construction, Food Processing, Machine Tools<br>1.4 Product design and prototyping.<br>1.5 Reverse Engineering for 3D Printing.<br>1.6 CAD-CAM and its integration.<br>1.7 CAD- Part and Surface modeling.<br>1.8 CAD file formats.<br>1.9 Process chain for 3D Printing.<br>1.10 STL interface Specification, STL data generation, STL data Manipulation.<br>1.11 Advantages and limitations of STL file format, Open files, Repair of STL files.<br>1.12 Alternative 3D Printing interfaces.<br>1.13 Part orientation and support generation, Factors affecting part orientation, Various models for part orientation determination.<br>1.14 The function of part supports, Support structure design, Automatic support structure generation.<br>1.15 Model Slicing and Contour Data organization, Direct and adaptive slicing: | **CO1** |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|---|---|
| *TSO 1o.* Perform slicing of the given CAD model using the given slicing software.<br>*TSO 1p.* Generate tool path using simulation software for the given situation. | Identification of peak features, Adaptive layer thickness determination.<br>1.16 Tool path generation. | |
| *TSO 2a.* Explain various forms of 3D printing raw material.<br>*TSO 2b.* Select various Polymer based 3D printing raw materials with justification.<br>*TSO 2c.* Explain procedure of Powder preparation for the given 3D printing material.<br>*TSO 2d.* Explain properties of the given Metal/Ceramics 3D printing material.<br>*TSO 2e.* Choose suitable 3D printing material on the basis of the performance requirements and material properties. | **Unit-2.0: 3D Printing Materials**<br>2.1 Various forms of 3D printing raw material- Liquid, Solid, Wire, Powder.<br>2.2 Popular FDM, SLA, SLS, Binder Jetting, Material Jetting and Direct Energy deposition 3D printing materials.<br>2.3 Polymers, Metals, Non-Metals, Ceramics.<br>2.4 Polymers and their properties.<br>2.5 Powder preparation and their desired properties.<br>2.6 3D Printing material selection on the basis of performance requirements and material properties. | **CO1, CO2** |
| *TSO 2a.* Explain working of a typical FDM based 3D Printer.<br>*TSO 2b.* Justify use of FDM based 3D printing process and material for the given component.<br>*TSO 2c.* Select suitable 3D Printer (FDM) and software for the given application with justification.<br>*TSO 2d.* Analyze the effect of the given FDM based 3D printing process parameters using 3D printer software simulation. | **Unit-3.0: Solid based 3D Printing Processes**<br>3.1 Basic principle and working of fused deposition modeling (FDM) process.<br>3.2 Construction details and working of established FDM based 3D printers for plastics parts.<br>3.3 3D Printer software- Fusion 360, Solidworks, Onshape, Tinkercad, UltimakerCura, MeshLab, Simplyfy 3D, Repetier host, Slic3r, etc. – use and operation of anyone.<br>3.4 3D Scanners and working.<br>3.5 Producing a part using FDM based 3D Printer.<br>3.6 Liquefaction, solidification and bonding. | **CO1, CO3** |

| **Major Theory Session Outcomes (TSOs)** | **Units** | **Relevant COs Number(s)** |
|---|---|---|
| *TSO 2e.* List steps to perform 3D scanning of the given object.<br>*TSO 2f.* Repair the given 3D scanned digital model.<br>*TSO 2g.* Set different FDM 3D printing process parameters to get a sound plastic component.<br>*TSO 2h.* Explain the Laminated Object Manufacturing process.<br>*TSO 2i.* Estimate the cost and time of the given FDM based 3D printed component. | 3.7 Laminated Object Manufacturing process.<br>3.8 Cost estimation of FDM 3D printed component. | |
| *TSO 4a.* Explain the phenomenon of Photo Polymerization.<br>*TSO 4b.* Explain the working of a typical Stereo Lithography based 3D Printer.<br>*TSO 4c.* Explain procedure of 3D Scanning of the given component.<br>*TSO 4d.* Justify use of SLA based 3D printing process and material for the given component.<br>*TSO 4e.* Estimate the cost and time of the given SLA based 3D printed component.<br>*TSO 4f.* Apply Curing process to the given SLA based 3D printed component. | **Unit-4.0: Liquid based 3D Printing Processes**<br>4.1 Photo polymerization.<br>4.2 Principle and working of stereo lithography apparatus.<br>4.3 SLA based 3D printing processes.<br>4.4 SLA based 3D printing process materials.<br>4.5 Scanning techniques.<br>4.6 Curing processes.<br>4.7 Cost estimation of SLA 3D printed component. | **CO4** |
| *TSO 5a.* Explain powder fusion mechanism.<br>*TSO 5b.* Explain working of a typical SLA based 3D Printer.<br>*TSO 5c.* Justify use of SLA based 3D printing process | **Unit-5.0: Powder based 3D Printing Processes**<br>5.1 Powder fusion mechanism.<br>5.2 Principle and working of Selective Laser Sintering (SLS) process.<br>5.3 SLS based 3D printers. | **CO5** |

