Scientific Research Publishing

Modern Economy, 2026, 17(7), 946-989
https://www.scirp.org/journal/me
ISSN Online: 2152-7261
ISSN Print: 2152-7245

International Cooperation in Economics and Management under Five-Dimensional Synergy: A Case Study

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How to cite this paper: Liu, L. Y. (2026). International Cooperation in Economics and Management under Five-Dimensional Synergy: A Case Study. *Modern Economy, 17,* 946-989.
https://doi.org/10.4236/me.2026.177048

Received: March 11, 2026
Accepted: May 31, 2026
Published: July 31, 2026

Abstract

The rapid advancement of artificial intelligence is fundamentally reshaping international cooperation in talent development, particularly in economics and management at applied universities. This transformation calls for a fundamental rethinking of how applied universities engage with international partners to develop talent in these fields. Existing scholarship on "five-dimensional synergy" has largely focused on enumerating its constituent elements, offering limited theoretical elaboration or empirical testing of the interactive mechanisms among its dimensions. To address this gap, we construct a five-dimensional synergy framework—comprising policy support, technological empowerment, cultural integration, ecological synergy, and capacity building—grounded in an integrated theoretical perspective drawing from synergetics and system dynamics. The framework generates three testable hypotheses concerning feedback loops among the five dimensions. These hypotheses are empirically tested through a case study of the School of Economics and Management at Beijing Institute of Petrochemical Technology, drawing on fieldwork conducted between 2023 and 2026. Our analysis draws on in-depth interviews with 59 respondents across four stakeholder groups: 22 faculty members, 5 administrators, 22 enterprise representatives, and 10 students and graduates. Loop hypothesis testing focuses on the 22 faculty respondents, as they are the primary agents directly implicated in the feedback mechanisms under investigation. Evidence from other stakeholder groups is used for contextual triangulation and to diagnose specific dilemmas reported in Section 5.4. All counts and percentages appearing in the manuscript refer to the full sample of 59 unless explicitly noted otherwise. Examining the operational status of each of the three feedback loops, the findings reveal that all three receive partial empirical support, though each exhibits distinct patterns of disruption. Loop 1, policy ↔ technology, operates as a unidirectional mechanism in which policy drives

technology adoption but technological feedback fails to inform policy revision. Loop 2, technology ↔ capacity, shows supply-driven momentum hampered by stalled transformation. Loop 3, culture ↔ ecology, demonstrates that surface-level integration is achievable while deep-seated synergy remains elusive. The disruption of loop operating conditions—insufficient start-up costs, delayed information feedback, and inadequate system resilience—constitutes the underlying cause of loop failure. The feedback-loop interactive model proposed herein advances the five-dimensional synergy framework beyond a static checklist of elements toward an analytically coherent structure with internal causal linkages, offering both a theoretical instrument and a practical reference for innovating international cooperation models at applied universities.

Keywords

Five-Dimensional Synergy, Applied Universities, International Cooperation Models, Optimization Pathways, Empirical Testing

1. Introduction

1.1. Research Background

The rapid advancement of artificial intelligence is fundamentally transforming the operational logic and organizational forms of higher education. Traditional "project-driven" international cooperation—characterized by sporadic student exchanges, faculty visits, and short-term collaborative projects—faces mounting pressure to evolve in the AI era. New collaborative forms such as virtual teaching and research centers, online dual-degree programs, and cross-border data sharing are continually emerging, challenging conventional face-to-face cooperation models. At the same time, AI is driving a systemic restructuring of competency requirements for economics and management professionals, rendering piecemeal project-based cooperation inadequate for addressing the deep-seated demands of talent development transformation. In this context, applied universities confront a central question: how to move beyond fragmented "project-driven" models toward systematic, institutionally embedded international cooperation innovation.

Beijing's policy environment provides important institutional support for addressing this question. The 2024 release of the *Beijing Science and Technology Innovation Internationalization Enhancement Action Plan* marked the first incorporation of "coordinated institutional reform across education, science and technology, and talent development" into the internationalization policy framework, signaling a paradigm shift from "project-based management" toward "systematic governance". This policy shift opens an institutional window for the systemic innovation of international cooperation models in higher education. However, translating policy-level guidance into systematic institutional practice at the university level demands further theoretical exploration and empirical investigation.

1.2. Research Questions and Objectives

Addressing this question requires an analytical framework capable of integrating multiple dimensions—policy, technology, culture, ecology, and capacity. In recent years, "five-dimensional synergy" has been increasingly applied as an integrative analytical framework in education management and evaluation. Feng Jikang (2026) articulated a five-dimensional synergistic mechanism framework encompassing structural synergy, procedural synergy, institutional synergy, resource synergy, and cultural synergy, examining how universities integrate into national innovation systems. Zhao Jun (2025) proposed a "five-dimensional integration, bidirectional drive" paradigm for the international cultivation of graduate talent, constructing an internationalization training system across five dimensions: curriculum, faculty, research, exchange, and management. However, the specific connotations of the "five dimensions" vary across these studies, and all treat them as a checklist of parallel elements, lacking in-depth articulation of the interactive mechanisms and feedback loops among dimensions.

Three progressive questions guide our investigation. First, how can a five-dimensional synergy framework applicable to the international cooperation context of applied universities be constructed, and how does it differ from existing "five-dimensional" concepts? Second, do the three proposed feedback loops actually exist in practice, and how do they operate? Third, how can practical dilemmas be diagnosed and optimized through analysis of loop operating conditions?

1.3. Research Significance

The theoretical contributions of our work are twofold. At the conceptual level, by critically examining existing "five-dimensional synergy" research, we clarify the distinctions and connections between our framework and prior work, thereby defining the boundaries of its originality. At the mechanistic level, our approach not only proposes theoretical hypotheses concerning three feedback loops among the five dimensions but also empirically tests each loop's operational status, providing a new analytical tool for understanding the systemic characteristics of international cooperation models at applied universities. Practically, using the School of Economics and Management at Beijing Institute of Petrochemical Technology as a case study, we diagnose practical dilemmas in five-dimensional synergy implementation and propose optimization pathways, offering a replicable reflective framework for similar applied universities.

1.4. Research Method and Case Overview

A case study research design was adopted for this investigation, focusing on the international cooperation practices of the School of Economics and Management at Beijing Institute of Petrochemical Technology from 2023 to 2026. Data collection employs semi-structured in-depth interviews as the primary method, supplemented by document and archival analysis and non-participant observation, to empirically test and refine the five-dimensional synergy framework.

The selection of the School of Economics and Management at Beijing Institute of Petrochemical Technology as the case rests on three considerations. First, the school has been building its international cooperation network since 2001, establishing long-term collaborative relationships with over 30 higher education institutions across more than 20 countries and regions, thereby accumulating rich practical experience. Second, since 2023, the school has systematically explored new models of international cooperation in the AI context, achieving preliminary results in cross-border teaching and research collaboration, digital curriculum development, and industry-education integration. Third, as a representative example of Beijing municipal applied universities, its experience offers valuable reference for similar institutions.

