

Bridging the Gap Between Product Development and Entrepreneurship in Engineering Curriculum: A Framework-Based Approach Aligned with NEP 2020

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Abstract

Despite advancements in technical education, Indian engineering graduates frequently enter the workforce lacking critical competencies in product development (PD) and entrepreneurship. This imbalance has drawn scrutiny from industry and policymakers alike, with national directives such as the National Education Policy (NEP 2020) emphasizing a shift toward “experiential, holistic, integrated and inquiry-driven” learning models. Similarly, the All-India Council for Technical Education (AICTE) has embedded innovation labs, internship mandates and entrepreneurship courses into its revised model curriculum to cultivate job creators, not just job seekers. However, implementation remains fragmented across institutions. To address this, disconnect, this paper proposes a structured curricular framework that integrates PD and entrepreneurship (PD&E) across all four years of undergraduate engineering education. The proposed framework comprises five iterative stages: Discover, Define, Develop, Launch and Ecosystem. It offers a scalable pathway to embed innovation through coursework, studio-based activities and incubation linkages. A hypothetical case scenario involving an IoT-based “Smart Purifier” is utilized to illustrate the framework’s applicability. The model simultaneously addresses known skill gaps in communication, prototyping, intellectual property (IP) literacy and business modelling. Supported by policy mechanisms such as the National Innovation and Startup Policy (NISP) and the Institutional Innovation Council (IIC) network, this integrative approach seeks to align academic programs with the entrepreneurial and innovation imperatives of India’s evolving knowledge economy.

Keywords: Product development, entrepreneurship, curricular framework, NEP 2020, higher education, technical education

INTRODUCTION

The landscape of engineering education is undergoing a transformative shift, shaped by the increasing demand for graduates equipped not only with technical proficiency but also with innovation-driven and entrepreneurial capabilities. In knowledge-based economies, engineers are expected to transcend their traditional roles as technical problem solvers and evolve into product innovators and venture enablers [1]. This transition necessitates an education system that fosters critical thinking, design fluency and commercialization literacy at every stage of the academic journey.

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India’s National Education Policy [2] (NEP 2020) provides a compelling directive for such transformation. The policy outlines a future-ready curriculum that is “experiential, holistic, integrated,

inquiry-driven” and strongly aligned with twenty-first-century competencies. Among its recommendations is the cultivation of creativity and entrepreneurship through project-based pedagogy, institutional flexibility and closer industry-academic cooperation. The emphasis on “vocational exposure” and “entrepreneurship education” as part of undergraduate technical programs reflects the urgent need to embed product development and entrepreneurial orientation into mainstream engineering curricula.

Complementing this vision, the All India Council for Technical Education (AICTE) has issued revised model curricula that reinforce the NEP directives. These include mandatory internships, the establishment of Innovation and Design Centers (IDEA Labs) and elective courses on entrepreneurship and intellectual property rights [3]. AICTE explicitly states that such measures are intended to create “job creators” by enabling students to undertake industry-relevant projects and innovation exercises during their studies.

Institutional frameworks have also evolved to support this policy environment. The Ministry of Education’s Innovation Cell launched the Institutes’ Innovation Council (IIC) network in 2018, covering over 2700 higher education institutions across India. These councils are tasked with fostering innovation culture on campus by conducting hackathons, incubation drives and startup mentorship programs [4]. Additionally, the National Innovation and Startup Policy (NISIP[5] 2019) mandates each higher education institution to develop its own policy guidelines for nurturing entrepreneurship among students and faculty [5].

Despite this ecosystem-level support, ground-level implementation of integrated product development and entrepreneurship (PD&E) remains inconsistent. Many engineering programs retain siloed structures where innovation is addressed episodically through isolated electives or co-curricular events rather than holistically embedded in the curriculum. Hands-on exposure to the complete lifecycle of product innovation, from ideation to commercialization, is rare in structured academic settings. Consequently, students often graduate with limited understanding of real-world product deployment, startup ecosystems or commercialization pathways.

To address this disconnect, the present study introduces a scaffolded framework that integrates PD&E learning objectives throughout all four years of undergraduate engineering education. The model seeks to establish curricular continuity, where students gradually progress from creativity and empathy in the early semesters to business modelling and venture incubation by the final year. The framework is aligned with NEP and AICTE goals and is intended to serve as a blueprint for institutions seeking to enhance their innovation capacity and entrepreneurial outputs. A hypothetical product development scenario is used later in the paper to demonstrate the operationalization of the framework within an academic setting.

METHODOLOGICAL APPROACH (CONCEPTUAL SYNTHESIS)

“This paper is a conceptual framework study. The PD&E model was derived through a structured synthesis of

- (a). National policy intent and ecosystem mechanisms that emphasize experiential learning and innovation culture, and
- (b). Established engineering education frameworks that support staged skill development.