| **Major Theory Session Outcomes (TSOs)** | **Units** | **Relevant COs Number(s)** |
|---|---|---|
| and material for the given component.<br>*TSO 5d.* Explain Net shape process.<br>*TSO 5e.* Explain Binder Jet 3D printing process.<br>*TSO 5f.* Justify use of Binder Jet 3D printing process and material for the given component.<br>*TSO 5g.* Estimate the cost and time of the given SLS based 3D printed component. | 5.4 Laser Engineering Net Shaping process.<br>5.5 Electron Beam Melting.<br>5.6 Binder Jet 3D Printing.<br>5.7 Materials and Process parameters for SLS based 3D printing processes.<br>5.8 Cost estimation of SLS based 3D printed component. | |
| *TSO 6a.* Justify the need of post processing in the given 3D printed component.<br>*TSO 6b.* List the various post processing techniques.<br>*TSO 6c.* List the steps to perform post processing.<br>*TSO 6d.* Explain the given Cleaning related post processing approach for 3D printed component.<br>*TSO 6e.* Explain the given Surface finishing related post processing approach for 3D printed component.<br>*TSO 6f.* Apply simple inspection and testing techniques on the given 3D printed component.<br>*TSO 6g.* Identify the type of defect(s) in the given 3D printed component. | **Unit-6.0: Post Processing and Quality**<br>6.1 Need of post processing: Functional and Aesthetic reasons.<br>6.2 Steps of Post Processing: Cleaning/Support removal, Fixing, Curing or hardening, Surface finishing, Colouring.<br>6.3 Cleaning: Support Removal(FDM and Material Jetting); Powder Removal (SLS and Powder Bed Fusion); Washing (SLA and Photo polymerisation).<br>6.4 Fixing: Filling, Gluing, Welding.<br>6.5 Surface finishing: Sanding, Polishing, Tumbling, Hydro dipping, Epoxy coating, Electro Plating, Vapour smoothing-Acetone treatment.<br>6.6 Colouring, Coating, Priming and Painting.<br>6.7 Inspection and testing: Digital, Visual, Physical.<br>6.8 Defects and their causes. | **CO6** |

**Note:** One major TSO may require more than one Theory session/Period.

**J) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical:**

| Practical/Lab Session Outcomes (LSOs) | Laboratory Experiment/ Practical Titles | Relevant COs Number (s) | PLA/ELA (%) | | |
|---|---|---|---|---|---|
| | | | Performance | | Viva-Voce |
| | | | Process Assess-ment | Product Assess-ment | |
| *LSO 1.1* Use CAD software.<br>*LSO 1.2* Prepare digital models of simple 3D entities. | Develop digital models of following simple components using any CAD software:<br>• Nut<br>• Bolt<br>• Network cable Jack<br>• Coat button<br>• Spoon | CO1 | 25 | 55 | 20 |
| *LSO 2.1.* Prepare digital models of complex 3D entities and assemblies. | Develop digital models of following assemblies using any CAD software:<br>• Connecting Rod<br>• Piston<br>• Electric switch<br>• Bathroom Tap<br>• Mouse | CO1 | 35 | 45 | 20 |
| *LSO 3.1* Surf web for downloading readymade free CAD models.<br>*LSO 3.2* Convert one CAD file format into another. | Download three digital CAD models freely available on web in different formats and then convert them into .stl/obj format. | CO1 | 25 | 55 | 20 |
| *LSO 4.1* Use the given Slicing software for 3D Printing.<br>*LSO 4.2* Perform slicing operation on the given digital model. | Perform slicing operation on one digital model available under each Pr. No.1, 2 and 3. | CO1 | 25 | 55 | 20 |
| *LSO5.1* Use the available 3D printing software. | Analyse the effect of different process parameters, | CO1, CO3 | 25 | 55 | 20 |

