Contemporary Education Frontiers, 2026, Volume 4, Issue 7
https://bbwpublisher.com/journal/CEF
Online ISSN: 3029-1860
Print ISSN: 3029-1879

Synergistic Mechanisms and Implementation Pathways for University–Enterprise Collaborative Cultivation of Professional Degree Postgraduates under the Dual Integration of Science–Education and Industry–Education

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Abstract: The collaborative cultivation of professional degree postgraduates by universities and enterprises represents a critical strategy for aligning with national strategic imperatives and addressing the persistent disconnect between high-level applied talent development and industrial practice. The integration of science and education, together with the integration of industry and education, constitutes the two pivotal pillars of this endeavor. Their synergistic advancement not only enhances training quality but also strengthens the capacity of talent to underpin industrial upgrading. Drawing on synergy theory and resource dependence theory, this paper systematically unpacks the underlying mechanisms of the dual integration—namely, demand-driven orientation, resource consolidation, process coupling, and institutional safeguarding. On this basis, we propose four actionable pathways: establishing a full-chain system of "demand–training–evaluation"; building an integrated resource platform that aligns platforms, curricula, and faculty; fostering a "science–education" and "industry–education" double-helix integration process; and perfecting a tripartite safeguarding framework involving government, universities, and enterprises. This study aims to provide both theoretical insights and practical guidance for deepening the reform of professional degree postgraduate education and for advancing school-enterprise collaboration from superficial cooperation toward deep-seated synergy.

Keywords: Science–education integration; Industry–education integration; Professional degree postgraduates; University–enterprise collaborative education; Synergistic mechanisms

Online publication: July 26, 2026

1. Introduction

University–enterprise collaborative cultivation serves as the core vehicle for integrating industry and education. It holds significant strategic value in breaking down barriers between academic training and industrial practice, enhancing students' practical and innovative capabilities, and aligning the educational

chain with the industrial chain [1]. The integration of science and education, together with the integration of industry and education, constitutes the underlying driving forces: the former supplies the source of knowledge innovation, while the latter provides resources for industrial practice. Together, they complement each other to precisely match talent cultivation with industrial demands. The report of the 20th National Congress of the Communist Party of China called for "coordinated innovation in vocational education, higher education, and continuing education, and promoting the integration of general and vocational education, industry–education integration, and science–education integration" [2], urging a dual-driven approach to move university–enterprise collaboration from fragmented to systematic and from superficial to in-depth cooperation. Furthermore, the Ministry of Education's Opinions on Promoting the Classified Development of Academic and Professional Degree Postgraduate Education emphasizes that deepening science–education and industry–education integration should serve as the lever to foster the differentiated cultivation of academically innovative and practically innovative talents, and that the goals and pathways of university–enterprise collaborative cultivation should be reconfigured under the "science + industry" dual-integration framework [3]. As the primary channel for cultivating high-level applied talents, professional degree postgraduate education bears the important mission of meeting industrial needs by developing talents with solid professional foundations, strong practical skills, and high professional competence [4].

Currently, university–enterprise collaborative cultivation for professional degree postgraduates still faces multiple practical dilemmas [5]. The setup of specialty programs and the updating of course content lag behind industrial iterations, while enterprises lack sufficient motivation to participate, resulting in a supply-demand mismatch. The "dual-qualified" teaching staff—those with both academic and industrial expertise—is structurally insufficient: university faculty often lack industrial experience, whereas industry experts are not well-versed in pedagogical practices, thus limiting collaboration to a superficial level [6]. Training processes suffer from a lack of systematic planning, and professional degree programs tend to drift toward an academic orientation, weakening their practical and vocational emphases [7]. Furthermore, coordination among multiple stakeholders remains loose, governance mechanisms are underdeveloped, and partnerships are "superficially cooperative but not deeply integrated" [8]. The root cause lies in the long-standing separation of the science-education and industry-education pathways, which have failed to achieve organic integration [9].

Drawing on synergy theory [10] and resource dependence theory [11], this paper analyzes the intrinsic mechanisms of university–enterprise collaborative cultivation under the "science + industry" dual-integration framework. It identifies four core mechanisms—demand-driven orientation, resource consolidation, process coupling, and institutional safeguarding—and accordingly proposes four actionable pathways: constructing a full-chain system of "demand–training–evaluation"; building an integrated resource platform that aligns platforms, curricula, and faculty; fostering a double-helix integration process of "science-education" and "industry-education"; and perfecting a tripartite safeguard system involving government, universities, and enterprises. This study aims to help break through existing cultivation dilemmas, enhance quality, and provide a reference for moving university–enterprise collaboration from formal cooperation toward deep-seated synergy.