1.5. Paper Structure

The argument proceeds through a progressive logic: theoretical construction → loop testing → dilemma diagnosis → causal analysis → optimization pathways. Chapter 2 presents a literature review, systematically examining research on international cooperation models at applied universities and the five-dimensional synergy framework. Chapter 3 constructs the "feedback-loop" theoretical model of five-dimensional synergy, proposing three theoretical hypotheses. Chapter 4 describes the research design. Chapter 5 presents the case findings, including sequential testing of the three feedback loops. Chapter 6 conducts dilemma diagnosis and causal analysis. Chapter 7 proposes optimization pathways and concludes the study.

2. Literature Review

2.1. Research on International Cooperation Models at Applied Universities

Research on the internationalization of higher education is systematically examined here, evolving from conceptual definition, through model classification, to mechanistic analysis. Knight (2004) defined the internationalization of higher education as "the process of integrating an international, intercultural, or global dimension into the purpose, functions or delivery of postsecondary education", establishing a foundation for subsequent inquiry. Altbach and Knight (2007) supplemented this with motivational analysis, demonstrating that internationalization pathways vary significantly across countries and regions due to differences in historical traditions, economic conditions, and policy orientations. De Wit and Altbach (2021) further pushed the discussion toward a new framework, emphasizing that post-pandemic internationalization is shifting from "mobility-driven" to a new phase in which "internationalization at home" and "virtual internationalization" are equally important. This theoretical shift provides new coordinates for analyzing the internationalization practices of applied universities.

At the level of model classification, existing research has typologized international cooperation models along multiple dimensions. Based on stakeholder configuration, models fall into three categories: inter-institutional cooperation, uni-

versity-industry cooperation, and government-led models. By depth of cooperation, they range from project-based cooperation, through institutional cooperation, to strategic cooperation. By form of cooperation, they include student exchange, joint training, cross-border campus establishment, and research collaboration models. Tsinghua University School of Economics and Management (2020) categorized open international education into three basic forms: "bringing in", "going out", and "online integration". These classifications provide useful analytical frameworks for understanding the diversity of international cooperation models.

Focusing on applied universities, international scholarship offers several exemplary models. The University of Cincinnati in the United States, as the birthplace of cooperative education, has pioneered the integration of classroom learning with paid professional work experience since 1906, embedding internationalization training within students' corporate internships and overseas practice to form an "industry-education integrated" internationalization pathway (Wang & Zhang, 2018; Chen, 2017). Northeastern University, another prominent exemplar, launched its cooperative education program in 1909 and has since developed it into the cornerstone of its experiential learning model (Northeastern University, 2026a). Today, Northeastern partners with over 4,600 employees worldwide, with students participating in co-op and experiential learning programs across 151 countries (Northeastern University, 2026b). The university's global network spans multiple campuses across continents, and its students graduate with up to 18 months of professional experience (Northeastern University, 2026a), providing a distinctive model for integrating global experiential learning into applied talent development. Singapore Institute of Technology and Nanyang Polytechnic represent a model of "government-led with enterprise embeddedness". Through national strategies such as SkillsFuture, the Singapore government directly translates industrial demand into educational standards, transforming enterprises from "end users" of talent into "co-designers". These models provide useful references for applied universities, though direct transplantation faces differences in institutional environments and resource endowments.

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Research within China has focused more on policy drivers and regional practices. Wang Zhanjun (2024) analyzed the functional positioning of Beijing universities' international cooperation in the context of Beijing-Tianjin-Hebei coordinated development, noting that regional coordination provides new institutional space for university international cooperation. Shi Song (2025) proposed the view that "high-quality educational openness empowers the innovative development of 'Double First-Class' initiatives", emphasizing the synergy between

open education and connotative development. However, existing research on the systematic analysis of international cooperation models at applied universities remains insufficient, particularly lacking in-depth revelation of the internal operating mechanisms of these models.

2.2. Research Status and Conceptual Analysis of the "Five-Dimensional Synergy" Framework

The "five-dimensional synergy" framework, as an integrative analytical tool, has been widely applied across multiple domains in recent years. However, the specific connotations of the "five dimensions" vary considerably across studies, necessitating careful conceptual analysis.

In the field of education management and evaluation, Feng Jikang (2026) articulated a five-dimensional synergistic mechanism encompassing structural synergy, procedural synergy, institutional synergy, resource synergy, and cultural synergy, examining the pathways through which universities integrate into national innovation systems. This framework's five dimensions focus on organizational architecture, research processes, institutional design, resource allocation, and cultural construction, with the university as the unit of analysis and national innovation system integration as its orienting purpose.

Turning to talent development, Zhao Jun (2025) proposed a "five-dimensional integration, bidirectional drive" paradigm for the international cultivation of graduate talent, constructing an internationalization training system across five dimensions: curriculum, faculty, research, exchange, and management. This framework's five dimensions focus on the various components of graduate training, with the talent development process as the unit of analysis and the quality of internationalized training as its orienting purpose.

In a different vein, Zhang and Shao (2025) constructed a "five-dimensional synergy" evaluation framework in the governance evaluation domain, centered on the plurality of governance subjects, the fairness of governance institutions, the innovativeness of governance tools, the security of governance processes, and the inclusiveness of governance outcomes. This framework takes the urban governance system as its unit of analysis and governance effectiveness evaluation as its orienting purpose.

Additionally, "five-dimensional synergy" has been applied to vocational education talent development, university research commercialization, legal talent development, and other contexts. In the field of ideological and political education, Mei and Zhou (2024) constructed a "five-dimensional synergy" education model under the framework of the "Great Ideological and Political Course", demonstrating its applicability in value-oriented talent cultivation. In the domain of higher education evaluation, Jiang, Song, and Sheng (2023) applied the five-dimensional synergy logic to construct an evaluation index system for the internationalization of Chinese medicine higher education, extending the framework's applicability to specialized disciplinary contexts. Shao and Zhang (2023) further extended the

five-dimensional framework to the education management of international students in Chinese universities, demonstrating its utility in cross-border student affairs and intercultural support systems. While the specific meanings of the "five dimensions" vary across these studies, they share a common methodological feature: treating the five dimensions as a checklist of parallel elements and discussing the construction pathways of each dimension separately, without in-depth articulation of the interactive mechanisms and feedback loops among dimensions.

The distinctions from the present framework are threefold. First, our five dimensions—policy support, technological empowerment, cultural integration, ecological synergy, and capacity building—are distilled from a systematic review of the core elements of international cooperation practice at applied universities, with the "international cooperation model of applied universities" as the unit of analysis, rather than the university as a whole, the talent development process, or the urban governance system. Second, we not only propose five dimensions but also seek to reveal the feedback loops and bidirectional drive relationships among them, upgrading the framework from a "checklist of elements" to a "mechanistic loop", and empirically testing each loop's operational status—this constitutes the primary theoretical contribution distinguishing our work from prior studies.

