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The Dual-Subject–Three-Loop Linkage: A Theoretical Framework for University Innovation and Entrepreneurship Education Derived from Pedagogical Practice

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Abstract: This study proposes a "Dual-Subject–Three-Loop Linkage" theoretical framework for university innovation and entrepreneurship education, distilled from systematic pedagogical practice. The model comprises three interlinked loops—Teaching-Research, Technology-Entrepreneurship, and Industry-Education Synergy—governed by dual subjects (faculty professors and innovation-entrepreneurship educators). By constructing a "Technological Intensity–Industrialization Degree" (τ-ι) coordinate system, the framework externalizes the innovation process into quantifiable expressions, revealing the interactive mechanisms among undergraduates, graduate students, and faculty. It provides theoretical guidance for optimizing research translation efficiency and serves as a metric tool for institutional policy-making.

Keywords: Innovation and entrepreneurship education; Cyclical construction; Research translation; Industry-education synergy; Educational theory-practice nexus

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1. Introduction

China's 15th Five-Year Plan for Economic and Social Development policy directive on deep integration of technological innovation, industrial innovation, and education-science-talent frameworks establishes the strategic context for university science-innovation systems. Contemporary ecosystems comprise two primary subjects: faculty professors driving the Teaching-Research Loop (knowledge dissemination and scientific output) and

innovation-entrepreneurship educators leading the Technology-Entrepreneurship Loop (research translation and university-industry integration) [1,2]. However, empirical evidence reveals that innovation performance depends less on external resources than on internal synergy within Teaching-Research Loops [3]. Undergraduates, graduate students, and faculty operate within divergent training orientations, evaluation systems, and career pathways, generating heterogeneity in value perception and benefit acquisition that creates structural fatigue between research and entrepreneurial chains [4,5]. To address this, innovation-entrepreneurship educators—equipped with industrial insight and cross-boundary integration capabilities—must strategically reorient the Teaching-Research Loop to mobilize faculty aligned with national strategic priorities, thereby enhancing vertical connectivity and generating industrially viable research outputs. **Figure 1** shows the roles in the university innovation and entrepreneurship ecosystem.

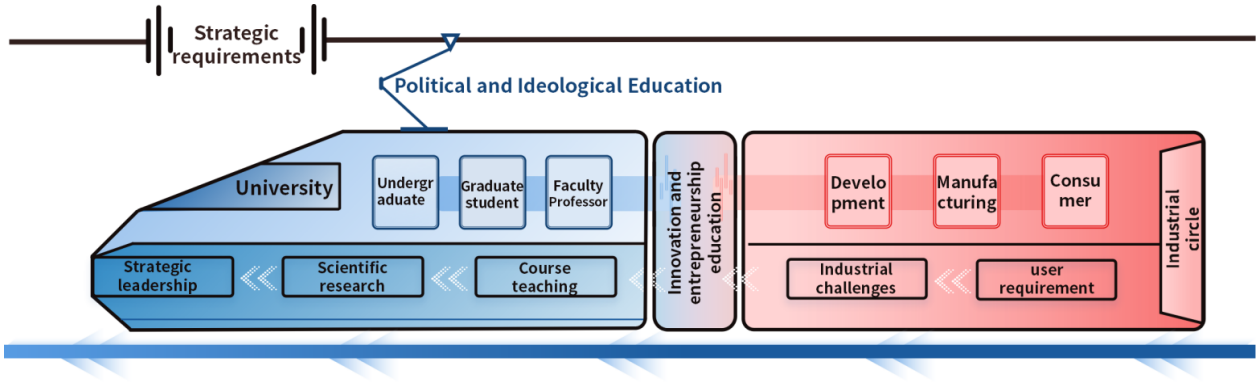

Figure 1. Schematic diagram of roles in the university innovation and entrepreneurship ecosystem

University research production involves three distinct roles—undergraduates, graduate students, and faculty—with divergent capabilities and resource requirements that constrain research-innovation integration [6,7]. Undergraduates possess nascent research capabilities requiring structured training; graduate students expend excessive energy on preliminary work, diminishing experimental efficiency; and faculty demand high-quality outputs alongside mentorship responsibilities. Systematic mechanisms must coordinate these needs by immersing undergraduates in authentic research, enabling graduates to concentrate on core validation, and equipping faculty with industrially aligned project resources. This differentiated support holistically enhances research chain integration and translation potential.