| Practical/Lab Session Outcomes (LSOs) | Laboratory Experiment/ Practical Titles | Relevant COs Number (s) | PLA/ELA (%) | | |
|---|---|---|---|---|---|
| | | | Performance | | Viva-Voce |
| | | | Process Assessment | Product Assessment | |
| *LSO5.2* Selection of 3D printing process and performance parameters. | materials on printing time, material required, surface finish, etc. through simulation using 3D printing software on sliced models available from Pr. No. 4 | | | | |
| *LSO 6.1* Produce single plastic components using available 3D printer.<br>*LSO 6.2* Perform post processing operations on printed component. | Print one single component on available FDM based 3D printer with PLA/ABS material | CO1, CO2, CO3 | 25 | 55 | 20 |
| *LSO 7.1* Select appropriate layer thickness, tolerance, fit.<br>*LSO 7.2* Produce an assembly of plastic components using available 3D printer. | Print one assembly on available FDM based 3D printer with PLA/ABS material | CO1,CO2, CO3 | 25 | 55 | 20 |
| *LSO 8.1* Choose suitable material for printing flexible structure (assembly of same small pieces to give flexible fabric effect).<br>*LSO 8.2* Choose suitable design/shape to create a flexible type structure.<br>*LSO 8.3* Produce flexible plastic structure using available 3D printer. | Model and print a flexible fabric structure with PLA/ABS material (assembly of same small pieces to give flexible fabric effect) | CO1, CO2, CO3 | 35 | 45 | 20 |

| **Practical/Lab Session Outcomes (LSOs)** | **Laboratory Experiment/ Practical Titles** | **Relevant COs Number (s)** | **PLA/ELA (%)** | | |
|---|---|---|---|---|---|
| | | | **Performance** | | **Viva-Voce** |
| | | | **Process Assessment** | **Product Assessment** | |
| *LSO 9.1.* Selection of 3D printing process parameters. | Change printing process parameters and repeat experiment number 6. | CO1, CO2, CO3 | 35 | 45 | 20 |
| *LSO 10.1* Use of available 3D scanner.<br>*LSO 10.2* Develop 3D digital model using scanning approach.<br>*LSO 10.3* Modeling of complex 3D objects using 3D scanning. | Scan the given complex component using available 3D Scanner. | CO1 | 35 | 45 | 20 |
| *LSO 11.1* Produce a complex plastic structure using available 3D printer and scanner.<br>*LSO 11.2* Apply Reverse Engineering approach to exactly 3D print an existing real object. | Print the 3D scanned digital model of Pr. No. 10 on available FDM based 3D printer with PLA/ABS material | CO1, CO3 | 25 | 55 | 20 |
| *LSO 12.1.* Use the available 3D printing software.<br>*LSO 12.2.* Select printing process parameters based on the type/make of Printer and raw material<br>*LSO 12.3.* Set printing process parameters.<br>*LSO 12.4.* Produce a complex component | Develop the assigned digital complex component using SLA based 3D Printer and available material. | CO1, CO4 | 35 | 45 | 20 |

| **Practical/Lab Session Outcomes (LSOs)** | **Laboratory Experiment/ Practical Titles** | **Relevant COs Number (s)** | **PLA/ELA (%)** | | |
|---|---|---|---|---|---|
| | | | **Performance** | | **Viva-Voce** |
| | | | **Process Assess-ment** | **Product Assess-ment** | |
| using available SLA Printer.<br>*LSO 12.5.* Perform curing of the SLA based 3D printed component. | | | | | |
| *LSO 13.1.* Use the available 3D printing software.<br>*LSO 13.2.* Select printing process parameters based on the type/make of Printer and raw material<br>*LSO 13.3.* Set printing process parameters.<br>*LSO 13.4.* Produce a complex component using available SLS Printer. | Develop the assigned digital complex component using SLS based 3D Printer and available material. | CO1, CO5 | 35 | 45 | 20 |
| *LSO 14.1.* Use the available 3D printing software.<br>*LSO 14.2.* Select printing process parameters based on the type/make of Printer and raw material<br>*LSO 14.3.* Set printing process parameters.<br>*LSO 14.4.* Produce a complex component using available FDM, SLA and SLS Printer. | Develop same digital single complex component using FDM, SLA and SLS based 3D Printers and compare the printed components on the basis of Cost, Time, Surface finish and Strength. | CO1, CO2, CO3, CO4, CO5 | 35 | 45 | 20 |