2.3. Literature Review and Research Gaps

Synthesizing the above literature, existing research exhibits three significant shortcomings. First, systematic analytical frameworks for international cooperation remain underdeveloped. Most studies proceed from a single dimension, lacking systematic articulation of the interactive mechanisms among the various elements of international cooperation. International cooperation at applied universities particularly requires an analytical framework capable of integrating multiple dimensions—policy, technology, culture, ecology, and capacity. Second, while existing "five-dimensional synergy" research provides valuable analytical tools for understanding the synergistic characteristics of educational systems, the connotations of the five dimensions vary across studies, and all treat them as a checklist of parallel elements, leaving the interactive mechanisms and feedback loops among dimensions unrevealed. Third, empirical testing of theoretical frameworks is insufficient. Most existing research remains at the level of theoretical construction or policy recommendation, lacking in-depth examination of the operational mechanisms of the five-dimensional synergy framework in real educational contexts.

Addressing these gaps matters because without a systematic understanding of how the five dimensions interact and influence one another, both researchers and practitioners lack the analytical tools needed to diagnose why international cooperation efforts succeed or fail. The absence of empirical testing further means that existing frameworks remain speculative rather than evidence-based, limiting their practical utility for institutional decision-making.

Building on these research gaps, we pursue two progressive theoretical tasks. First, on the basis of distinguishing our framework from existing "five-dimen-

sional" concepts, we construct a "feedback-loop" theoretical model of five-dimensional synergy applicable to the international cooperation context of applied universities. Second, using the School of Economics and Management at Beijing Institute of Petrochemical Technology as a case study, we sequentially test the operational status of the three feedback loops and determine whether the theoretical hypotheses are supported by the data.

3. Theoretical Framework: The "Feedback-Loop" Model of Five-Dimensional Synergy

3.1. Dimensional Origins and Conceptual Analysis of the Five-Dimensional Synergy Framework

To ensure the five dimensions were derived systematically rather than selected arbitrarily, we conducted a structured literature review following the integrative review approach proposed by Whittemore and Knafl (2005). The search was performed across three databases—Web of Science, Scopus, and CNKI—covering publications from 2010 to 2025. The search string combined terms related to "international cooperation in higher education", "talent development", and "economics and management" with terms such as "policy", "technology", "culture", "ecosystem", and "capacity building". Initial screening of titles and abstracts yielded 847 records. After removing duplicates and applying inclusion criteria—peer-reviewed journal articles or conference proceedings, English or Chinese language, and explicit relevance to international cooperation models in higher education—187 full text articles were assessed for eligibility. We then employed a concept centric synthesis approach, extracting recurrent themes and categorizing them into five clusters that corresponded to the core functional domains of international cooperation practice: institutional framework (policy support), infrastructural enablers (technological empowerment), relational dimensions (cultural integration), structural arrangements (ecological synergy), and outcomes (capacity building). This process confirmed that the five dimensions are grounded in the extant literature rather than solely reflecting the authors' theoretical preferences.

The five-dimensional synergy framework constructed herein comprises five dimensions: policy support, technological empowerment, cultural integration, ecological synergy, and capacity building. These dimensions are distilled from a systematic review of the core elements of international cooperation practice at applied universities, with the "international cooperation model of applied universities" as the unit of analysis.

The specific connotations and literature sources of the five dimensions are as follows. The "policy support" dimension derives from research on education policy-driven international cooperation. Policy provides the legitimacy framework, resource guarantees, and institutional foundation for international cooperation—a necessary condition for systematic collaboration. The "technological empowerment" dimension originates from discussions on digital transformation in education in the AI era. AI technology not only transforms pedagogical means but also

reshapes the objectives and pathways of talent development, elevating technology from an "auxiliary tool" to a "transformative force". The "cultural integration" dimension derives from research on cross-cultural education and international talent development. The deep obstacles to international cooperation often lie not at the institutional level but at the cultural level—cross-cultural understanding is a prerequisite for effective multi-stakeholder collaboration. The "ecological synergy" dimension originates from theories of industry-education integration and multi-stakeholder collaborative governance. International cooperation at applied universities involves multiple stakeholders—government, enterprises, universities, and overseas institutions—requiring the construction of a "government-enterprise-university-overseas" collaborative ecology. The "capacity building" dimension derives from research on faculty development and student competence. The ultimate objective of international cooperation is the improvement of talent development quality, with capacity serving as the key indicator for evaluating cooperation effectiveness.

Distinction from existing "five-dimensional" concepts: Feng Jikang's (2026) five dimensions are structural synergy, procedural synergy, institutional synergy, resource synergy, and cultural synergy, focusing on the university as a whole and its integration with the national innovation system. Zhao Jun's (2025) five dimensions are curriculum, faculty, research, exchange, and management, focusing on the graduate training process. Our five dimensions—policy support, technological empowerment, cultural integration, ecological synergy, and capacity building—focus specifically on the international cooperation model of applied universities. The three approaches differ in their units of analysis, applicable contexts, and core concerns.

The logic of dimensional selection: These five dimensions constitute an integrated framework because they jointly respond to five core questions facing international cooperation at applied universities. Policy support addresses "whether there is institutional support"; technological empowerment addresses "whether there are tools"; cultural integration addresses "whether there is conceptual consensus"; ecological synergy addresses "whether there is a cooperation platform"; and capacity building addresses "whether there are tangible outcomes". The five questions are interrelated and mutually conditioning. Compared to Feng Jikang's (2026) five dimensions focusing on university institutional structure and Zhao Jun's (2025) five dimensions focusing on the training process, our framework directly corresponds to the five core questions of international cooperation practice, offering stronger relevance in explaining the dilemmas of international cooperation at applied universities.

Three levels of originality characterize our framework. First, the five dimensions are systematically distilled for the international cooperation context of applied universities, with a unique combination and unit of analysis. Second, we not only propose five dimensions but also seek to reveal the feedback loops and bidirectional drive relationships among them, upgrading the framework from a "checklist of elements" to a "mechanistic loop". Third, we identify three condi-

tions for effective loop operation—start-up costs, timeliness of information feedback, and system resilience—endowing the framework with diagnostic functionality. These three elements together constitute the theoretical contribution distinguishing our work from prior studies.

3.2. Theoretical Foundations: Integrating Synergistics and System Dynamics

The theoretical construction of our work is grounded in an integrated perspective drawing from synergetic and system dynamics. Synergistics holds that the key to a system's progression from disorder to order lies in the nonlinear interactions and synergistic effects among its subsystems. Central to synergetic is the concept of the "order parameter", which governs the behavior of subsystems and determines the system's macrostructure. The order parameter is not externally imposed but emerges spontaneously from the interactions among a system's internal elements. Identifying a system's order parameter captures the key to understanding its evolutionary direction. System dynamics emphasizes that the behavior of complex systems is driven by feedback loops. System evolution is not a unidirectional linear causal chain but a multiplicity of causal cycles. The core value of feedback loop analysis lies in revealing a system's "endogeneity"—the roots of problems often lie not externally but, in the system's, internal structural relationships.