2. Theoretical framework: The Dual-Subject–Three-Loop Linkage model

2.1. Model formulation

This study proposes a "Dual-Subject–Three-Loop Linkage" framework comprising: (1) faculty-led Teaching-Research Loop (academic breakthroughs, high-intensity output); (2) educator-driven Technology-Entrepreneurship Loop (industry application); and (3) Industry-Education Synergy Loop (demand feedback, joint training, collaboration). Analogous to complex thermodynamic systems, this framework employs τ-ι coordinate visualization [8] to elucidate nonlinear cyclical mechanisms (**Figure 2**).

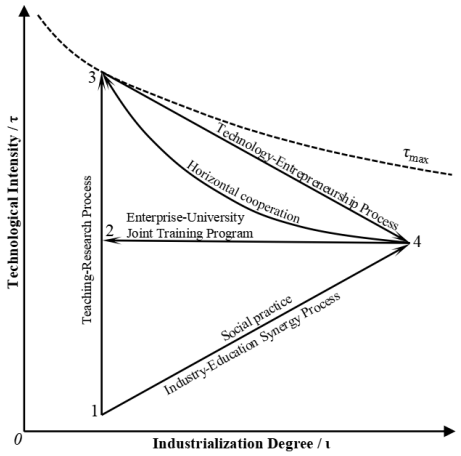

Figure 2. τ-ι diagram of university innovation and entrepreneurship cycle (1, Undergraduates; 2, Graduate students; 3, Faculty professors; 4, Industry)

To further reveal operational principles and the joint action mechanism of the three loops while providing measurable analytical methods, this study proposes a "Technological Intensity–Industrialization Degree" two-dimensional coordinate system, offering an explicit representation of university leadership in socioeconomic development. Within the Teaching-Research Loop, innovative concepts continuously transform into technological accumulation, involving the concept of Technological Intensity (τ, derived from Technology) as the vertical axis variable, while research achievements' entrepreneurial practice involves its breadth and maturity of promotion, forming the Industrialization Degree concept (ι, derived from Industrialization) as the horizontal axis variable. The dynamic evolution of typical university socioeconomic service segments can be regarded as a binary function of τ and ι, with their rates expressed as time derivatives. An infinitesimal action advancing a certain technological intensity τ toward industrialization generates a micro areal unit α (achievement) enclosed with the horizontal axis, representing that action's socioeconomic contribution:

$$\delta\alpha = \tau \, d\iota \tag{1}$$

Long-term accumulation of interconnected industrialization-promoting micro-actions signifies coupled accumulation of corresponding micro-industrialization effectiveness. Integrating these elements yields the total industrial development contribution α of that technological support:

$$\alpha = \int_{\iota_2}^{\iota_1} \tau(\iota) \, d\iota \tag{2}$$

Furthermore, the Industry-Education Synergy Loop feeds industrial demands back into the Teaching-Research Loop, enabling effective coupling with the loop composed of undergraduates, graduate students, and faculty professors, plus the Technology-Entrepreneurship Loop. The synergistic operation of the three loops manifests as a closed contour formed by three curves in the diagram. The enclosed area represents the net contribution value of a university original technology from conception to industrialization, denoted as $\Delta\alpha_{net}$:

$$\Delta\alpha_{net} = \oint \tau \, d\iota \tag{3}$$

The Dual-Subject–Three-Loop Linkage model externalizes university science-innovation-entrepreneurship socioeconomic service performance into graphical and mathematical expressions, providing clear conceptual mapping for understanding the logical mechanism of university innovation-entrepreneurship education.

2.2. The teaching-research process

Research topics originate at low τ_min from strategic needs and individual inspiration, progressing through

undergraduate-, graduate-, and faculty-led stages with monotonic τ increase ($d\tau > 0$). Under ideal pre-industrialization conditions ($d\iota = 0$), the Teaching-Research Loop follows a vertical trajectory. Innovation-entrepreneurship educators introduce authentic industrial demands while undergraduates develop creative solutions through competitions, generating temporary industrialization regressions ($d\iota < 0$) that enhance potential contribution magnitude ($\alpha > 0$) by aligning conceptual frameworks with future industrial directions.

