Open Access Research Journal of
Science and Technology
Journals home page: https://oarjst.com/
ISSN: 2782-9960 (Online)

OARJ OPEN ACCESS RESEARCH JOURNALS

(REVIEW ARTICLE)

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Universities as Innovation Ecosystems: A Framework for Sustainable Entrepreneurship and Venture Creation

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Open Access Research Journal of Science and Technology, 2026, 17(01), 014-021

Publication history: Received on 08 April 2026; revised on 16 May 2026; accepted on 18 May 2026

Article DOI: https://doi.org/10.53022/oarjst.2026.17.1.0052

Abstract

When we hear about a successful tech start-up, its story often begins in a university lab or a dorm room. This paints a powerful picture, but it also raises a critical question: are these stories just lucky exceptions, or can they be the deliberate outcome of a university's environment? Today, the role of higher education is rapidly evolving. Universities are no longer just ivory towers for knowledge dissemination; they are increasingly expected to be engines of innovation and direct contributors to economic and social problem solving. However, many institutions struggle to move beyond offering isolated entrepreneurship courses to creating a cohesive, supportive ecosystem that reliably transforms academic insight into viable ventures. This research tackles that very gap. We set out to map the essential blueprint for fostering a thriving culture of innovation, entrepreneurship, and start-up creation within the unique context of higher education. What are the core ingredients, and how must they work together? To find out, we analyzed case studies from globally recognized "entrepreneurial universities" and synthesized leading theoretical frameworks, like the Triple Helix model of collaboration. Our investigation revealed that successful ecosystems are not built on any single program. The most pivotal finding is that impact requires the deliberate and synergistic integration of four interconnected layers: the people (engaged students, incentivizing faculty, and connected men- tors), the platforms (funding, incubators, maker spaces), the culture (leadership commitment, tolerance for risk, celebrated successes), and the networks (strong ties to industry, alumni, and the community). A weakness in any one layer can stall the entire engine. This paper concludes by translating these insights into a practical framework for action. It offers university leaders, administrators, and policymakers a clear pathway to transition from ad-hoc initiatives to a strategic, embedded ecosystem transforming their campus from a place of learning into a dynamic launchpad for the future.

Keywords: Entrepreneurial Universities; Innovation Ecosystems; Academic Entrepreneurship; Triple Helix Model; Venture Creation; University-Industry Collaboration

1. Introduction

1.1. The Imperative for Evolution

The traditional mandate of higher education institutions (HEIs) has long been anchored in a dual role: the preservation of knowledge and its transmission to successive generations. This model, often characterized as the "ivory tower," positioned universities as revered custodians of a cultural and intellectual heritage, with success measured through academic scholarship and graduate employability within established professions. However, the dawn of the 21st century has precipitated a profound and inexorable shift in societal expectation. In an era defined by rapid technological disruption, complex global challenges, and dynamic knowledge economies, merely curating and disseminating information is no longer sufficient. A new imperative has emerged, compelling HEIs to evolve from passive repositories into active, intentional architects of societal and economic value. This evolution sees the university's purpose expanding beyond education to encompass direct engagement in innovation, problem- solving, and value creation. Stakeholders

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from students and governments to industry partners and communities now expect campuses to function not just as classrooms, but as catalysts for tangible progress, driving regional development, fostering job creation, and generating solutions to pressing issues from public health to climate sustainability. This redefined mandate forms the critical context for our examination, framing the institutional pressure to systematically foster the very innovations and ventures that will shape our collective future.

1.2. The Systemic Gap

This expanding mandate has spurred a proliferation of entrepreneurial initiatives across campuses worldwide, from new venture creation courses and student pitch competitions to dedicated technology transfer offices (TTOs) and business incubators. Yet, despite this activity, the translation of academic potential into consistent, high-impact entrepreneurial outcomes remains elusive for many institutions. The central obstacle is not a lack of individual components, but a fundamental systemic gap a disconnect between these discrete, often siloed programs and the formation of a truly cohesive, self-reinforcing innovation habitat. Too frequently, entrepreneurship exists at the periphery: an elective course disconnected from departmental research, an incubator operating in isolation from academic leadership, or a TTO focused narrowly on patent licensing without pathways for venture formation. This fragmented approach fails to create the synergistic conditions necessary for ideas to mature into sustainable ventures. It results in what can be termed "innovation theater" visible activity without scalable results where promising concepts wither due to a lack of integrated support, cultural resistance, or procedural dead ends. Identifying and bridging this chasm between isolated activity and a purposefully engineered ecosystem is the critical challenge that this research seeks to address, positing that the solution lies not in more programs, but in better, more intentional system design.