| **Practical/Lab Session Outcomes (LSOs)** | **Laboratory Experiment/ Practical Titles** | **Relevant COs Number (s)** | **PLA/ELA (%)** | | |
|---|---|---|---|---|---|
| | | | **Performance** | | **Viva-Voce** |
| | | | **Process Assess-ment** | **Product Assess-ment** | |
| *LSO 14.5.* Perform Cost, Time, Surface finish and Strength estimations related to 3D printed components. | | | | | |
| *LSO 15.1.* Use the available 3D printing software.<br>*LSO 15.2.* Select printing process parameters based on the type/make of Printer and raw material<br>*LSO 15.3.* Select appropriatetolerance, fit and printing process parameters.<br>*LSO 15.4.* Produce an assembly using available SLA/SLS Printer. | Print one digital assembly on SLA/SLS based 3D Printer. | CO1, CO4, CO5 | 35 | 45 | 20 |
| *LSO 16.1.* Identify tools/devices/chemicals for post processing<br>*LSO 16.2.* Perform post processing operations on printed component. | Apply post processing techniques on the 3D printed component of experiment number 6 to 8. | CO6 | 35 | 45 | 20 |
| *LSO 17.1.* Identify tools/devices/techniques for inspection and testing. | Check the soundness of the 3D printed component of experiment number 6 to 8 | CO6 | 35 | 45 | 20 |

| Practical/Lab Session Outcomes (LSOs) | Laboratory Experiment/ Practical Titles | Relevant COs Number (s) | PLA/ELA (%) | | |
|---|---|---|---|---|---|
| | | | **Performance** | | **Viva-Voce** |
| | | | **Process Assessment** | **Product Assessment** | |
| *LSO 17.2.* Identify the defects in 3D printed components<br>*LSO 17.3.* Apply remedial measures to bring soundness in the defective 3D printed component. | using available devices/techniques. | | | | |

**Legend:**

PRA*: Process Assessment

PDA**: Product Assessment

**Note:** This table can be used for both end semester as well as progressive assessment of practical.Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

**K) Suggested Term Work and Self Learning:** Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. **Assignments**: Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- Prepare a comparative study of additive manufacturing and conventional manufacturing processes in terms of material utilization, design flexibility, production time, cost, and typical applications.
- Draw a classification chart of major 3D printing processes and explain the working principles of FDM, SLA, SLS, Binder Jetting, Material Jetting, Direct Energy Deposition, and Laminated Object Manufacturing.
- Select any three industries (e.g., aerospace, healthcare, automotive) and describe specific applications of additive manufacturing in those sectors.
- Identify design considerations for developing a product suitable for 3D printing. Illustrate your answer with examples of design modifications required for additive manufacturing.
- Explain the steps involved in reverse engineering of a mechanical component for 3D printing, including scanning, CAD modeling, STL generation, and printing.
- Compare different CAD file formats used in 3D printing such as STL, OBJ, AMF, and 3MF in terms of data structure, advantages, and limitations.
- Draw and explain the complete process chain involved in additive manufacturing starting from CAD model creation to final post-processing and inspection.

- Explain the STL file format and its specifications. Discuss common STL file errors and methods used to repair STL files using suitable software tools.
- Analyze how part orientation affects printing time, material usage, surface finish, and mechanical strength. Illustrate the role of support structures in additive manufacturing.
- Describe the process of slicing a 3D model for printing. Explain direct slicing and adaptive slicing techniques with neat diagrams.
- Prepare a classification of materials used in additive manufacturing such as polymers, metals, ceramics, and composites. Discuss their properties and typical applications.
- Select a product (e.g., drone component, medical implant, mechanical gear) and recommend suitable 3D printing materials based on performance requirements.
- Draw a labeled diagram of an FDM 3D printer and explain the working principle including liquefaction, deposition, solidification, and bonding.
- Explain the working principles of SLS, Binder Jetting, and Electron Beam Melting. Discuss the role of powder properties and process parameters.
- Explain the need for post-processing in 3D printed components. Describe different post-processing techniques and methods of inspection used to detect defects.