Graduate students accelerate project advancement (increasing $d\tau/dt$) by building upon undergraduate preliminary investigations, reducing early-stage preparation costs. Faculty coordinate resource allocation and task decomposition, integrating outcomes into sustainable research series addressing strategic needs. This nested complementary system creates self-reinforcing feedback loops ($d\tau > 0$, $d\iota > 0$). Innovation-entrepreneurship educators subsequently function as critical translation hubs, redirecting research from academic-only paths toward multi-objective logics encompassing social value and industrial feasibility. Through project planning and incubation support, they enable technology decomposition and complexity reduction, preventing "value suspension" and facilitating the transition from laboratory to engineering applicability and market validation.

2.3. The technology-entrepreneurship process

University research translation manifests as phased technological intensity attenuation ($d\tau < 0$) concurrent with industrialization advancement ($d\iota > 0$), generating downward curvature. This attenuation stems from non-ideal factors—including personnel diversion toward marketing/investment activities and manufacturing processes' inability to replicate laboratory conditions precisely. Faculty professors and innovation-entrepreneurship educators jointly function as directional valves, regulating ι-τ transitions to guide smooth migration toward industrially applicable intervals. Educators' industrial insight enables engineering support while linking corporate resources to provide practical entry points, preventing achievements from stagnating at high-content terminals. Under their mentorship, students conduct market analysis and techno-economic feasibility studies, establishing commercial foundations for productization. University platforms establish entrepreneurship studios as pilot validation carriers, furnishing operational support for corporate registration while creating sustainable talent cultivation environments. This configuration forms a self-consistent loop between research innovation and industrial application, ensuring stable ecosystem evolution.

2.4. The industry-education synergy process

The Industry-Education Synergy Process channels industrial demands back into the Teaching-Research Loop, generating a negative industrialization offset while expanding the university innovation system's potential value. This expansion leverages structural advantages where undergraduates, graduate students, and faculty collaboratively execute demand-responsive research. Innovation-entrepreneurship educators embed cutting-edge industrial needs into undergraduate projects, enabling student transformation from knowledge recipients to problem identifiers despite low technological intensity ($d\tau < 0$). This maximizes potential research output for industrial service development and establishes preliminary industrial-talent connectivity.

Graduate students constitute a critical intermediary zone, producing stable industrial-adaptable research through joint training mechanisms while maintaining relatively stable technological intensity ($d\tau \approx 0$). Faculty professors synergistically translate high-tech achievements into industrialization-viable solutions ($d\tau > 0$, $d\iota > 0$) via project coordination and team optimization. Partitioned research activities progressively accumulate into knowledge systems supporting subsequent translation, sustaining the demand-response process. Throughout, systematic ideological-political education embeds national strategic orientation into research agendas, aligning

activities with science-technology and industrial development blueprints. This three-loop linkage, realized through dual-subject coordination, forms the core structure of the university innovation-entrepreneurship chain.

Any nodal disconnection across the three loops—Teaching-Research blockage impeding sustained innovation, Technology-Entrepreneurship grounding failure constraining academic self-consistency, or Industry-Education Synergy detachment from industrial reality—renders Δα_net unsolvable. The Dual-Subject–Three-Loop Linkage model mandates holistic innovation chain connectivity, enabling continuous contributions through problem identification, scientific breakthroughs, and industrial implementation, thereby fulfilling universities' tripartite mission of talent cultivation, research excellence, and social service.

3. Conclusion and outlook

This study derives the "Dual-Subject–Three-Loop Linkage" theoretical framework from pedagogical practice, analogizing the university innovation ecosystem to complex thermodynamic systems. The τ-ι coordinate system provides a novel quantitative lens for analyzing the transformation from knowledge creation to industrial application.

The framework identifies three core loops and articulates how faculty professors and innovation-entrepreneurship educators function as directional valves regulating capital flow across these cycles. It elucidates the nested synergies among differentiated academic roles and positions innovation-entrepreneurship educators as critical bridging agents preventing research translation failures.

The primary theoretical contribution lies in unifying fragmented elements of innovation-entrepreneurship education into a coherent model, transforming qualitative observations into measurable assessment through the $\Delta\alpha_{net}$ metric. This bridges educational theory and practice while addressing structural fatigue between research and entrepreneurship chains. Future research should validate the model across diverse institutional contexts and refine its measurement indicators, providing a foundation for comparative studies and policy optimization.

Disclosure statement

The authors declare no conflict of interest.

Author contributions

Conceptualization: Zhe Zheng, Yujia Pang
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