First, policy directions that stress experiential, inquiry-driven learning and the need for creativity and innovation in education were reviewed. Second, entrepreneurship and innovation policy guidance that recommends institutional mechanisms for startup and IP support, student credit options, and structured mentoring was examined. Third, synthesized learning design ideas from outcome-based education and Bloom’s revised taxonomy to ensure outcome progression were carried out. Also, the model to international PD/innovation education structures such as design thinking tools, the CDIO syllabus (including its 2022 updates), and interdisciplinary product development practice (IPD) was mapped.

Finally, this synthesis was converted into a four-year scaffold and stage-wise activity blueprint. The framework is validated in this manuscript through cross-alignment with these sources and internal consistency across stages; the paper does not report field implementation or pilot outcome data.

LITERATURE REVIEW

A substantial body of educational research underscores the need to align engineering curricula with experiential, innovation-focused and entrepreneurship-enabling pedagogies. Traditional models, which prioritize technical theory and rote learning, have been shown to inadequately prepare students for complex, real-world problem-solving and value creation tasks. The shift toward project-based and outcome-driven education is reflected in global academic practices and is strongly echoed in Indian policy frameworks such as the National Education Policy[2] (NEP 2020) .

One of the foundational paradigms shaping this transition is Outcome-Based Education (OBE). OBE emphasizes aligning instructional design, learning activities and assessment mechanisms with clearly defined learning outcomes. These outcomes include not only cognitive objectives but also affective and psychomotor competencies such as creativity, teamwork and ethical reasoning. Brindha[6] (2020) emphasizes that OBE is particularly effective when integrated with Bloom's Revised Taxonomy, allowing for the structured progression from foundational knowledge to higher-order skills like design, evaluation and innovation . This theoretical orientation has informed numerous curricular reforms aiming to foster not just subject mastery, but employability and entrepreneurial readiness.

Design thinking frameworks have emerged as effective pedagogical tools for inculcating innovation and user-centred problem-solving in engineering students. The Stanford design school model comprising stages such as Empathize, Define, Ideate, Prototype and Test, encourages iterative development and responsiveness to stakeholder needs Design thinking resources also support embedding these methods in engineering learning activities [7]. Design thinking also aligns with the NEP's vision of inquiry-based learning, wherein students are challenged to identify real-world problems and co-create solutions with societal relevance .

Entrepreneurship education (EE) is a closely related pedagogical domain that extends design thinking into the domain of venture creation. Scholars distinguish between entrepreneurship education focused on venture creation and entrepreneurial mindset education, which cultivates skills such as opportunity recognition, adaptability and risk management. Sababha et al.[8] (2020) report that mandatory entrepreneurship workshops within engineering curricula significantly improve students' entrepreneurial attitudes and intentions . The use of tools like the Business Model Canvas (BMC) and Minimum Viable Product (MVP) development further reinforces learning by connecting abstract theory with market-driven decision-making.

Interdisciplinary programs exemplify the operationalization of these theories. For example, the Integrated Product Development (IPD) course at the University of Michigan's Tauber Institute combines students from engineering, business and design to co-develop new products [9]. This model allows for collaborative ideation, cross-functional teamwork and exposure to product lifecycle dynamics. Similarly, the CDIO (Conceive–Design–Implement–Operate) framework emphasizes a systems-level approach to engineering education. It integrates technical proficiency with business and operational competencies, recognizing that engineering innovation rarely occurs in isolation [10].

In India, multiple initiatives aim to localize these global models. The Institutes' Innovation Council (IIC) manual explicitly encourages higher education institutions to organize project-based competitions, faculty innovation workshops and student startup bootcamps. The National Innovation and Startup Policy (NISIP) further mandates institutions to support IP generation, incubation and startup acceleration . However, despite these frameworks and tools, adoption often remains fragmented. Without a coherent curricular integration plan, the impact of these initiatives is limited.

Therefore, while the theoretical and institutional foundations for PD&E integration are strong, their translation into curriculum and pedagogy needs deliberate scaffolding. The subsequent sections of this paper build upon these insights to propose a structured PD&E framework that is contextually grounded, policy-aligned and educationally rigorous.

SKILL GAPS IN INDIAN ENGINEERING GRADUATES

Despite possessing a robust technical foundation, Indian engineering graduates frequently exhibit critical deficiencies in applied and entrepreneurial skill domains. A recurring concern highlighted by both employers and policymakers is the persistent gap between what is taught in engineering institutions and the competencies required by modern industry. This misalignment is especially evident in areas such as communication, prototyping, intellectual property (IP) awareness and market readiness. All of these are essential for successful product development and entrepreneurship.

Global employability and future-of-work reports highlight gaps in higher-order skills such as problem-solving, innovation, and adaptability. This shortfall is attributed to the limited focus on experiential learning and minimal exposure to real-world problem-solving scenarios during the course of their education. These findings are echoed in India's National Education Policy [2] (NEP 2020), which emphasizes the need for "critical thinking and creativity" and advocates for hands-on, inquiry-based pedagogies.