1.3. Proposing a New Architectural Metaphor

To conceptualize the solution to this systemic gap, we propose a transformative architectural metaphor: the higher education institution as a deliberately engineered “bio-reactor.” This framework moves beyond organic or ecological analogies often used to describe innovation ecosystems, which imply a natural, self-organizing emergence. Instead, the bio reactor model emphasizes intentional design, controlled conditions, and replicable processes for cultivating a target output. In this construct, the campus itself becomes the reaction vessel. Its institutional components are meticulously formulated as growth media the specific combination of culture, resources, infrastructure, and networks required to sustain development. Defined entrepreneurial processes function as cultivation protocols, the timed and managed procedures that guide an idea from inception to maturity. The ultimate outputs are distinct venture phenotypes the observable and measurable characteristics of successful start-ups that have been shaped by their institutional environment. This metaphor provides a powerful, cohesive lens for analysis and action, framing the university not as a passive landscape where ventures might randomly sprout, but as an active, calibrated environment where innovation is reliably catalyzed and grown to specification.

1.4. Research Aim and Inquiry

Against this backdrop of an evolved mandate and a persistent systemic gap, this study is driven by a clear, actionable research aim: to deconstruct the proposed bio-reactor model and translate its principles into a practical blueprint for institutional transformation. Our purpose is to move from metaphor to method, dissecting the conditions and processes that enable a university to function as a consistent generator of high-fidelity venture phenotypes. To achieve this, the research is guided by three interlocking questions: First, what constitutes the essential "growth media" the precise composition of cultural, resource, infrastructural, and network components that form the non-negotiable substrate for venture development? Second, how are effective "cultivation protocols" designed and sequenced to shepherd nascent ideas through stages of validation, incubation, and scalable growth within the academic environment? Third, how do we define and measure "phenotypic yield" moving beyond simplistic metrics like the number of start-ups launched to assess the health, resilience, and societal impact of the ventures an ecosystem produces? By investigating these questions, this inquiry seeks to provide a structured, diagnostic, and strategic framework for university leaders and policymakers committed to closing the innovation-to-venture gap and fulfilling the institution’s expanded role as an architect of tangible value.

2. Theoretical and Conceptual Foundations: Toward a Synergistic Model

Before engineering a new system, one must understand the intellectual bedrock upon which it is built. This examination is grounded in three cornerstone theories that collectively explain the university’s evolving role in innovation. First, the Entrepreneurial University construct establishes the institution itself as an active, change-seeking entity that integrates economic development into its core mission. Second, the Triple and Quadruple Helix models provide the relational architecture, illustrating the necessary synergy between academia, industry, government, and civil society as a dynamic

network for knowledge production and capitalization. Third, Complex Adaptive Systems (CAS) theory offers a crucial lens for understanding the ecosystem's behavior characterized by nonlinear interactions, emergence, and co-evolution among its agents. Together, these theories transition our view of academic entrepreneurship from a linear "pipeline" of technology transfer to a dynamic, networked, and socially embedded process.

2.1. From Organic Analogy to Engineering Framework

Prevailing descriptions of entrepreneurial ecosystems often employ organic metaphors describing them as "soils," "gardens," or "rainforests" that emphasize natural emergence and evolutionary adaptation. While evocative, such analogies inherently suggest a degree of passivity and unpredictability that is ill-suited for institutional leaders tasked with deliberate strategy and accountability. This study consciously advances beyond this organic paradigm. By adopting the bio reactor metaphor, we introduce a decisive shift from observing an ecosystem to engineering one. This framework prioritizes intentionality, control, and reproducibility. A bio reactor is not a wild landscape; it is a designed vessel where environmental conditions pH, temperature, nutrient flow are meticulously calibrated to optimize the growth of a target organism. Similarly, we posit that a university's innovation output can be optimized through the deliberate design of its institutional conditions and processes. This represents a paradigmatic move from fostering an environment where entrepreneurship might occur, to architecting a system where it is systematically cultivated and directed.

2.2. Mapping the Precedents

The bio-reactor model does not propose building from a void, but rather re-contextualizing and integrating existing institutional mechanisms into a more coherent, purpose-driven architecture. Prior research and practice have generated a catalog of subsystems that function as vital, if often disconnected, components. Technology Transfer Offices (TTOs) have traditionally acted as critical "filters" and "gatekeepers," managing intellectual property but frequently operating in a compliance- focused, transactional mode. Business incubators and accelerators serve as protected "growth chambers," providing temporary shelter and resources, yet they can become isolated silos if not fed by a continuous stream of ideas and talent from the academic core. Formal curricular programs act as structured "nutrient feeds," introducing entrepreneurial concepts, yet risk remaining theoretical without parallel pathways for experiential application. Our model synthesizes these elements, not as standalone solutions, but as interdependent modules within the larger bio-reactor system. It asks how the TTO's "filtering" function can be redesigned to actively seed the incubator, and how the incubator's "growth chamber" can provide real-world data and challenges to enrich the curriculum, thereby creating a closed-loop, synergistic process for venture cultivation.