Applying this integrated perspective to the analysis of five-dimensional synergy yields two theoretical tools. Synergistics helps identify which dimension serves as the order parameter. In the AI era, "technological empowerment" exhibits characteristics of an order parameter due to its profound influence on competency structures, policy content, and cultural interaction patterns. System dynamics helps analyze the feedback loops among the five dimensions—their interactions are not a unidirectional linear chain but a multiplicity of causal cycles. This integrated perspective enables the five-dimensional synergy framework to evolve from "static classification" to "dynamic evolution".

3.3. The Five-Dimensional Interactive Feedback-Loop Model: Three Theoretical Hypotheses

Under the above theoretical framework, the five-dimensional interactive feedback-loop model comprises three core feedback loops. The theoretical hypotheses for each loop are proposed below.

Loop 1: Bidirectional drive between policy support and technological empowerment. Its operational logic is that policy provides the legitimacy framework and resource guarantees for technology application, while the actual effects of technology application in turn drive the iterative optimization of policy. The 2024 release of Beijing's *Education Sector AI Application Guidelines* for the first time proposed new AI-empowered education application scenarios such as "using intelligence to support construction"—a typical case of technology driving policy iteration. Accordingly, **Hypothesis H1** is proposed: there exists a bidirectional

drive relationship between policy support and technological empowerment—policy investment promotes technology application, and technology application effects feed back into policy formulation, driving policy iteration.

Loop 2: Bidirectional drive between technological empowerment and capacity building. The application of AI tools drives the restructuring of faculty and student competency structures—faculty need to master AI-assisted teaching tools, and students need to develop AI literacy and data thinking. Capacity improvement in turn generates demand for more advanced tools and deeper applications. Accordingly, **Hypothesis H2** is proposed: there exists a bidirectional drive relationship between technological empowerment and capacity building—the application of technological tools enhances faculty and student capabilities, and capacity improvement in turn drives demand for more advanced technologies.

Loop 3: Bidirectional drive between cultural integration and ecological synergy. Cross-cultural understanding is a prerequisite for multi-stakeholder collaboration, while effective ecological synergy in turn deepens the parties' understanding and identification with each other's cultures, forming a virtuous cycle of "culture-institution-behavior". Accordingly, **Hypothesis H3** is proposed: there exists a bidirectional drive relationship between cultural integration and ecological synergy—cross-cultural understanding promotes multi-stakeholder collaboration, and collaborative deepening in turn feeds back into cultural identification.

The three loops do not operate independently but are nested and interrelated. The technology-capacity loop provides tools and talent for culture-ecology; the culture-ecology loop provides institutional environment and cultural soil for technology-capacity; policy support runs through all loops, providing the legitimacy framework and resource guarantees. Together, the three loops constitute the overall operational mechanism of five-dimensional synergy.

3.4. Operating Conditions of the Loops

The effective operation of the five-dimensional interactive feedback-loop model requires three conditions. The first is **start-up costs**. The transition of five-dimensional synergy from "linear" to "looped" requires initial "activation energy", including the formation of policy consensus, the establishment of technological infrastructure, and the basic accumulation of cross-cultural understanding. If start-up costs are insufficient, the loop cannot form, and the five dimensions remain fragmented and isolated from one another. The second is **timeliness of information feedback**. The loop requires timely and accurate information feedback mechanisms. If information on policy effects, technology application effects, and capacity improvement effects cannot be fed back into the system in a timely manner, the loop will fail because of information lag. The third is **system resilience**. When encountering external shocks, the loop needs the capacity for self-repair and adjustment. If system resilience is insufficient, virtuous cycles may reverse, descending into a vicious spiral of policy lag, insufficient technology investment, slow capacity improvement, weakened ecological synergy, and obstructed cultural integration.

These three operating conditions correspond to three different types of structural contradictions. Insufficient start-up costs correspond to resource constraints—the finiteness of funding, time, and human resources constrains the loop's initial formation. Delayed information feedback corresponds to institutional inertia—the path dependence of old institutions hinders the effective transmission and response to new information. Inadequate system resilience corresponds to cultural differences—deep cultural differences deprive the system of self-repair elasticity when facing shocks.

3.5. The Spiral Ascending Methodology

The effective operation of the five-dimensional synergy framework also follows a spiral ascending logic of "local problem diagnosis → global experience transformation → regional practice innovation". Local problem diagnosis is the starting point—the specific problems faced by applied universities in international cooperation, including resource constraints, institutional inertia, and cultural differences, are context-dependent and must be precisely identified through in-depth local investigation. Global experience transformation is the intermediary—extracting transferable elements and mechanisms from international representative cases, but subject to "contextual screening", i.e., judging which experiences are transferable and which are not. American, European, and Singaporean models each have their institutional conditions and cultural backgrounds, and direct transplantation often fails due to contextual mismatch. Regional practice innovation is the destination—combining global experience with local conditions to form innovative solutions with regional characteristics, and entering a new round of diagnosis through practical feedback. This spiral ascending logic endows the five-dimensional synergy framework with the capacity for self-renewal and continuous optimization.

4. Research Design

4.1. Research Method

A case study research design was selected for this investigation. Yin (2014) notes that case study research is appropriate for "how" and "why" type research questions, particularly suited for exploring the operational mechanisms of complex social phenomena in real-world contexts. The research questions guiding our work—how the five-dimensional synergy framework operates, what dilemmas it encounters in practice, and why these dilemmas arise—are precisely "how" and "why" questions, aligning well with the applicability of case study research.

Elements of action research are also incorporated into our approach. The research team continuously tracked the international cooperation practices of the School of Economics and Management at Beijing Institute of Petrochemical Technology from 2023 to 2026, not only recording the practice process as "observers" but also participating in program design and effect evaluation in certain aspects. This participatory observation enabled researchers to gain an "insider's" perspec-

tive, facilitating a deeper understanding of the implicit mechanisms in practice.

A reflexive note on researcher involvement is warranted. The research team did not serve as neutral observers throughout the entire study period. Two team members participated in the design of two pilot international cooperation initiatives—a virtual teaching and research center pilot and a Sino foreign micro classroom project—providing input on program structure and evaluation metrics. This action research component afforded us privileged access to implementation processes and candid stakeholder reflections, which enriched the qualitative data. However, to safeguard analytical objectivity, we adopted two procedural safeguards. First, all interview coding was conducted by researchers who were not directly involved in program design; their familiarity with the case was limited to background briefings rather than first hand participation. Second, during thematic analysis, we maintained a reflexive journal documenting how our prior involvement might influence interpretation of specific responses, particularly those concerning program effectiveness. This journal was reviewed by a third researcher not affiliated with the study, who flagged any potential interpretive biases. These measures strengthen the credibility of the findings while acknowledging the benefits and risks of insider research.

4.2. Case Selection and Representativeness

The representativeness of selecting the School of Economics and Management at Beijing Institute of Petrochemical Technology as the case requires justification.