2. Existing problems

2.1. Misalignment between university and enterprise needs: Real industrial problems fail to enter the cultivation process effectively

In current professional degree postgraduate programs, the translation of industrial demands into educational objectives remains inefficient, resulting in a prominent supply–demand mismatch [12]. Universities lag behind industrial iterations in specialty setup and curriculum renewal [13]. Meanwhile, enterprises face high participation costs, and their genuine technical requirements and problems are often not transformed into

research topics; cooperation tends to remain at superficial levels such as internships and site visits [14–15]. Students' practical activities are disconnected from actual industrial contexts, manifesting as superficial collaboration, fragmented practice, and one-dimensional evaluation. This leads to a structural imbalance between training supply and industrial demand, making it difficult to form an effective closed loop in which "industry poses problems, universities solve them, and industry verifies the solutions."

2.2. Rigid resource barriers: Cross-sector flow and effective integration of resources among multiple stakeholders are difficult

Resource integration among universities, enterprises, and research institutions remains insufficient, and sharing is inadequate [16]. There is a lack of institutionalized channels for the flow of disciplinary knowledge, industrial platforms, and cutting-edge facilities among the three parties, and divergent interests further hinder the formation of shared goals [17]. Practice bases and engineering centers are insufficient in number and uneven in quality [18]. On-campus supervisors lack industrial experience, while industry mentors lack pedagogical expertise [19]. Moreover, the mechanism for translating research resources into teaching resources is underdeveloped. These resource deficiencies keep the "science-education" and "industry-education" pathways operating in parallel over the long term, preventing the emergence of synergistic effects.

2.3. Fragmented cultivation process: Insufficient systematic coupling between the science-education and industry-education chains

The integration of academic training and practical training is weak, and the linkage between science-education and industry-education is poorly coordinated, with the cultivation process lacking systematic planning [15]. The coverage of joint university-enterprise enrollment is limited; practical sessions are scattered in the intervals between courses, of insufficient duration, and composed of fragmented tasks, preventing students from engaging in complete projects. Course teaching is disconnected from on-site enterprise practice, and there is insufficient interaction between thesis topics and corporate needs [20]. Most students only undergo short-term internships and gain no systematic understanding of the entire R&D process. Professional degree programs tend to drift toward an academic orientation, weakening their vocational and practical characteristics [13]. The absence of process coupling makes it difficult for the science-education and industry-education chains to form an interlocking, spiral-shaped interactive relationship at every stage of talent cultivation.

2.4. Insufficient institutional supply: Lack of effective institutional safeguards for the rights, responsibilities, and interests of multiple stakeholders

The shortage of institutional safeguards results in loose coordination among multiple stakeholders and underdeveloped governance mechanisms [12]. Given the substantial differences in interests among parties, enterprises lack strong incentives to participate, and coordinating their rights and interests becomes difficult [14]. The division of responsibilities and rights between universities and enterprises remains ambiguous, and the collaboration of practice mentors tends to be formalistic and short-term [19]. Evaluation criteria are overly uniform, placing excessive emphasis on academic papers while insufficiently recognizing engineering practice achievements. The dual-mentor system has not been effectively implemented. These institutional deficiencies deprive demand-driven orientation, resource integration, and process coupling of a solid supporting foundation, making it difficult for university-enterprise collaboration to evolve from formal cooperation into deep-seated synergy.

3. Synergistic mechanisms

3.1. Theoretical foundation

This study draws upon synergy theory and resource dependence theory to construct an analytical framework for university–enterprise collaborative cultivation under the dual integration of science–education and industry–education.

(1) Synergy theory. Synergy theory posits that subsystems within a system generate synergistic effects through nonlinear interactions, driving the system from disorder to order [16]. In the context of this study, universities, enterprises, and research institutions constitute a composite cultivation system, wherein the integration of science and education and the integration of industry and education intertwine and mutually reinforce each other, collectively steering the evolution of the system.

(2) Resource dependence theory. Resource dependence theory suggests that organizations reduce environmental uncertainty and form interdependent relationships by exchanging critical resources [17]. Universities possess talent and knowledge reserves, enterprises offer industrial scenarios and engineering platforms, and research institutions provide cutting-edge facilities and project resources. The essence of the dual integration lies in breaking down resource barriers and facilitating the flow and reorganization of key elements.