One of the most cited gaps pertains to communication skills. A study by Babu et al. [11] (2023) indicates that approximately 78% of engineering graduates lack proficient communication skills, significantly affecting their employability. In the context of product development and entrepreneurship, this deficiency can hinder cross-functional collaboration, client interaction and investor engagement activities that are critical in turning technical solutions into viable ventures.

Prototyping experience is another area where graduates are underprepared. Many engineering programs emphasize theoretical design and simulation over iterative physical prototyping. This results in students being unfamiliar with fabrication tools, user testing procedures and feedback integration processes. Reagle et al. [12] (2017) note that when students are not required to produce functioning prototypes, promising ideas often remain undeveloped.

This phenomenon is described as the "Valley of Death" in product innovation. The GEM India Report highlights this capability gap, noting that many young individuals express entrepreneurial intent but lack the skills and institutional support to launch successful ventures [13]. This disconnect restricts students from experiencing the complete product lifecycle and learning how to respond to user needs dynamically.

Intellectual property (IP) awareness and legal literacy are also notably low among engineering graduates. Despite increasing national emphasis on IP generation and protection; as evidenced by initiatives such as the National Innovation and Startup Policy (NISP [5]2019), few undergraduate programs incorporate structured learning on patents, copyrights or technology transfer mechanisms [5]. As a result, students are often unable to safeguard or commercialize their innovations effectively, leaving them vulnerable to idea theft or regulatory challenges.

Further, there is a significant lack of exposure to market validation and business modeling. While students may undertake mini-projects, they are rarely guided to conduct market surveys, analyze user segments or assess financial feasibility. The absence of such business-context learning leads to solutions that are technically sound but commercially unviable. Sababha et al. [8](2020) argue that embedding entrepreneurship modules within core curricula significantly enhances entrepreneurial intent and bridges the awareness gap in these domains.

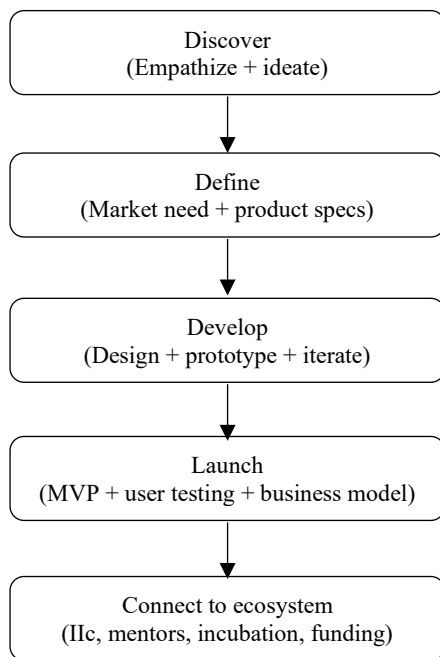


Figure 1. A five-stage PD&E framework integrating design thinking and entrepreneurship into engineering education.

Collectively, these skill gaps highlight the limitations of current engineering curricula in fostering job creators and product innovators. They reinforce the necessity of curricular reform that integrates PD&E components as fundamental, rather than peripheral, aspects of engineering education. Addressing these gaps demands a structured framework that scaffolds innovation, design and entrepreneurship skills across all stages of undergraduate learning. The same framework is discussed in detail in the following section.

PROPOSED PD&E INTEGRATED FRAMEWORK

To address the systemic gaps in communication, prototyping, intellectual property awareness and commercialization readiness among engineering graduates, a structured and integrative framework for embedding

Product Development and Entrepreneurship (PD&E) across the curriculum is essential. Drawing inspiration from established models such as the Stanford Design Thinking process, the CDIO (Conceive–Design–Implement–Operate) initiative and interdisciplinary programs like the Integrated Product Development (IPD) course at the University of Michigan, this section proposes a five-stage framework tailored to the Indian engineering education context. Each stage is aligned with NEP 2020’s call for experiential, inquiry-based learning and AICTE’s emphasis on innovation and startup orientation in undergraduate programs (Figure-1).

To give an overview of the proposed PD&E integration logic, Figure 1 presents the five-stage framework from early problem discovery to ecosystem linkage.

Stage 1: Discover

The Discover phase emphasizes understanding user needs, contextual challenges and unmet demands through methods such as user interviews, ethnographic observations and field immersion. This stage corresponds to the “Empathize” phase in design thinking and the “Conceive” component of CDIO. Students are encouraged to identify problems grounded in real-world contexts such as environmental challenges, local community needs or industry pain points. Activities may include brainstorming sessions, problem-framing exercises and issue trees.

Stage 2: Define

In this stage, students translate user insights into actionable product requirements, user personas and value propositions. The Define phase helps narrow the scope of the project and ensures alignment with actual needs. Students formulate a clear problem statement and identify potential stakeholders, use cases and functional objectives. This phase ensures that development efforts are not solution-driven in isolation but rather need-driven with measurable outcomes.