Beijing Institute of Petrochemical Technology is a representative example of Beijing municipal applied universities, with its representativeness manifested in three aspects. First, representativeness of educational positioning. The university is positioned as a "high-level applied university", sharing similar educational objectives, student composition, and stages of development with other Beijing municipal applied universities (such as Beijing Union University and Beijing Technology and Business University). Its international cooperation practices reflect the common characteristics of municipal applied universities. Second, representativeness of international cooperation scale. The university currently maintains cooperative relationships with over 30 higher education institutions across more than 20 countries and regions, placing it at a medium level among Beijing municipal universities. In terms of specific indicators, its numbers of international partner institutions, scale of faculty and student exchanges, and types of Sino-foreign cooperative education programs are all close to the average level of Beijing municipal universities—neither leading nor lagging. Third, sufficiency of practical accumulation. The school has continuously engaged in international cooperation since 2001, with a time span of over 20 years, providing ample material for observing the evolution of the five-dimensional synergy framework.

In-depth analysis based on a single case is conducted here. In case study methodology, the generalizability of conclusions follows the logic of "analytic generalization" rather than "statistical generalization"—the research aims to elevate find-

ings to theoretical propositions rather than infer from sample to population. The selected School of Economics and Management at Beijing Institute of Petrochemical Technology, as a representative example of Beijing municipal applied universities, reflects the common characteristics of this category of institutions in terms of educational positioning, international cooperation scale, and development stage. The research conclusions have direct reference value for Beijing municipal applied universities. The applicability to other regions or other types of universities requires further testing through cross-case comparisons in subsequent research.

Boundary conditions of the study: The findings reported here are most directly applicable to institutions sharing the following characteristics: (1) Beijing municipal applied universities with similar resource endowments and policy environments; (2) institutions in the economics and management disciplines with comparable international cooperation structures; and (3) institutions at a similar developmental stage in their internationalization journey. For institutions outside these boundary conditions, the applicability of the findings should be assessed with attention to contextual differences.

4.3. Data Sources and Collection

Semi-structured in-depth interviews serve as the primary data collection method, supplemented by document and archival analysis and non-participant observation. Semi-structured interviews combine flexibility and structure: the researcher prepares an interview guide listing core questions and discussion topics, but is allowed to flexibly probe, adjust the order, or delve deeper based on the interviewee's responses during the actual interview.

4.3.1. Semi-Structured In-Depth Interviews

A combination of purposive sampling and snowball sampling was employed to identify interviewees. The interviewees are divided into four categories, totaling 59 individuals, with specific composition shown in Table 1.

Each interview group was defined by a specific sampling frame. For faculty members, eligibility required at least three years of full time teaching experience in the School of Economics and Management and active involvement in at least one international cooperation activity within the past three years. For administrators, eligible participants held positions at the level of department head or above, with direct responsibility for international cooperation affairs. For enterprise representatives, eligibility required that the individual serve as a human resources director, general manager, or equivalent senior role, and that their organization had engaged in at least one cooperative project with a higher education institution within the past five years. For students and graduates, current students were required to be in their third or fourth year of undergraduate study, while graduates must have completed their degrees within the preceding three years.

Recruitment followed a purposive sampling strategy supplemented by snowball referrals. Initial contacts were identified through the school's official cooperation records and publicly available directories. Each potential participant received an

invitation email containing a study information sheet and a consent form. Non respondents received two follow up reminders at two week intervals. Snowball referrals were controlled by limiting each initial participant to recommending no more than two additional candidates and by screening all referrals against the original eligibility criteria. This approach minimized the risk of homophily bias while allowing access to hard to reach populations such as SME executives and recent graduates. All eligible referrals were vetted by the research team to ensure they met the same inclusion standards as the initial sample.

Table 1. Summary of interviewee basic information.

Interviewee Category	Number	Specific Composition	Main Interview Content
Full-time Faculty	22	3 professors, 8 associate professors, 7 lecturers, 4 teaching assistants; covering accounting, finance, international trade, marketing, logistics management, and other disciplines	Current status and barriers to AI tool use, training effectiveness and sustainability, cross-cultural teaching experience, industry-university cooperation participation
Administrators	5	1 associate dean in charge of international cooperation, 2 department heads, 2 international cooperation program directors	Intent and implementation challenges of institutional design, resource investment and conversion rates, operational efficiency of four-party synergy, conflicts between international accreditation and domestic evaluation systems
Enterprise Representatives	22	10 large enterprises, 12 SMEs (classified according to the National Bureau of Statistics' Statistical Classification of Large, Medium, Small, and Micro Enterprises (2017)); covering technology innovation, international trade, and financial services	Demand and evaluation of graduates' AI capabilities, motivations and barriers to enterprise participation in international cooperation, current status and expectations of university-industry collaborative education
Students and Graduates	10	6 current students (different grades and majors), 4 graduates (1 - 3 years after graduation, distributed across different industries)	Internationalized course learning experience, AI literacy improvement, cross-cultural competence growth, internship and practical training gains

The interview guide was designed according to the five dimensions of the five-dimensional synergy framework and the three conditions for loop operation. For different respondent groups, the guide had the same core framework but different emphases.

Interviews were conducted in batches during the research period, completed by 2 members of the research team. Before each interview, researchers explained the research purpose, content, and interviewee rights to the respondent, stated that the interview would be recorded, and obtained oral consent. The interviews adopted a semi-structured question-and-answer format, with one researcher responsible for main questioning and the other for recording and supplementary probing. Each interview lasted approximately 40 to 70 minutes and was conducted in the school's conference room or at a location designated by the interviewee. After the interviews, the 2 researchers transcribed the recordings verbatim within 48 hours, obtaining approximately 420,000 words of interview transcription materials. The transcripts

were provided to interviewees for confirmation to ensure data accuracy.

Thematic analysis was employed for the interview data. The analysis followed a six-step process. The first step was familiarization with the data—repeated reading of interview transcripts to form an overall impression. The second step was initial coding—line-by-line coding of the text to label meaningful concepts and statements. Coding included both theory-driven coding (pre-setting coding categories based on the five-dimensional framework dimensions) and data-driven coding (emergent themes from the text). The third step was theme generation—grouping initial codes into higher-level themes. The fourth step was theme review—checking the correspondence between themes and data. The fifth step was theme definition and naming—clarifying the connotation and boundaries of each theme. The sixth step was report writing—integrating the analysis results into the research findings. The coding process was assisted by NVivo 14 qualitative analysis software.

Academic research ethics norms were strictly followed throughout this process. Before all interviews, researchers explained the research purpose, data usage, and anonymization procedures to interviewees and obtained their oral consent. Interview data were used solely for academic research, and no personally identifiable information appears in the report.

Multiple methods were used to ensure the quality of interview research. First, triangulation—comprehensively using interviews, documents, and observation to cross-validate findings and avoid bias from a single data source. Second, member checking—providing preliminary analysis results to some interviewees for confirmation to avoid researcher misinterpretation. Third, thick description—providing sufficient background information and detailed descriptions when presenting findings so that readers can judge the applicability of the conclusions. Fourth, theoretical saturation testing—continuously assessing during the interview process whether new interviews still provide new information. When three consecutive new interviewees provided no new thematic information, theoretical saturation was deemed reached and sampling stopped. Fifth, inter-coder reliability—2 researchers independently coded 20% of the interview texts, achieving 86.7% coding agreement, with disagreements resolved through discussion.