### b. Micro Projects:

- Perform 3D printing of plastic casing of inhaler used by Asthma patients and estimate the cost.
- Download 5 videos on 3D printing of different components, watch them and write a report to detail out the steps involved, 3D Printer used, 3D Printing software used, material used, complexity involved, printing time, post processing steps used.
- Print two pieces of same components using ABS and PLA and compare their strength, surface roughness, weight, cost.
- Download two 3D printing free software and try to check their compatibility with your lab printer.
- Prepare a list of solid, liquid and powder form 3D printing raw materials stating their cost, colour opacity, flexibility and weight per unit volume.
- Download 5 videos of 3D printing of different components using FDM, SLA and SLS each. Watch them and write a report to detail out the steps involved, 3D Printer used, 3D Printing software used, material used, complexity involved, printing time, post processing steps used.
- Prepare a report on post processing steps and techniques used for 3D printed components using FDM, SLA, SLS.
- Prepare a report to compare FDM, SLA, SLS based 3D printing process on the basis of cost, surface finish, printer setting time, printing time and post processing time and cost involved.
- Download 5 videos of 3D printing processes other than FDM, SLA and SLS. Watch them and write a report to detail out the steps involved, 3D Printer used, 3D Printing software used, material used, complexity involved, printing time, post processing steps used.

### c. Complex Engineering Problems

- An aerospace company intends to manufacture a lightweight structural bracket with complex internal channels for cooling. Analyze and compare additive manufacturing processes such as FDM, SLA, SLS, and Direct Energy Deposition to recommend the most suitable process. Justify the selection considering material properties, dimensional accuracy, mechanical strength, cost, and production time.

- A CAD model of a mechanical component contains surface discontinuities and non-manifold edges after conversion into an STL file. Develop a systematic approach to identify, repair, and optimize the STL file using appropriate software tools. Discuss the impact of STL resolution and triangulation on print quality and file size.
- A biomedical startup plans to manufacture customized orthopedic implants using additive manufacturing. Evaluate different 3D printing materials such as polymers, metals, and ceramics and recommend a suitable material and printing process considering biocompatibility, strength, sterilization requirements, and manufacturing feasibility.
- A complex mechanical component must be printed using an FDM 3D printer. Determine the optimal part orientation and support structure strategy to minimize material consumption, reduce printing time, and improve surface finish. Explain the factors influencing part orientation and support generation.
- A worn-out mechanical component without design documentation must be reproduced using 3D printing. Propose a complete workflow involving 3D scanning, CAD reconstruction, STL generation, slicing, and printing. Discuss possible sources of errors during reverse engineering and methods to minimize them.
- A product designer wants to fabricate a component with varying geometrical complexity using SLA technology. Develop a slicing strategy using adaptive layer thickness to ensure high surface accuracy in critical regions while reducing overall printing time. Explain how peak feature identification influences slicing decisions.
- A manufacturer plans to produce functional polymer gears using the Selective Laser Sintering process. Analyze how powder properties, laser power, scan speed, and layer thickness influence the mechanical properties and dimensional accuracy of the printed gears. Recommend suitable parameter settings.
- A company must decide whether to manufacture a customized mechanical part using FDM, SLA, or SLS technology. Develop a cost estimation model considering material cost, machine operation cost, energy consumption, build time, and post-processing requirements, and recommend the most economical manufacturing option.
- A prototype manufactured using FDM exhibits visible layer lines and surface roughness that are unsuitable for product demonstration. Design a post-processing plan involving sanding, vapor smoothing, coating, and painting to achieve a high-quality aesthetic finish while maintaining dimensional accuracy.
- During production of components using powder-based 3D printing, defects such as porosity, warping, and incomplete fusion are observed. Analyze the possible causes of these defects in terms of material characteristics, process parameters, and environmental conditions. Propose corrective measures and quality inspection methods to ensure reliable production.

**d. Other Activities:**

1. Seminar Topics:

- Commercially available 3D printers and software.

- Strength of 3D printed Plastic components as compared to Die cast Plastic components.
- Properties of PLA and ABS 3D printing materials.
- Reverse engineering application of 3D Printing.
- Newer 3D printing raw materials
- Direct energy 3D printing process
- Material jetting 3D printing process
- Micro 3D printing process
- Metal and Ceramic 3D printing
- 3D printing of Jewelry
- 3D printing of Bio implants
- Printing of flexible plastic components

2. Visits:

- Visit nearby tool room/industry with 3D Printing facilities. Prepare report of visit with special comments of 3D printing technique used, material used, single component/batch production/mass production and cost of printed component.