Stage 3: Develop

The Develop phase involves iterative prototyping and testing of potential solutions. Students engage in low-fidelity and high-fidelity prototyping, integrating feedback loops at each step. This phase is inspired by both the “Prototype” and “Test” stages of the Stanford model and the “Design–Implement” stages of CDIO. Key tools introduced here include Technology Readiness Level (TRL) mapping, design-for-manufacturability principles and materials selection. Studio-based and laboratory sessions form the backbone of this stage, enabling hands-on learning and iterative refinement.

Stage 4: Launch

At this stage, students move beyond technical validation toward market readiness. They engage in business modeling, financial planning and go-to-market strategy development. Core tools introduced include the Lean Canvas, minimum viable product (MVP) design, pricing models and pitch preparation. This phase aims to bridge the gap between academic prototypes and commercially viable products. By linking product design with entrepreneurial thinking, students begin to explore viability, feasibility and desirability in real terms .

Stage 5: Ecosystem Integration

The final stage involves connecting student projects to the broader entrepreneurship and innovation ecosystem. Students interface with institutional incubation centers, participate in mentorship programs and explore avenues for seed funding and IP protection. AICTE’s Institutional Innovation Council (IIC) platform and the National Innovation and Startup Policy (NISP) guidelines provide the structural support for this stage [4, 5]. This stage ensures that promising projects are not only completed academically but also positioned for real-world implementation, patent filing and venture creation (Table-1).

For quick reference, Table 1 summarizes the focus and representative activities associated with each stage. This scaffolded model addresses both vertical and horizontal integration of PD&E in engineering education. Vertically, it spans all years of the undergraduate program; horizontally, it integrates across disciplines, thus combining technical development with business modelling and design thinking. By embedding this model into course structures, assessment rubrics and credit-bearing activities, institutions can institutionalize innovation competencies without relegating them to extracurricular domains.

This integrated approach also aligns with the NEP 2020 vision, which emphasizes "integration of vocational education programs into mainstream education" and promotes entrepreneurial education as a means to foster self-reliance. Moreover, it provides a tangible pathway to operationalize AICTE’s curriculum directives on innovation, internships and industry-linked capstone projects.

Table-1. Framework summary.

Stage	Focus	Representative Activities
Discover	Problem Identification & Empathy	Field studies, user interviews, secondary research
Define	Requirement Framing & Value Mapping	Problem statement, stakeholder matrix, TRL estimation
Develop	Prototyping & Design Validation	CAD modeling, lab testing, simulation, user feedback loops
Launch	Business Readiness & Go-to-Market	Lean Canvas, pricing strategy, MVP showcase
Ecosystem	Incubation & IP/Startup Support	Pitch sessions, IPR workshops, mentoring via IIC and institutional incubators