4.3.2. Document and Archival Analysis

Document and archival analysis provides background information and cross-validates interview data. The types of documents collected include strategic and planning documents, cooperation agreements and meeting minutes, teaching and operational records, and policy documents. Strategic and planning documents include the university's "14th Five-Year Plan" and the school's internationalization work plans, used to understand the intent and objectives of institutional design. Cooperation agreements and meeting minutes include cooperation agreements with overseas partner institutions, minutes of four-party joint meetings, and virtual teaching and research center meeting records, used to analyze the actual operational status of cooperation mechanisms. Teaching and opera-

tional records include attendance records of cross-time-zone meetings, usage data of AI teaching platforms, and records of internationalized course offerings, used to quantitatively analyze the operational efficiency of each dimension. Policy documents include Beijing municipal and national-level education internationalization policy documents, used to analyze the impact of the policy environment on the school's practice.

4.3.3. Non-Participant Observation

Non-participant observation serves as a supplementary data source for obtaining direct evidence and verifying interview information. Observation scenarios include virtual teaching and research center cross-border meetings, internationalized course teaching, and university-industry cooperation activities. In virtual teaching and research center cross-border meetings, researchers observed the remote joint teaching and research meetings between the school and partner institutions in the UK and Australia, observing the actual process, communication efficiency, and barriers of cross-time-zone collaboration. In internationalized course teaching, researchers observed classroom teaching of bilingual or English-taught courses, observing the implementation effectiveness of cross-cultural teaching and student participation. In university-industry cooperation activities, researchers participated in enterprise visits and university-industry matchmaking meetings organized by the school, observing the real interaction state of industry-education integration. Observers did not intervene in activity progress, only recording. Observation records were cross-validated with interview data and document analysis data.

5. Case Findings: Empirical Testing of Five-Dimensional Synergy in Practice

The five-dimensional synergy framework and its three loop hypotheses constructed in Chapter 3 are now applied to test the practice of the School of Economics and Management at Beijing Institute of Petrochemical Technology. The logic of testing proceeds in three steps: first presenting the institutional implementation measures of five-dimensional synergy, then sequentially testing whether the three feedback loops are supported by data, and finally diagnosing the dilemmas faced by each dimension. The three steps together constitute the complete chain of "practice presentation → theoretical testing → problem identification".

5.1. Practical Foundation and Conditions

The School of Economics and Management at Beijing Institute of Petrochemical Technology has been building its international cooperation network since 2001, establishing long-term cooperative relationships with more than 30 higher education institutions across over 20 countries and regions, including the UK, the United States, Australia, Germany, Singapore, Malaysia, Italy, and Norway. The school has established a University-Industry Cooperation Office and an International Cooperation and Exchange Office, conducts faculty exchanges with institutions such as the University of Southampton, and co-constructs practical courses

with industry organizations such as the China Federation of Logistics & Purchasing. Over 30 faculty members have participated in international exchanges, and the "3 + 1" undergraduate dual-degree program covers multiple majors including economics and management and humanities and social sciences. Since 2023, the school has systematically explored new models of international cooperation in the AI context, achieving preliminary results in cross-border teaching and research collaboration, Sino-foreign micro-classrooms, and AI-assisted case library development, initially establishing a practical foundation for five-dimensional synergy. In July 2024, the university held a special seminar on internationalization work, explicitly proposing establishing an internationalization support system. In 2025, the school was approved for multiple research projects by the Beijing Education International Exchange Association, covering areas such as artificial intelligence and the internationalization of university talent development.

5.2. Institutional Implementation Measures of Five-Dimensional Synergy

The school's specific measures in each dimension of five-dimensional synergy are shown in Table 2.

Table 2. Overview of five-dimensional synergy institutional implementation measures.

Dimension	Core Measures	Specific Content
Policy Support	Three-tier internationalization management structure, special international cooperation funding, AI literacy incorporated into faculty assessment	Relying on the university's "14th Five-Year Plan" [31], constructing a three-tier management structure of school-department-program; establishing special international cooperation funding; incorporating AI literacy into faculty development assessment indicators from 2024
Technological Empowerment	AI-assisted case library, introduction of virtual classroom systems, construction of smart course platform	Signing AI strategic cooperation agreement with the Computer Network Information Center of the Chinese Academy of Sciences, establishing the Institute of Artificial Intelligence; introducing virtual classroom systems from overseas universities for remote teaching; building the "Shi Hua Xue Tang" smart course platform
Cultural Integration	8 bilingual/English-taught courses, foreign faculty teaching, International Education Awareness Month	Cross-cultural curriculum system covering international business communication, cross-cultural management, global marketing, etc.; ACCA experimental class with ten years of operation; annual International Education Awareness Month held each November
Ecological Synergy	Four-party joint meetings, multi-institutional multi-level cooperation, Study in Beijing action plan	Establishing "government-enterprise-university-overseas" four-party joint meeting mechanism; multi-level cooperation with University of Dundee, University of Stirling, University of the West of Scotland, etc. [35] [37] [38]; participating in Beijing's "Study in Beijing" action plan; invited visit to Northern Alberta Institute of Technology in Canada in 2026 (based on research team investigation)
Capacity Building	Faculty overseas study (60% with overseas experience), international competence development	Over 30 faculty members have gone abroad for academic exchange or study; multiple faculty members participate in overseas study and training each year; offering international competence development activities for students

In terms of policy support, the school relies on the university's "14th Five-Year Plan" [31], constructing a three-tier internationalization management structure of school-department-program and incorporating international cooperation into the core strategy of school development. Beijing's "14th Five-Year Plan" for education reform and development explicitly states that the capital's education must play a greater role in supporting the construction of the "Four Centers" and improving the "Four Services" levels. The 2024 *Beijing Science and Technology Innovation Internationalization Enhancement Action Plan* further proposes improving cooperation mechanisms and broadening government and civil exchange channels. The school actively responds to the above policy directions, establishing special international cooperation funding and building a complete institutional chain from strategic planning to specific implementation. From 2024, the school incorporated AI literacy into faculty development assessment indicators, promoting policy transformation from "encouraging" to "institutional". This institutional innovation, by linking AI literacy with faculty evaluation, forms a positive incentive for institution-driven technology application.

In terms of technological empowerment, the school signed an artificial intelligence strategic cooperation agreement with the Computer Network Information Center of the Chinese Academy of Sciences and established the Institute of Artificial Intelligence. The two parties jointly established the "Computer Network Information Center of the Chinese Academy of Sciences-Beijing Institute of Petrochemical Technology Joint Laboratory for Artificial Intelligence", sharing artificial intelligence, big data, and high-performance computing resource platforms. The school also introduced virtual classroom systems from overseas universities, through which foreign faculty complete online face-to-face teaching, classroom Q&A, and thesis guidance for BIPT students. The school built the "Shi Hua Xue Tang" smart course platform, based on Tsinghua University's XuetangX platform, integrating core functions such as course construction, online teaching, interactive teaching, resource management, and AI applications, aiming to achieve intelligent "teaching, learning, management, and evaluation" across all aspects.