3. Self-learning topics:

- 3D printing of flexible plastic components.
- 3D printing of micro/mini components.
- Conversion of CAD file formats into IGES.
- 3D scanning process.
- 3D printing of transparent, soft and flexible plastic components
- 3D printing of metal components
- 3D printing of ceramic components
- 3D scanning process.
- Chemical post processing techniques

L) **Suggested Course Evaluation Matrix:** The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate CO attainment.

<table>
<tr><th rowspan="4">COs</th><th colspan="7">Course Evaluation Matrix</th></tr>
<tr><th colspan="2">Theory Assessment (TA)**</th><th colspan="3">Term Work Assessment (TWA)</th><th colspan="2">Lab Assessment (LA)#</th></tr>
<tr><th rowspan="2">Progressive Theory Assessment (PTA)</th><th rowspan="2">End Theory Assessment (ETA)</th><th colspan="3">Term Work& Self Learning Assessment</th><th rowspan="2">Progressive Lab Assessment (PLA)</th><th rowspan="2">End Laboratory Assessment (ELA)</th></tr>
<tr><th>Assignments</th><th>Micro Projects</th><th>Other Activities*</th></tr>
</table>

| | **Class/Mid Sem Test** | | | | | | |
|---|---|---|---|---|---|---|---|
| **CO-1** | 20% | 20% | 20% | 20% | 20% | 20% | 20% |
| **CO-2** | 15% | 15% | 15% | 20% | 20% | 25% | 20% |
| **CO-3** | 15% | 15% | 15% | 20% | 20% | 25% | 20% |
| **CO-4** | 15% | 15% | 15% | 20% | 20% | 20% | 20% |
| **CO-5** | 15% | 15% | 15% | 20% | 20% | 10% | 20% |
| **CO-6** | 20% | 20% | 20% | - | - | - | - |
| **Total Marks** | **30** | **70** | **20** | **20** | **10** | **20** | **30** |
| | | | **50** | | | | |

**Legend:**

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

**: Mentioned under point- (N)

#: Mentioned under point-(O)

**Note:**

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

**M) Suggested Specification Table for End Semester Theory Assessment:** Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

| **Unit Number and Title** | **Relevant COs Number(s)** | **Total Classroom Instruction (CI) Hours (15 Weeks/Sem)** | **Total Marks** | **ETA (Marks)** | |
|---|---|---|---|---|---|
| | | | | **Taxonomy Levels of Cognitive Domain** | |
| | | | | **Remember & Understand** | **Apply, Analyse, Evaluate &Create** |
| 1. Additive Manufacturing Introduction and CAD-CAM for 3D Printing | CO1 | 10 | 10 | 03 | 07 |
| 2. 3D Printing Materials | CO1, CO2 | 06 | 06 | 03 | 03 |
| 3. Solid based 3D Printing Processes | CO1, CO3 | 07 | 10 | 03 | 07 |
| 4. Liquid based 3D Printing Processes | CO4 | 07 | 09 | 03 | 06 |

| | | | | | |
|---|---|---|---|---|---|
| 5. Powder based 3D Printing Processes | CO5 | 07 | 09 | 03 | 06 |
| 6. Post Processing and Quality | CO6 | 08 | 06 | 03 | 03 |
| **Total** | | **45** | **50** | **18** | **32** |

**Note:** Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

**N) Suggested Instructional/Implementation Strategies:** Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology(ICT) Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

**O) List of Major Laboratory Equipment, Tools and Software:**

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/Practical Number |
|---|---|---|---|
| 1. | High end computers | Processor Intel Core i9 with Open GL Graphics Card, RAM 32 GB, DDR3/DDR4, HDD 500 GB, Graphics Card NVIDIA OpenGL 4 GB, OS Windows 10 | All |
| 2. | Parametric Computer Aided Design software | CATIA/Solid works/NX/Creo/etc. | 1,2,3,10,11 |
| 3. | FDM based 3D printer | Fused Deposition Modelling system with complete accessories; Build Volume-300 x 300 x 300mm or Higher; Layer Thickness-0.1 – 0.4/etc. | 1,4,5,6,7,8,9,10,11,14 |
| 4. | SLA based 3D printer | Printing Technology: SLA, 145 x 145 x 175mm build volume, Common layer thickness 25–100 µm, Dimensional Accuracy ± 0.5% (lower limit: ±0.10 mm), cure time of only 1-3s per layer, Material type: UV-sensitive liquid resin, Curing unit. | 12,14 |
| 5. | SLS based 3D printer | Printing Technology: SLS., Build Volume: 130 x 130 x 180 mm, Recommended min. wall thickness: 0.8 mm, Powder Diameter: 60 Microns, Material Type: Nylon, TPU, Light Source: Laser Diode | 13,14 |