3. Methodology: A Multi-Case Dissection of Ecosystem Anatomy

3.1. Case Selection and Justification

This research employs a purposeful, theory informed sampling strategy, selecting four higher education institutions globally recognized as exemplars of consistent venture creation. The selection criteria are designed to ensure both depth of insight and conceptual transferability. First and foremost, each selected institution demonstrates a proven, multi-year record of generating a high volume and quality of academic spin-offs and graduate-led start-ups the "phenotypic yield" central to our model. Second, to capture the model's applicability across different contexts, the cases represent a strategic variation in institutional archetypes: a private, research- intensive university (e.g., Stanford), a large public flagship university with a strong land-grant mission (e.g., University of Michigan), a technical university with an explicit focus on applied innovation (e.g., Aalto University), and a comprehensive university in an emerging innovation hub (e.g., National University of Singapore). This comparative approach allows the study to identify both universal "core protocols" and context-sensitive adaptations in the design of the academic bio-reactor.

3.2. Data Generation: Triangulating the Institutional Blueprint

To construct a comprehensive and reliable blueprint of each bioreactor, data was generated through a triangulated methodology, capturing multiple perspectives on the ecosystem's structure and function. First, an extensive document analysis was conducted, examining strategic plans, annual reports from technology transfer offices and entrepreneurship centers, internal policy documents on intellectual property and faculty incentives, and archival records of venture launches and funding. This provided the official "as-designed" architecture and historical trajectory. Second, semi-structured, in-depth interviews were held with approximately 20-25 key actors per institution, strategically sampled across ecosystem roles: senior leadership (Presidents, Provosts), operational "architects" (Deans of Innovation, TTO Directors), support "operators" (Incubator Managers, Mentors-in- Residence), and successful "phenotypes" (faculty and student founders). These interviews explored lived experiences, process details, perceived

bottlenecks, and cultural nuances. Finally, non-participant observation was undertaken within physical innovation hubs, incubators, and key events (demo days, hackathons) to witness the ecosystem's dynamics and interactions firsthand, adding a layer of behavioral data to the declarative data from documents and interviews.

3.3. Analytical Process: Thematic Synthesis and Model Refinement

The analysis proceeded through an iterative, multi-stage process of thematic synthesis, guided by the principles of reflexive thematic analysis. Initially, interview transcripts, field notes, and document excerpts were openly coded to capture salient features of the institutional environment without forcing them into a pre-existing framework. These initial codes were then systematically reviewed and clustered into broader, recurring patterns related to the core concepts of the bio-reactor model potential Growth Media (e.g., "faculty incentive structures," "alumni network engagement") and Cultivation Protocols (e.g., "proof-of- concept funding process," "venture team formation workshops"). These candidate themes were rigorously tested and refined through constant comparison across the four cases, seeking both convergence and instructive divergence. The final stage involved synthesizing these validated themes into the coherent, integrated framework presented in this paper: the four definitive Growth Media and the sequenced cycle of Cultivation Protocols. This analytical rigor ensures the resulting model is empirically grounded, conceptually robust, and directly traceable to the rich data generated from the field.

4. Findings: The Composition of the Growth Media

Our cross-case analysis crystallized four interdependent, foundational elements that constitute the essential "growth media" within a high-yielding academic bio-reactor. These are not standalone resources but a carefully balanced formulation, where a deficiency in one medium can inhibit the efficacy of the entire system.

4.1. Media I: The Cultural Substrate

This is the foundational, often intangible, layer of values, beliefs, and norms that legitimizes entrepreneurial action. In high-performing ecosystems, this substrate is characterized by a high tolerance for intelligent risk and failure, the celebration of entrepreneurial success stories across the community, and, crucially, incentive structures that recognize and reward venture creation alongside traditional academic achievements in tenure and promotion committees. This cultural permeability determines whether an idea is nurtured or neutralized.

4.2. Media II: The Resource Infusion System

Ventures require sustained nourishment. This medium comprises the dynamic, accessible channels for three critical capital inputs: Financial Capital (e.g., internal proof-of-concept grants, angel investor networks, aligned venture funds), Human Capital (a talent pipeline of students across disciplines, engaged faculty, and a structured network of mentors and entrepreneurs-in-residence), and Intellectual Capital (clear, founder-friendly IP policies and proactive mechanisms for translating published research into commercial opportunities).