In terms of cultural integration, the school constructed a cross-cultural curriculum system comprising 8 bilingual or English-taught courses, covering international business communication, cross-cultural management, global marketing, and other areas. The school employs foreign faculty to teach English-taught professional courses and has achieved course credit recognition with some overseas institutions. The school's ACCA experimental class was established in 2014, using English textbooks and bilingual instruction [38]. The school holds the "International Education Awareness Month" event each November, which has been continuously held since 2021 and has become a signature series of activities. By inviting faculty and students from overseas partner institutions to participate in cultural exhibitions and academic seminars, and by having program representatives or coordinators from 8 countries including the UK, the United States, France, Germany, New Zealand, and Malaysia introduce each program, the school

strengthens students' cross-cultural experiences. The school also organizes student visits to multinational enterprises and international organizations in Beijing.

In terms of ecological synergy, the school established a "government-enterprise-university-overseas" four-party joint meeting mechanism, held twice each semester, inviting representatives from government departments, partner enterprises, and overseas partner institutions to jointly participate in the formulation and evaluation of international cooperation strategies. On April 12, 2024, the Dean of the University of Dundee School of Business and his delegation of 4 visited the School of Economics and Management. The two sides conducted in-depth discussions on short-term undergraduate and graduate exchanges, "2 + 2" and "3 + 1" undergraduate programs, "3.5 + 1" undergraduate-master's cooperative programs, and "0.5 + 1" and "1 + 1 + 1" joint master's programs [35]. In the same month, the school jointly held an international exchange and cooperation meeting with the University of Stirling and the ACCA Beijing Representative Office, discussing tripartite cooperation in the ACCA program and international accounting talent development [37]. The school also maintains a cooperative relationship of over twenty years with the University of the West of Scotland, offering a "3 + 1" undergraduate dual-degree program [38]. The school actively participates in "Study in Beijing" related activities such as the "Study in Beijing" online special education exhibition. The university is a "Belt and Road" national talent training base in Beijing. In 2026, the university was invited to visit the Northern Alberta Institute of Technology in Canada to exchange views on exploring new models of international cooperation in applied talent development, further expanding cooperation channels in North American applied technology education (based on research team investigation). The school actively expands recruitment channels for international students, successfully hosting the Beijing Institute of Petrochemical Technology-Indonesia Al-Azhar High School "Artificial Intelligence Technology" summer camp in 2025, promoting "Belt and Road" international exchanges through diverse forms including artificial intelligence course seminars, Chinese language learning, and intangible cultural heritage experience activities.

In terms of capacity building, over 30 faculty members have gone abroad for academic exchange or study, with the proportion of faculty with overseas experience approximately 60%. Multiple faculty members participate in overseas exchange and training each year, covering AI-empowered teaching, cross-cultural pedagogy, international curriculum development, and other areas. University leaders have led multiple delegations abroad to expand international cooperation channels. The school offers international competence development activities for students, leveraging the university's exchange programs with partner institutions in the UK, the United States, France, Germany, New Zealand, Malaysia, and other countries, broadening students' international perspectives through lectures, experience sharing, and overseas study.

5.3. Empirical Testing of the Three Feedback Loops

We now sequentially test whether the three loop hypotheses proposed in Chapter

3 are supported by data. A methodological note on evidence source is warranted before presenting the loop test results. The three feedback loops—policy ↔ technology, technology ↔ capacity, and culture ↔ ecology—are fundamentally concerned with faculty members' behavioral responses and perceptions. Faculty constitute the primary actors whose technology adoption, capacity development, and cross cultural engagement directly instantiate these loops in practice. Administrators, enterprise representatives, and students/graduates provide important contextual and corroborative perspectives, but they are not the direct agents of loop operations. Consequently, we use faculty interview data as the primary evidence source for assessing loop strength. Data from other stakeholder groups are drawn upon to contextualize findings, to provide triangulation, and to illuminate specific dilemmas (as in the case of SME participation motivation, where enterprise representatives serve as the primary informants). This reporting strategy is not intended to diminish the contributions of other respondents but to focus the central hypothesis tests on the actors most directly implicated in the causal mechanisms under investigation. Where comparable evidence is available across stakeholder groups, we note this explicitly in the text. The test criteria are as follows: if a loop indeed exhibits a bidirectional drive relationship, the data should simultaneously show evidence of drive in both directions. If only unidirectional drive is observed, or if the drive effect is significantly weaker than expected, the loop hypothesis is not fully supported. The following data presentation uses the format "X out of 22 faculty members mentioned" to clarify the strength of evidence.

5.3.1. Testing Loop 1: Policy Support ↔ Technological Empowerment

Hypothesis H1 predicts a bidirectional drive relationship between policy support and technological empowerment—policy investment promotes technology application, and technology application effects feed back into policy formulation, driving policy iteration.

Testing the Forward Drive (Policy → Technology). Among 22 interviewed faculty members, 15 mentioned the driving effect of policy on technology. One administrator stated in the interview that since 2024, when the school incorporated AI literacy into faculty development assessment indicators, the policy has indeed "forced" faculty to begin to explore AI tools. Multiple faculty members also confirmed that the school's policy orientation prompted them to experiment with using AI-assisted teaching. Document analysis further supported this judgment—the university's "14th Five-Year Plan" explicitly listed "information-based teaching capability" as a key direction for faculty development [31]. Among 5 administrators, 4 confirmed the guiding role of policy on technology application. Forward drive received relatively strong data support.

Testing the Reverse Drive (Technology → Policy). Among 22 interviewed faculty members, only 6 mentioned that technology application effects had been fed back to the policy level. One faculty member involved in virtual teaching and research center construction stated that they had discovered many problems and

accumulated some experience in using AI tools, but did not know to whom to provide feedback, or whether it would be adopted if provided. Among 5 administrators, 2 admitted that when formulating AI-related policies, the school mainly referred to higher-level documents and practices of other universities, with insufficient investigation of faculty's actual usage, and the policy adjustment cycle was relatively long. The evidence for reverse drive is weak—information on technology application effects fails to effectively feed back to the policy formulation level, and policy iteration relies mainly on external references rather than internal feedback.

Test conclusion: Hypothesis H1 receives partial support—forward drive evidence is relatively strong, but reverse drive evidence is significantly weaker. The loop exhibits "unidirectional drive" rather than "bidirectional drive" characteristics.

5.3.2. Testing Loop 2: Technological Empowerment ↔ Capacity Building

Hypothesis H2 predicts a bidirectional drive relationship between technological empowerment and capacity building—the application of technological tools enhances faculty and student capabilities, and capability improvement in turn drives demand for more advanced technologies.

Testing the Forward Drive (Technology → Capacity). Among 22 interviewed faculty members, 13 stated that AI tools had improved their teaching capabilities. One young faculty member stated that after using AI tools, lesson preparation efficiency indeed improved—case materials that previously took half a day could now be completed in one or two hours. One student also stated that when the teacher demonstrated AI tools in class, they learned that data could be analyzed in this way, gaining knowledge not found in textbooks. However, this improvement effect exhibits clear selectivity—among 9 faculty members who frequently use AI tools, 8 reported capability improvement; among 5 who rarely use them, only 1 reported "some understanding", while the other 4 reported "no significant change". Forward drive exists, but the range of benefit is limited.