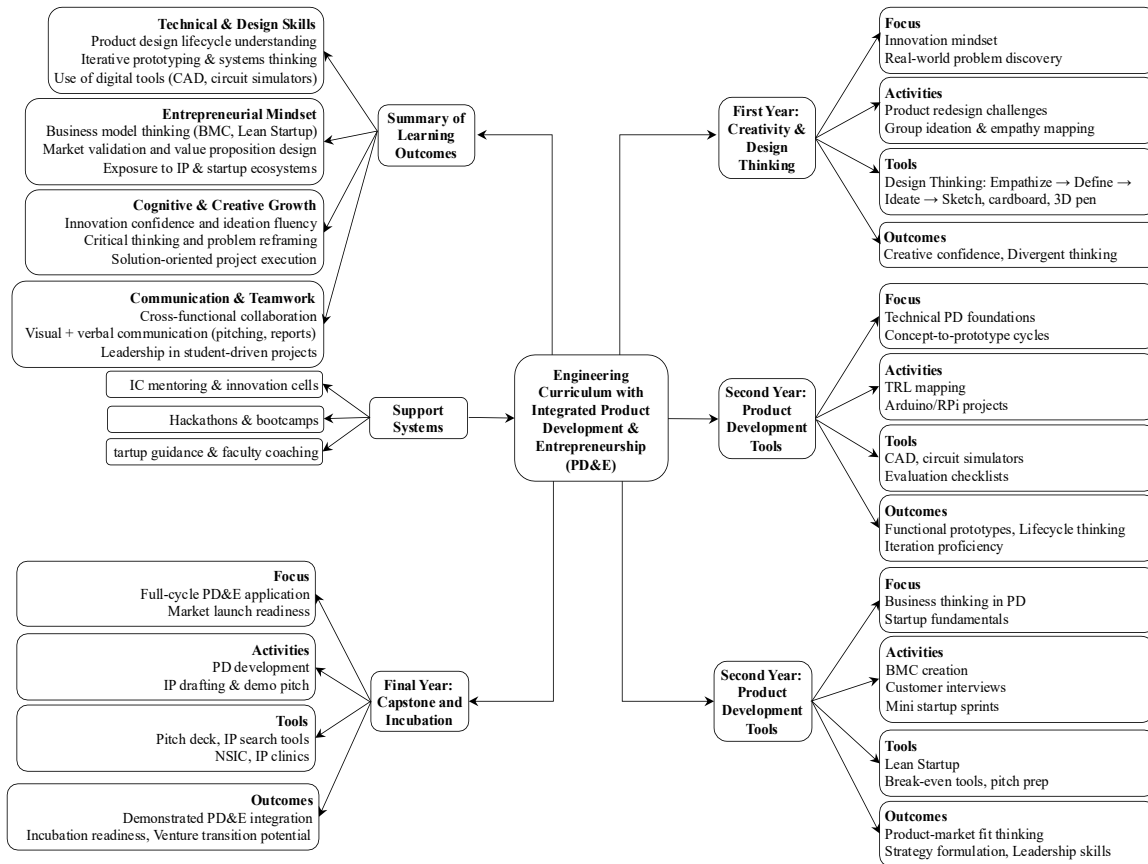


Figure 2. Mindmap depicting semester-wise integration of PD&E activities across the undergraduate engineering curriculum.

Table 2. Summary of curriculum integration.

Year	Focus Area	Skills Developed	Example Deliverables
FE	Creativity & Design Thinking	Empathy, Ideation, Problem Framing	Redesign challenge, problem statements
SE	Product Development Tools	Prototyping, Functional Analysis, TRL Awareness	CAD models, basic working prototypes
TE	Entrepreneurship Lab	Business Modeling, Market Research, IP Literacy	Business Model Canvas, cost analysis, user survey reports
BE	Capstone & Incubation	MVP Development, Startup Planning, IPR and Investor Readiness	Capstone report, prototype demo, IP submission draft, pitch deck

ACTIVITY BLUEPRINT FOR CURRICULUM

To translate the PD&E framework into an implementable curriculum pathway, Figure 2 presents a semester-wise integration map across four years. The map highlights progressive activities, tools, and expected outcomes. Rather than isolating innovation and entrepreneurship into standalone electives or short-term programs, this blueprint embeds PD&E components across all four years of the undergraduate engineering journey, aligned with the stages of the proposed framework. Figure 2 presents a semester-wise curricular integration of Product Design & Entrepreneurship (PD&E) components into the undergraduate engineering program. The mindmap visually outlines key activities, tools, and outcomes mapped to each academic year, emphasizing a progressive learning pathway from foundational design thinking to capstone incubation (Figure-2) (Table-2).

This section outlines a semester-wise progression plan, ensuring gradual skill acquisition and conceptual maturity. It draws from best practices observed in globally recognized programs such as the

Integrated Product Development course at the University of Michigan , project-based engineering curricula and AICTE's model curriculum directives on design thinking and startup orientation .

First Year (FE): Creativity and Design Thinking

Objective

Cultivate foundational creativity, empathy and problem-framing skills.

Key Components

- Introduction to design thinking principles
- Observation-based assignments
- Brainstorming and ideation techniques
- Exposure to social, environmental and local challenges

Activities

- Redesigning everyday products with improved usability
- Group exercises in empathy mapping and problem identification
- Introduction to Bloom's Taxonomy and its application in engineering thinking

At this stage, emphasis is placed on divergent thinking, open-ended exploration and design sensitivity. Evaluation may focus on creative ideation rather than technical precision.

Second Year (SE): Product Development Tools

Objective

Introduce tools and methods for systematic product design and prototyping.

Key Components

- CAD modeling and simulation basics
- Prototyping tools and materials
- Technology Readiness Levels (TRLs) and functional analysis
- Lifecycle mapping and user requirements

Activities

- Mini-projects involving Arduino, Raspberry Pi or basic electromechanical systems
- Guest lectures on industrial product development pipelines
- Design evaluation workshops using peer critique and iteration

This phase strengthens convergent thinking and introduces design-to-build principles. Students begin to work on low-fidelity prototypes and are encouraged to analyse feasibility and constraints.

Third Year (TE): Entrepreneurship Lab

Objective

Develop entrepreneurial competencies through venture-oriented exercises.

Key Components

- Business Model Canvas (BMC) and Lean Startup methodology
- Basics of startup finance and unit economics
- Market research and customer segmentation
- Intellectual property basics and introduction to patent search

Activities

- Team-based product conceptualization followed by BMC development
- Market validation via primary surveys or digital engagement

- Cost modeling and breakeven analysis
- Engagements with local entrepreneurs and institutional IIC mentors

This phase marks a critical inflection point where technical ideas are translated into business concepts. Students begin to evaluate market fit and prepare for real-world pitching scenarios [5][8].

Final Year (BE): Capstone + Incubation

Objective

Apply cumulative learning in a product development and venture creation context.