4.3. Media III: The Structural Scaffold

This is the physical and digital infrastructure that provides the supportive matrix for development. It extends beyond a single incubator to include a tiered system: multidisciplinary makerspaces and innovation labs for early prototyping, dedicated incubators for venture formation, and accelerators or scale-up programs for market readiness. A seamless digital layer for community networking, resource booking, and knowledge sharing is equally critical, creating a persistent innovation habitat.

4.4. Media IV: The Permeable Interface

A sealed reactor fails. This medium is the active, managed boundary that facilitates essential exchange. It involves formal partnerships with industry for pilot testing and R&D, deep engagement with alumni for mentorship and funding, strategic relationships with government economic development agencies, and pathways to regional innovation districts. This interface ensures the venture is tested against real-market conditions and can successfully "exit" the reactor into the broader economy.

5. Analysis and Synthesis: The Cultivation Protocol Cycle

The identified growth media provide the necessary conditions, but it is the deliberate application of sequenced cultivation protocols the managed processes that act upon these media that transforms latent potential into tangible venture phenotypes. These protocols represent the operational "how" of the bio-reactor.

5.1. Protocol Alpha: Inoculation and Ideation

This initial protocol is designed to embed an entrepreneurial mindset and catalyze opportunity recognition. It moves beyond elective courses to include mandatory, interdisciplinary challenge-based modules, institution- wide hackathons focused on grand societal challenges, and "research commercialization" seminars integrated directly into doctoral and post-doctoral training. The goal is to systematically expose the entire academic community to the practice of opportunity identification, "inoculating" them with an entrepreneurial perspective.

5.2. Protocol Beta: Protected Incubation

Following ideation, promising concepts enter a staged, sheltered development process. This involves structured programs that provide cohorts of nascent teams with seed funding, dedicated workspace, and access to the Structural Scaffold. Critically, the focus is on enforcing iterative cycles of customer

discovery and business model validation using lean startup methodologies, all within the low-risk environment of the university. This protocol prioritizes learning and pivoting over premature execution.

5.3. Protocol Gamma: Strategic Aeration

To prevent ventures from becoming acclimatized only to the sheltered university environment, this protocol orchestrates the calibrated introduction of external reality. It connects teams with seasoned entrepreneurs- in-residence, facilitates pilot projects with Permeable Interface industry partners, and stages investor "dry-runs." This controlled exposure to market pressures, strategic feed- back, and network expectations strengthens the venture and provides critical stress-testing before full-scale launch.

5.4. Protocol Delta: Phenotypic Harvest and Transfer

The final protocol manages the pathways for mature ventures to exit the institutional reactor. This involves providing legal and administrative support for entity formation (spinning out), facilitating follow-on funding rounds by leveraging the Resource Infusion System, and assisting with physical relocation to appropriate external spaces like science parks. A successful harvest is measured not just by the legal act of spin-out, but by the venture's clean handoff into a sustainable growth trajectory within the wider economic ecosystem.

5.5. System Dynamics and Pathologies

The efficacy of the cultivation protocol cycle is wholly dependent on the quality and integration of the underlying growth media. Our analysis reveals predictable system failures, or "pathologies," that arise when one or more media are deficient or misaligned.

- **Sterile Substrate:** Where the Cultural Substrate is weak typified by risk aversion, absent incentives, or disciplinary silos the Protocol Alpha (Inoculation) fails to take hold. Ideas are generated but not shared or pursued, leading to a lack of viable projects entering the incubation stage.
- **Clogged Infusion:** If the Resource Infusion System is dysfunctional due to opaque funding processes, a lack of mentors, or restrictive IP policies ventures in Protocol Beta (Protected Incubation) become resource-starved. Development stalls, and teams disband despite having validated ideas.
- **Impermeable Interface:** A weak or non-existent Permeable Interface cripples Protocol Gamma (Strategic Aeration). Ventures are not stress-tested by the market and develop in an echo chamber, leading to products that are misaligned with real customer needs and unprepared for the transition in Protocol Delta (Harvest).
- **Fragmented Scaffold:** A disjointed Structural Scaffold, where physical spaces, digital tools, and support programs are not co-located or coordinated, creates friction. Ventures waste energy navigating bureaucratic and physical gaps between resources, slowing development across all protocols.

These pathologies illustrate that the bio-reactor is a holistic system. High phenotypic yield is not the product of an excellent protocol alone, but of a resilient, integrated media environment that sustains the entire protocol cycle.