3.2. Elucidation of the synergistic mechanisms

Building on the above theories, this study identifies four core mechanisms that underpin university–enterprise collaborative cultivation under the "science + industry" dual-integration framework: demand-driven orientation (spurred by real industrial problems), resource integration (cross-sector flow and reconfiguration of resources among multiple stakeholders), process coupling (spiral interaction between the science-education and industry-education chains), and institutional safeguarding (interest-sharing and coordination of rights and responsibilities) [21]. These four mechanisms are mutually reinforcing and collectively form a complete logical chain for talent cultivation.

3.2.1. Demand-driven mechanism anchored in real industrial problems

University–enterprise collaborative cultivation originates from the pull of real industrial demands. National policies emphasize the need to orient cultivation toward industrial needs and practical application, requiring research topics to be extracted directly from the frontline of industry. Enterprises should treat their genuine problems as sources of research topics, steering educational objectives from knowledge transmission toward problem-solving, and from an academic orientation toward a practice-oriented one. Industrial problems possess both research value and practical attributes. By taking these problems as their theses, graduate students address both scientific inquiry and practical work simultaneously, thus achieving the unity of science-education and industry-education from the very outset.

3.2.2. Resource integration mechanism based on cross-sector flow and reconfiguration of multi-stakeholder resources

Resource integration aims to promote the cross-sector flow and reconfiguration of cultivation resources, rather than their mere accumulation. Through institutionalized coordination, the disciplinary resources of universities, the innovative resources of research institutions, and the practical resources of industry can be elevated from shallow sharing to deep restructuring, generating synergistic forces for cultivation. This integration involves three types of resources: knowledge resources (theoretical systems and practical knowledge), platform resources (laboratories and engineering technology centers), and human resources (academic supervisors and industry experts). Given that no single stakeholder possesses all the necessary resources, mutual complementarity among multiple parties is essential to optimize cultivation outcomes.

3.2.3. Process coupling mechanism based on spiral interaction between the science-education and industry-education chains

The dual integration of science-education and industry-education emphasizes deep coupling and spiral interaction between the two chains throughout the entire cultivation process: in the enrollment phase , joint university-enterprise recruitment is implemented to diversify the student pool; in the training phase, alternating academic and practical work is arranged, with clearly defined duration and content for enterprise-based practice; in the curriculum phase, core courses are co-developed by universities and enterprises to keep content aligned with industrial technologies; and in the evaluation phase, the central criterion is the ability to solve real engineering problems, with greater weight given to practical outcomes. At each stage, the two chains are embedded in and support each other, enabling graduate students to research genuine issues, develop real capabilities, and gain hands-on experience in authentic environments. Academic training and practical training are thus integrated into a spiraling, mutually elevating process, forming a closed-loop cultivation system in which "classrooms are set on the production line, theses originate from the production line, and outcomes return to the production line."

3.2.4. Institutional safeguarding mechanism based on interest-sharing and coordination of rights and responsibilities

The sustained operation of the dual integration of science-education and industry-education relies on institutional safeguards. In terms of governance, a collaborative framework involving government, universities, and enterprises needs to be established. In terms of interests, a sharing mechanism should be built to ensure that all stakeholders receive reasonable returns, thereby sustaining their motivation. In terms of evaluation, diversified criteria should be adopted, allowing the submission of practical outcomes such as product designs and equipment developments for degree conferral. Additionally, institutional innovations such as joint university-enterprise councils can clarify the boundaries of rights and responsibilities, providing a stable institutional foundation for collaborative cultivation and facilitating the transition of the dual integration from a policy initiative to a routine practice.

4. Implementation pathways

Based on the analysis of the intrinsic mechanisms above, this paper proposes the following four implementation pathways.

4.1. Building a full-chain talent cultivation system that links "demand–training–evaluation"

A full-chain system encompassing demand, training, and evaluation should be established. At the demand end, enterprises continuously refine real-world problems to serve as the source of research topics. At the training end, an alternating academic-industrial model is implemented, with enterprise-based practice designated as a compulsory component. At the evaluation end, the core criterion is the ability to solve practical problems, and practical outcomes are recognized as valid grounds for degree conferral. This system, driven by demand from the very outset, forms a closed loop in which "industry poses problems, universities solve them, and industry verifies the solutions, " thereby ensuring that cultivation genuinely responds to industrial needs.