Key Components

- Capstone design projects integrated with business planning
- Proof-of-concept development
- IP filing process and regulatory landscape overview
- Incubation readiness and investor communication

Activities

- Multi-disciplinary team projects simulating product development cycles
- MVP demonstrations to academic-industry review panels
- Development of patent drafts or design registrations with institutional IP cells
- Mentored pitch sessions for funding via startup cells or external accelerators

For example, students may undertake a hypothetical capstone project such as the design of an “IoT Smart Purifier,” where they identify clean water access challenges, develop a prototype with sensors and connectivity, validate usage through surveys and model startup costs for deployment. This illustrative case can serve as a practice vehicle for PD&E execution without assuming actual implementation. Similar models such as the Entrepreneurial Capstone at the University of Colorado Boulder demonstrate how integrating technical design with commercialization skills prepares engineering students for venture creation [14]. Table 2 consolidates the year-wise PD&E focus areas, skills, and example deliverables.

By distributing PD&E learning progressively and contextually across semesters, this blueprint ensures that students not only understand the theory behind innovation and entrepreneurship but also acquire practical, iterative exposure. It reflects NEP 2020’s emphasis on “multidisciplinary and holistic education” and AICTE’s requirement of industry-relevant capstone projects as part of program outcomes .

CASE ILLUSTRATION (HYPOTHETICAL SCENARIO)

To demonstrate the applicability of the proposed PD&E framework and semester-wise activity blueprint, this section presents a hypothetical capstone scenario for a student team project titled “IoT Smart Purifier.” While fictitious in origin, the case illustrates the sequential execution of the five-stage framework across the four-year curriculum and serves as a model for institutional implementation. The IoT Smart Purifier example is used because it is easy for students to understand, strongly linked to daily life, and naturally supports interdisciplinary learning. It allows students to move step-by-step from need-finding and simple sensing concepts to prototype validation, basic business modeling, and pitch communication. This fits well with experiential and inquiry-driven learning expectations in national education reform, which emphasize learning by doing and solving real-world problems.

Discover Phase (First Year)

During the initial semester, a group of first-year students engages in classroom sessions on design thinking and empathy mapping. Through a problem-sensing assignment involving interviews in semi-urban communities, they identify concerns related to inconsistent water quality and lack of accessible

purification systems. The group maps these concerns into a preliminary problem statement centred on developing an affordable, smart water purification solution tailored for household use.

Define Phase (Second Year)

In the second year, the students are introduced to tools for defining user requirements and functional specifications. With guidance from faculty and industry speakers, they define key features for the proposed solution, such as automatic contamination detection, usage alerts and remote control capability. They develop early-stage models using TRL mapping and simulate key operating conditions using open-source CAD tools and Arduino-based mock-ups.

Develop Phase (Third Year)

In the third year, the students formally enroll in an Entrepreneurship Lab course where they apply Lean Startup principles to assess the market potential of their product idea. They create a Business Model Canvas that outlines customer segments (e.g., low-income households, schools), key resources, revenue models and distribution strategies. A minimum viable product (MVP) is developed using locally sourced components and usability feedback is collected through surveys administered during campus tech events.

Parallel to technical development, the team explores regulatory considerations, engages with the institution's IIC mentor pool and attends a workshop on patent search strategies. Faculty members evaluate progress through mid-semester design reviews and financial analysis assignments.

Launch Phase (Final Year)

In the capstone project phase, the team refines the MVP with improved components, embedded sensor calibration and an integrated user interface. A design-for-manufacture study is conducted to assess cost efficiency and a provisional patent draft is submitted through the institution's IP facilitation center. The team prepares a complete investor pitch deck, which includes usage analytics, target pricing, distribution plan and breakeven analysis.

A simulated demo day is organized by the startup cell in collaboration with the IIC, where teams present to an audience comprising faculty, alumni entrepreneurs and early-stage investors. While funding is not the objective in this hypothetical case, the activity familiarizes students with entrepreneurial communication, investor expectations and risk articulation.

OUTCOME REFLECTION

Although hypothetical, the "IoT Smart Purifier" case demonstrates how the PD&E framework can be operationalized within the constraints of an academic curriculum. Each stage offers meaningful pedagogical value: early ideation fosters user empathy; prototyping encourages hands-on learning; and exposure to entrepreneurship cultivates market orientation and innovation readiness.

Such integrative, course-embedded projects offer a tangible path for institutions aiming to align with NEP 2020's vision of "entrepreneurship as a key competence" and AICTE's emphasis on startup creation through capstone design projects. Moreover, they enable educators to assess higher-order learning outcomes, including creativity, systems thinking, business planning and team-based execution, in a holistic and structured manner. Table 3 maps the hypothetical IoT Smart Purifier project to PD&E phases, tools, and expected learning outcomes.(Table-3)

To operationalize the proposed PD&E framework in a classroom setting, it is essential to align each phase with measurable learning outcomes and assessment criteria. In this context, Table 4 presents a phase-wise evaluation approach for the IoT Smart Purifier case, mapping student evidence to corresponding assessment criteria across all stages of the framework (Table-4).

Table 3. Illustrative mapping of a hypothetical IoT Smart Purifier capstone project to PD&E curricular phases.