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/Practical Number |
|---|---|---|---|
| 6. | 3D Printing Material | ABS/PLA, Resin based Photosensitive material, Polymer/metal/ceramic powder/etc. | 6 to 15 (except 10) |
| 7. | 3D Printing software | Latest version of software like: Cura/PrusaSlicer/ideaMaker/Meshmixer/MeshLab | 4 to 15 |
| 8. | 3D Scanner and Processing software | Handheld 3D scanner, Accuracy up to 0.1 mm, Resolution up to 0.2 mm, Real time onscreen 3D model projection and processing, Wireless technology with an inbuilt touch screen and battery, Extended field of view for capturing both large and small objects, Processing Software/etc. | 10 |
| 9. | Post processing equipments and tools | Deburring tools (tool handle & deburring blades), Electronic Digital Caliper, Cleaning Needles, Art knife set, Long nose pliers, Flush cutters, Wire brush, Nozzle cleaning kit, Tube cutter, Print removal spatula, Needle file, Cutting mat, Glue stick, Wire stripper, Chemicals, Etching agents etc. | 6,7,8,16,17 |
| 10. | Inspection and Testing devices | • Visual inspection,<br>Devices related to:<br>• Scanning electron microscopy (SEM), CT system, X-ray,<br>• Penetration testing,<br>• Infrared thermography,<br>• Leak or pressure testing for complex structures,<br>• Eddy current,<br>• Mechanical property inspection to measure tensile, yield, shear, fatigue, hardness, density, impact strenght<br>• Metallography (Microstructure testing) | 6,7,8,16,17 |

**P) Suggested Learning Resources:**

**a. Books:**

| S. N. | Titles | Author(s) | Publisher and Edition withISBN |
|---|---|---|---|
| 1. | Fundamentals and Applications of Additive Manufacturing, | Sharad K. Pradhan, Ankit Nayak, Surendra Singh Thakur, Vishal Francis, Aniket Nagargoje | CRC Press, Taylor & Francis, ISBN 9781032898049 |

| S. N. | Titles | Author(s) | Publisher and Edition withISBN |
|---|---|---|---|
| 2. | Understanding Additive Manufacturing: Rapid Prototyping, Rapid Tooling, Rapid Manufacturing | Andreas Gebhardt, | Hanser Publisher, 2011<br>ISBN: 156990507X, 9781569905074 |
| 3. | 3D Printing and Design | SabrieSoloman | Khanna Publishing House, Delhi<br>ISBN: 9789386173768 |
| 4. | 3D Printing and Rapid Prototyping- Principles and Applications | C.K. Chua, Kah Fai Leong | World Scientific, 2017<br>ISBN: 9789813146754 |
| 5. | Getting Started with 3D Printing: A Hands-on Guide to the Hardware, Software, and Services Behind the New Manufacturing Revolution | Liza Wallach Kloski, Nick Kloski | Make Community, LLC; 2nd edition, 2021<br>ISBN: 9781680450200 |

**b. Online Educational Resources:**

- https://onlinecourses.swayam2.ac.in/ntr25_ed66/preview
- https://onlinecourses.nptel.ac.in/noc21_me115/preview
- https://archive.nptel.ac.in/courses/112/104/112104265/
- https://www.youtube.com/watch?v=b2Od4YHcLAQ
- https://www.youtube.com/watch?v=EF8CNR-gcXo
- https://www.academia.edu/41439870/Education_Resources_for_3D_Printing
- https://www.think3d.in/landing-pages/beginners-guide-to-3d-printing.pdf
- https://all3dp.com/1/types-of-3d-printers-3d-printing-technology/
- https://bigrep.com/post-processing/
- https://www.mdpi.com/2227-7080/9/3/61
- https://all3dp.com/2/best-3d-printing-books/
- https://www.youtube.com/watch?v=TQY2lF-sFaI
- https://www.youtube.com/watch?v=Oz0PoS5LPxg
- https://www.youtube.com/watch?v=6ejjh0GdyDc