4.2. Creating an integrated resource mechanism that unites "platform– curriculum–faculty"

A trinity resource integration mechanism should be developed, encompassing platform, curriculum, and faculty. At the platform level, universities and enterprises deepen their collaboration by jointly building engineering technology centers and co-established training bases. At the curriculum level, core courses are co-developed to incorporate cutting-edge industrial issues. At the faculty level, a dual-mentor system is implemented, with enterprises sending technical experts to serve as practice supervisors and universities assigning faculty members to take temporary posts in enterprises. These three pillars serve as critical leverage points, collectively driving resources from mere possession to active utilization and, ultimately, to effective transformation.

4.3. Establishing a training process system with a "science-education and industry-education" double-helix integration

A training process system featuring double-helix integration of science-education and industry-education should be established. In the curriculum phase, research training and industrial awareness are integrated; in the research practice phase, academic inquiry is aligned with real-world industrial problems; and in the thesis phase, theoretical innovation is combined with practical achievements. A four-stage progressive pathway—"topic selection practice, solution design practice, comprehensive practice, and innovative practice"—is explored to achieve deep coupling between research growth and industrial R&D processes. Process coupling serves as the dynamic mechanism of the dual integration, enabling the science-education and industry-education chains to intertwine and reinforce each other throughout the entire cultivation journey, thereby preventing their disconnection.

4.4. Perfecting a tripartite institutional safeguard system involving "government – universities – enterprises"

To ensure the sustained operation of the dual integration, a robust institutional safeguard system involving government, universities, and enterprises must be established. In terms of governance, a collaborative decision-making framework should be built, with clearly defined roles for each party. In terms of interests, a benefit-sharing mechanism should be designed to provide reasonable returns for all stakeholders, thereby sustaining their engagement. In terms of evaluation, diversified criteria should be adopted, giving due recognition to practical outputs such as product designs and equipment developments alongside academic publications. Moreover, institutional innovations such as joint university-enterprise councils can clarify the boundaries of rights and responsibilities, providing a stable institutional foundation. These measures collectively facilitate the transition of the dual integration from a policy-driven initiative to a routine, self-sustaining practice.

5. Conclusion

Drawing upon the policy foundations and existing research on the dual integration of science–education and industry–education, this paper has systematically examined the intrinsic mechanisms and implementation pathways of university–enterprise collaborative cultivation for professional degree postgraduates. The analysis reveals that the underlying mechanisms can be encapsulated in four mutually reinforcing dimensions—demand-driven orientation, resource integration, process coupling, and institutional safeguarding—which together constitute a logical chain of "initiation driven by demand, integration throughout the process, and sustained support through institutions." Correspondingly, four actionable pathways are proposed: a full-chain talent cultivation system, a trinity resource integration mechanism, a double-helix training process system, and a tripartite institutional safeguard system. These pathways effectively translate the theoretical mechanisms into operational practices, ensuring a coherent connection

from conceptual framework to practical implementation.

Future research may fruitfully explore three directions: the construction of quality evaluation systems within the dual-integration context, differentiated cultivation strategies tailored to various categories of professional degree postgraduates, and the mechanisms and pathways through which digital technologies can empower integrated cultivation. Such inquiries are expected to provide further support for perfecting the professional degree postgraduate education system with Chinese characteristics.

Funding

This study was supported by Guangdong Province Graduate Education Innovation Plan Project: Reform and Exploration of School Enterprise Collaborative Education Mechanism for Professional Degree Graduate Students Based on the Dual Integration of "Science and Education+Industry Education" (2025GDXM025); Key Research Project of Laboratory Management Professional Committee of Guangdong Higher Education Association: Reform and Practice of Process Assessment and Evaluation System for Circuit Experiment Based on "Four in One" (GDJ20250004)；Guangdong Province Higher Education Teaching Reform Project: Research and Practice on Circuit Experiment Teaching Reform Based on Innovative Ability Cultivation (K24102); China Higher Education Association-2026 Higher Education Science Research Planning Project-Research on the Reform and Development of University Laboratories Topic: Reform and Practice Exploration of "Five in One" Circuit Experiment Teaching Driven by Artificial Intelligence（CA265802001）; Key Project at the School Level of South China Agricultural University: Research and Practice on the Reform of Circuit Experiment Teaching Based on Innovative Ability Cultivation (JG2023010)；026 South China Agricultural University Graduate Education Innovation Program Project - Research Project on Practical Teaching Resource Development and Training Model Reform for Professional Degree Graduate Students: Innovation in University-Enterprise Collaborative Training Model for Professional Degree Graduate Students under AI-Driven Deep Integration of "Science-Education + Industry-Education"

Disclosure statement

The authors declare no conflict of interest.

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