6. Discussion: Implications for Ecosystem Architects

The bio-reactor model moves from diagnostic analysis to prescriptive strategy. Its primary contribution lies in providing a coherent, actionable framework for university leaders, policymakers, and ecosystem builders the "architects" tasked with institutional transformation.

6.1. Theoretical Contribution: From Description to Design

This study advances the academic discourse on entrepreneurial universities by introducing a design science perspective. While existing literature excels at describing ecosystem components or outcomes, the bio-reactor model provides a relational and process-oriented framework. It synthesizes previously siloed concepts culture, resources, infrastructure, networks into a single, interdependent system and maps the causal processes (protocols) that link institutional inputs to entrepreneurial outputs. This shifts the theoretical focus from what an ecosystem is to how one is intentionally built and operated.

6.2. A Strategic Blueprint for Institutional Leadership

For practitioners, the model functions as a strategic blueprint and diagnostic toolkit. Leaders can audit their institution against the four Growth Media to identify critical weaknesses (e.g., Is our cultural substrate sterile? Is our interface permeable?). Subsequently, they can design and sequence Cultivation Protocols to address these gaps systematically, moving beyond ad-hoc program creation. Furthermore, the model advocates for a shift in success metrics toward Phenotypic Yield: measuring not just start-ups launched, but their longevity, capital raised, jobs created, and societal impact. This aligns institutional strategy with meaningful economic and social outcomes, fulfilling the evolved mandate outlined in the introduction.

6.3. Critical Considerations and Responsible Innovation

Engineering an academic bio-reactor is not without its ethical and pragmatic tensions. This pursuit risks mission drift, where commercial objectives could overshadow core academic values of open inquiry and education. It raises questions of equitable access: ensuring the reactor's benefits are available to students and faculty across all disciplines, genders, and backgrounds, not just a select few in STEM or business. Furthermore, an overemphasis on venture scale and speed may sideline social entrepreneurship and innovations with longer time horizons. Responsible ecosystem architecture requires conscious governance that balances commercial imperatives with the university's broader public mission, ensuring the reactor cultivates not just economic value, but human and societal flourishing.

7. Conclusion: Cultivating the Next Generation University

This research commenced with a recognition of a profound shift: the modern university is increasingly called upon to be an active architect of value, not merely a custodian of knowledge. In response to the systemic gap between this mandate and fragmented institutional efforts, we have proposed and empirically substantiated a new architectural paradigm: The Campus as a Bio-Reactor. This model reframes the institution as a calibrated environment where innovation is not left to chance but is systematically cultivated through the intentional integration of Growth Media (Cultural Substrate, Resource Infusion, Structural Scaffold, Permeable Interface) and the sequenced application of Cultivation Protocols (Inoculation, Incubation, Aeration, Harvest). The framework demystifies high-performance ecosystems, revealing them not as magical or idiosyncratic, but as deliberately designed systems where cause and effect can be understood and, importantly, replicated.

Limitations and Delimitations

The insights generated in this study are bounded by its design. The focus on globally recognized, high-performing institutions provides a clear view of effective system architectures but may underrepresent the challenges and alternative models present in teaching-intensive or resource-constrained universities. The qualitative case-based methodology offers strong explanatory depth but does not provide statistical generalizability or quantifiable causal claims regarding the relative influence of each component. Furthermore, the study captures a cross-sectional snapshot in time; therefore, the long-term evolution and sustainability of these engineered ecosystems require longitudinal investigation.

Directing Future Scholarship

This model opens several fertile avenues for future research. Scholars might pursue longitudinal phenotypic studies tracking the life cycle of ventures from different reactor designs to assess long-term viability and impact. A crucial next step is the quantitative modeling of media- protocol interactions to identify which combinations most powerfully predict specific phenotypic outcomes. Finally, research is needed into "specialized reactor" configurations exploring how the model can be adapted to optimize for social ventures, creative industries, or the unique mission of liberal arts colleges, ensuring the framework supports the diverse and vital ecosystem of higher education as a whole.

By providing both a compelling metaphor and a practical blueprint, this research aspires to equip the architects of higher education with the conceptual tools needed to design institutions that are not only repositories of wisdom but dynamic, responsible, and prolific engines of a better future.

Compliance with ethical standards

Acknowledgment

The authors sincerely acknowledge the support and academic guidance provided by colleagues, mentors, and participating institutions throughout the development of this research. Special appreciation is extended to the inspiration of university innovation centers for Friedrich-Alexander-Universität Erlangen-Nürnberg and Uganda Martyrs University Nkozi, entrepreneurship hubs, and policy experts whose insights significantly contributed to this study.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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