Academic Year	PD&E phase	Key activities	Tools and methods used	Expected learning outcomes
First Year (FE)	Discover	Identify broad societal problem: water contamination- Observe user behavior in local communities- Brainstorm product ideas	Design Thinking (Empathize, Ideate)- Observation journals- Group ideation sessions	Understand user-centric design- Practice problem-framing and creative thinking
Second Year (SE)	Define & Develop	Define product requirements for water quality sensors- Develop early low-fidelity prototype- Test basic sensor performance	TRL Mapping- Arduino + water turbidity sensors- Rapid prototyping materials	Convert concepts into physical form- Learn prototyping and basic testing
Third Year (TE)	Develop & Launch	Conduct user surveys and market need analysis- Apply Business Model Canvas- Create MVP with cloud data logging	BMC Canvas- SurveyMonkey / Google Forms- IoT cloud platforms (e.g., ThingSpeak)	Link product design with market needs- Build minimal functional MVP
Final Year (BE)	Launch & Ecosystem	Refine prototype and develop PoC- Draft IP disclosure (hypothetical)- Prepare and present pitch at demo day	Pitch deck (Lean Canvas format)- IP search tools- IIC demo day or campus startup showcase	Demonstrate full-cycle PD&E capabilities- Learn pitching, IP basics, and incubation readiness

Table 4. Suggested evaluation approach for IoT smart purifier case (Phase-wise)

PD&E Phase	Student Evidence	Evaluation Criteria
Discover (FE)	Interview notes, observation journal, empathy map, problem statement	Clarity of problem framing, quality of user insight, relevance to context, teamwork contribution
Define (SE)	Requirement list, stakeholder map, basic TRL estimate, concept sketch	Completeness and traceability of requirements, feasibility reasoning, justification of selected features
Develop (SE/TE)	Prototype photos/videos, test logs, iteration records, basic performance results	Functionality of prototype, correctness of testing method, quality of iteration, effective use of feedback
Launch (TE/BE)	Business Model Canvas, simple cost model, customer validation summary, pitch draft	Logic of business model, evidence of customer validation, clarity of value proposition, quality of pitch communication
Ecosystem (BE)	IP search summary, disclosure draft (if applicable), demo day presentation, reflection report	Awareness of IP pathways, readiness for incubation or mentoring, professionalism in documentation and presentation

CHALLENGES AND ENABLERS

Implementing a structured Product Development and Entrepreneurship (PD&E) framework across engineering curricula presents both institutional challenges and systemic enablers. While national education policies and technical councils provide strategic direction, the successful operationalization of such models within academic institutions requires deliberate action on multiple fronts: faculty development, infrastructure investment, industry linkage and curriculum flexibility.

FACULTY PREPAREDNESS AND TRAINING

A significant implementation challenge arises from the current limitations in faculty expertise related to product innovation and entrepreneurship. Traditional engineering faculty, while proficient in core technical domains, may lack direct exposure to startup ecosystems, design thinking methods or commercialization pathways. This disconnect limits their ability to mentor PD&E-focused student projects effectively. Brindha [6] (2020) emphasizes the need for instructors to shift toward outcome-based models that support creative and professional skills development through guided facilitation rather than didactic delivery.

Faculty development initiatives such as AICTE-sponsored workshops, industry sabbaticals and collaborative curriculum design with entrepreneurs are essential to upskill educators. The NEP 2020 envisions bringing industry practitioners into academia through “Professors of Practice” positions, which can further bridge this expertise gap.

INFRASTRUCTURE AND RESOURCE CONSTRAINTS

Many engineering colleges, particularly in Tier 2 and Tier 3 cities, face infrastructural limitations in setting up makerspaces, rapid prototyping labs or digital design facilities. The absence of such physical resources impedes students’ ability to engage in iterative prototyping and experimental design. Initiatives like AICTE’s IDEA Labs and the Ministry of Education’s funding support for Institutional Innovation Councils (IICs) offer targeted financial mechanisms to address these deficits. However, access alone is not sufficient; institutions must also develop operational models for scheduling, maintaining and integrating lab-based learning with academic assessments.

A low-cost rollout is possible even in colleges without dedicated makerspaces. Early stages (Discover/Define) can run using existing classrooms, local community problem visits, simple surveys, and open-source documentation templates. Prototype work can begin with low-fidelity builds (cardboard models, basic sensor mock-ups, and shared departmental equipment), and then move to limited functional prototypes in small student groups. The curriculum can also use existing mini-project and capstone credits to avoid adding new credit load. Such approaches are consistent with policy guidance that encourages entrepreneurship education through curricular/co-curricular routes and allows students to earn academic recognition for startup-oriented work.

INDUSTRY MENTORSHIP AND ECOSYSTEM ENGAGEMENT

The success of entrepreneurship education depends significantly on exposure to real-world problems, market dynamics and investor perspectives. Yet, consistent industry-academic collaboration remains sparse in many institutions highlights that industry–academia collaboration needs structured mechanisms and shared expectations to improve engineering education outcomes. These gaps restrict students from validating ideas, obtaining user feedback or refining their business models.