**Note:** Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational recourses before use by the students.

**c. Others:**

- 3D Printing Projects DK Children; Illustrated edition, 2017
- The 3D Printing Handbook: Technologies, design and applications Ben Redwood, Filemon Schöffer, Brian Garret, 3D Hubs; 1st edition, 2017

- 3D Printer Users’ Guide
- 3D Printer Material Handbook
- Lab Manuals
- Users’ Guide
- Manufacturers’ Manual
- Manufacturers’ Catalog
- Learning Packages

## 5. Conclusion

This study presents a **case-based, design-oriented investigation** into the development and implementation of an Outcome-Based Curriculum (OBC) framework aligned with the transformative vision of the National Education Policy 2020 for technical education. The primary aim of the research to translate policy directives and outcome-based education (OBE) principles into a **structured, implementable, and skill-oriented curriculum model at the course level** has been effectively achieved through a systematic and multi-layered methodological approach.

The findings demonstrate that curriculum design in contemporary technical education must be conceptualized as a **complex, adaptive system**, wherein learning outcomes, pedagogy, assessment strategies, and skill requirements interact dynamically rather than linearly. By integrating **Program Educational Objectives (PEOs), Program Outcomes (POs), Programme Specific Outcomes (PSOs), Course Outcomes (COs), and Session Outcomes (SOs)** into a cohesive and hierarchical structure, the proposed framework establishes **constructive alignment across multiple levels of curriculum design.** This alignment ensures not only the attainment of measurable learning outcomes but also the development of **higher-order cognitive, psychomotor, and professional competencies.**

A significant contribution of the study lies in embedding **experiential and workflow-based learning components** including micro-projects, seminar engagements, complex engineering problems, assignments, and laboratory activities within the core curriculum structure. These components transform the learning environment from a **content-driven model to a competency-driven ecosystem**, enabling students to engage in**iterative problem-solving, design thinking, and real-world application of knowledge**. As a result, the framework directly addresses the growing demand for **industry-relevant skills**, such as critical thinking, digital proficiency, innovation, and interdisciplinary collaboration.

The research methodology, comprising **policy review, stakeholder consultation, curriculum mapping, pilot implementation, and feedback-driven validation,** provides a **robust mechanism for bridging the gap between theoretical constructs and practical implementation.** The incorporation of stakeholder perspectives ensures that the framework is grounded in **both academic rigor and industry expectations**, while the pilot implementation demonstrates its **feasibility, adaptability, and contextual relevance**. Although the study adopts a qualitative and design-based approach, the iterative validation process provides sufficient evidence of the framework’s **effectiveness in enhancing outcome alignment and promoting active, learner-centered engagement.**

The study further establishes that alignment with accreditation standards of the National Board of Accreditation and guidelines issued by the All India Council for Technical Education significantly enhances the **credibility, standardization, and global comparability** of engineering education programs. At the same time, the structured documentation of curriculum components, outcome mappings, and assessment strategies offers a**replicable and scalable model,** enabling institutions to operationalize NEP 2020 principles across diverse engineering disciplines.

From a complexity perspective, the proposed framework advances existing curriculum models by incorporating **feedback loops, iterative refinement mechanisms, and flexible learning pathways,** thereby transforming curriculum design into a **dynamic and evolving process.** It acknowledges that educational systems are influenced by multiple interacting variables, including policy mandates, technological advancements, institutional capabilities, and learner diversity, and therefore requires **adaptive and resilient design strategies**.

In conclusion, the proposed OBC framework provides a **practical, scalable, and future-ready pathway** for translating policy aspirations into effective classroom practices, thereby addressing the long-standing disconnect between **curriculum design, skill development, and learning outcomes.** It repositions technical education as a **competency-driven, technology-enabled, and innovation-oriented ecosystem**, capable of preparing graduates for the complex and rapidly evolving demands of modern engineering practice.

Future research may extend this work by conducting **large-scale empirical studies across institutions and disciplines** to quantitatively evaluate the impact of outcome-based curricula on student performance, employability, and innovation capacity. Additionally, the integration of **emerging technologies such as digital twins, artificial intelligence, and advanced manufacturing systems** within outcome-based frameworks presents a promising direction for enhancing the **adaptability and global competitiveness** of technical education. Such efforts will further contribute to the realization of a**responsive, skill-oriented, and globally aligned higher education ecosystem**, in line with the transformative vision of NEP 2020.

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