Enablers in this area include structured mentorship programs via IICs, collaborations with local startups and accelerators and alumni-based incubation mentoring. NEP 2020 explicitly calls for “experiential and vocational exposure” and industry-anchored internships, which can be leveraged to create more sustained PD&E mentorship pipelines.

CURRICULAR RIGIDITY AND ASSESSMENT MODELS

Rigid academic calendars, fixed credit structures and exam-oriented evaluations often constrain the flexibility required for PD&E integration. Open-ended, interdisciplinary projects may not align easily with current course syllabi or assessment rubrics. Moreover, academic success metrics may undervalue soft skills, design creativity or entrepreneurial risk-taking.

To counter this, institutions can adopt competency-based assessment models that evaluate outcomes like creativity, teamwork and design robustness. AICTE's model curriculum already permits minor degree tracks and interdisciplinary project credits, which can be used to legitimize PD&E-oriented coursework . Credit-linked innovation cells and co-curricular transcript recognition offer further incentives for students to pursue innovation beyond traditional grading schemes.

NATIONAL POLICY AND INSTITUTIONAL ALIGNMENT

On the systemic level, there is increasing convergence among government policies, accreditation bodies and industry expectations toward innovation-led education. NEP 2020, AICTE’s revised model curricula and the National Innovation and Startup Policy (NISP [5]2019) collectively advocate for embedding innovation and entrepreneurship within mainstream engineering programs. ARIIA rankings

have introduced quantifiable metrics for institutional innovation performance, such as number of IP filings, number of startups supported and faculty entrepreneurial activity.

These frameworks serve as macro-level enablers, motivating institutions to prioritize PD&E integration. However, without strong internal leadership, change agents within departments and sustained faculty engagement, policy directives may not translate into classroom transformation.

In summary, while the challenges to implementing an integrated PD&E framework are multifaceted, ranging from faculty capacity and resource constraints to curricular rigidity, the enabling mechanisms are equally robust. National policy alignment, targeted funding schemes, evolving accreditation frameworks and institutional innovation programs collectively create a conducive environment. It is the interplay of these drivers with localized strategies and educator commitment that determines the success of curriculum-wide innovation and entrepreneurship education.

LIMITATIONS

This work proposes a conceptual and policy-aligned framework, and it has three main limitations. First, the model is not yet validated through a multi-institution pilot implementation; therefore, outcomes such as startup numbers or prototype quality are not reported here. Second, engineering institutions differ widely in faculty readiness, lab access, industry linkage, and local ecosystem maturity, so implementation pace may vary across campuses. Third, the IoT Smart Purifier case is a hypothetical illustration used to explain stage-wise execution and assessment logic; it is not presented as evidence of impact. Future work can address these limitations through a pilot rollout, faculty feedback, and outcome tracking across multiple institutions.

CONCLUSION

The evolving demands of the global innovation economy call for a paradigm shift in engineering education, one that goes beyond traditional technical instruction to foster creativity, product innovation and entrepreneurial capability. In India, this shift is not only desirable but essential, as underscored by the National Education Policy [2] (NEP 2020) and the All-India Council for Technical Education (AICTE), both of which emphasize the integration of experiential, inquiry-based and startup-oriented learning models into engineering curricula.

This paper has addressed the systemic gaps that currently inhibit engineering graduates from emerging as innovators and job creators. It has identified deficiencies in communication skills, prototyping experience, IP literacy and commercialization readiness, all of which are critical for success in the product development and entrepreneurship (PD&E) domains. To remedy these challenges, a five-stage PD&E framework comprising of 'Discover, Define, Develop, Launch, Ecosystem' has been proposed. This model is pedagogically grounded in Bloom's Taxonomy and Outcome-Based Education and operationally aligned with international frameworks such as design thinking and CDIO [10].

A semester-wise activity blueprint was presented, detailing how institutions can scaffold PD&E competencies across all four years of undergraduate study. By moving from empathy and ideation in the first year to venture modelling and IP support in the final year, students can experience the full lifecycle of innovation in a structured, academically creditable manner. A hypothetical case scenario involving an IoT-based "Smart Purifier" illustrated how this framework can be applied within real institutional constraints to produce meaningful learning outcomes.

The proposed approach is further supported by national policy instruments including the National Innovation and Startup Policy (NISP), the Institutes' Innovation Council (IIC) network and AICTE's IDEA Lab and internship mandates. While challenges related to faculty expertise, infrastructure, industry engagement and curricular rigidity remain, these can be effectively addressed through strategic capacity-building, institutional leadership and alignment with national ranking frameworks like ARIIA.

In conclusion, bridging the gap between product development and entrepreneurship in engineering education is both a pedagogical imperative and a policy mandate. The framework and strategies outlined in this paper provide a feasible, scalable and contextually relevant roadmap for institutions seeking to produce engineers who are not only technically competent but also capable of designing market-ready innovations and launching sustainable ventures. By institutionalizing PD&E as a core curricular pathway, Indian engineering education can take a decisive step toward fulfilling its role in national economic development and global technological leadership.

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