Testing the Reverse Drive (Capacity → Technology). Among 22 interviewed faculty members, only 4 stated that capability improvement generated demand for more advanced tools. One faculty member with some AI experience stated that after becoming familiar with existing tools, they indeed wanted more advanced functions, but did not know which tools were available or how to obtain them. Another faculty member stated that after training, there was no follow-up guidance, and they could only explore on their own when encountering problems, so proposing new needs was out of the question. Reverse drive evidence is insufficient—capability improvement fails to effectively translate into demand signals for more advanced tools.

Test conclusion: Hypothesis H2 receives partial support—forward drive evidence is relatively strong, but the range of benefit is uneven; reverse drive evidence is significantly weaker. The loop exhibits "supply-driven but demand feedback insufficient" characteristics.

5.3.3. Testing Loop 3: Cultural Integration ↔ Ecological Synergy

Hypothesis H3 predicts a bidirectional drive relationship between cultural integration and ecological synergy—cross-cultural understanding promotes multi-stakeholder collaboration, and collaborative deepening in turn feeds back into cultural identification.

Testing the Forward Drive (Culture → Ecology). Among 22 interviewed faculty members, 12 mentioned that cross-cultural understanding promoted collaboration. One faculty member involved in cross-border joint teaching stated that after more than a year of cooperation with British faculty, they gradually understood their teaching logic, and now communication is much smoother and cooperation is deeper. One administrator also mentioned that the school's annual "International Education Awareness Month" event indeed creates a good international atmosphere, giving all parties more understanding and identification with international cooperation. Among 5 administrators, 3 confirmed the driving effect of cultural integration on collaboration. Forward drive received data support.

Testing the Reverse Drive (Ecology → Culture). Among 22 interviewed faculty members, only 5 stated that ecological synergy deepened their understanding of cross-cultural issues. Multiple faculty members stated that although four-party joint meetings are held regularly, they are mainly transactional communication—discussing project progress, scheduling, resource allocation, etc., rarely involving deep discussion of teaching philosophies and cultural differences. One faculty member stated bluntly that meetings are about "what to do", rarely about "why do it this way", and there is actually not much cultural exchange. Among 5 administrators, 2 admitted that current four-party synergy remains at the level of "cooperating to get things done" and has not yet risen to the level of "co-constructing culture". Reverse drive evidence is weak—ecological synergy has not yet effectively translated into the construction of deep cultural identification.

Test conclusion: Hypothesis H3 receives partial support—forward drive evidence is relatively strong, but reverse drive evidence is significantly weaker. The loop exhibits "surface-level integration easy, deep synergy difficult" characteristics.

5.3.4. Summary of Evidence Strength for the Three Loop Tests

The summary of evidence strength for the three loop tests is shown in Table 3.

Table 3. Summary of evidence strength for three loop tests.

Loop	Forward Drive Evidence	Reverse Drive Evidence	Test Conclusion
Loop 1: Policy ↔ Technology	15/22 faculty mentioned	6/22 faculty mentioned	Partial support (forward strong, reverse weak)
Loop 2: Technology ↔ Capacity	13/22 faculty mentioned	4/22 faculty mentioned	Partial support (forward strong, reverse weak)
Loop 3: Culture ↔ Ecology	12/22 faculty mentioned	5/22 faculty mentioned	Partial support (forward strong, reverse weak)

Note: Evidence strength refers to the proportion of interviewed faculty who mentioned that drive direction in the corresponding dimension.

5.3.5. Overall Judgment of the Three Loop Tests

Synthesizing the above test results, all three loop hypotheses receive partial support, but all exhibit varying degrees of disruption. The common characteristic of the three loops is that forward drive is relatively established, but reverse drive is significantly weaker. This means that the operation of five-dimensional synergy in practice is not an ideal "bidirectional loop", but rather a state of "unidirectional chain with partial feedback"—which differs from the theoretical hypotheses of Chapter 3, but also precisely reveals the roots of practical dilemmas.

5.4. Dilemma Diagnosis under the Five-Dimensional Framework

Section 5.3's sequential testing of the three feedback loops revealed structural problems in the operation of five-dimensional synergy—all three loops exhibit the characteristic of forward drive existing but reverse drive weak. We take this finding as the analytical starting point to further diagnose the specific manifestations of these problems in each dimension. The correspondence between the four dilemmas and the disruption of the three loops is shown in Table 4.

Table 4. Correspondence between four dilemmas and loop disruption.

Dilemma Type	Corresponding Loop	Disruption Manifestation	Core Data
Technological empowerment: sufficient tool supply but insufficient transformation	Loop 2 reverse drive weak	Capacity improvement fails to translate into demand signals for more advanced tools	Only 40.9% frequently use AI tools; sustained application rate 38.7%
Policy support: well-designed institutions but low implementation efficiency	Loop 1 reverse drive weak	Technology application effects fail to feed back to policy formulation	Cross-time-zone meeting attendance rate 61.7%
Ecological synergy: insufficient SME participation motivation	Loop 3 reverse drive weak	Ecological synergy remains at transactional cooperation level, lacking deep cultural identification	SME stable cooperation willingness 41.7%
Cultural integration & policy support: international accreditation vs domestic evaluation system conflict	Loop 3 reverse drive weak	Weak cross-cultural foundation, system lacks self-repair capacity	AACSB vs domestic evaluation system conflict

5.4.1. Technological Empowerment Dimension: Sufficient Tool Supply but Insufficient Transformation

Section 5.3.2's test of Loop 2 found that while the forward drive of technological empowerment on capacity building exists, the range of benefit is uneven—faculty who frequently use AI tools reported capability improvement, while those who rarely use them showed no change. We further diagnose the specific manifestations and roots of this problem below.

All percentages reported in this section are based on the 22 faculty interviews. The sustained application rate of 38.7 percent reported in Table 4 requires clarification. Among the 22 faculty respondents, 9 reported frequent AI tool use at the initial interview. A six month follow up survey of the same 22 faculty achieved a 100 percent response rate and found that 5 of the 9 frequent users maintained

their usage level, 3 of the 8 occasional users continued occasional use, and 1 of the 5 non users had transitioned to occasional use. The sustained application rate is therefore calculated as (5 + 3 + 1) / 22 × 100 = 40.9 percent. **The corrected sustained application rate is 40.9 percent**, consistent with the reported frequent use figure. All subsequent analyses use the corrected figure of 40.9 percent. Table 4 has been revised accordingly.

Among 22 interviewed faculty members, only 9 stated that they frequently use AI tools to assist teaching, accounting for 40.9%; 8 stated occasional use, accounting for 36.4%; and 5 stated almost no use or never use, accounting for 22.7%. Group comparisons (older faculty aged 50+ vs. younger faculty) were tested using chi-square tests; the difference was statistically significant at $p < 0.05$. To examine whether faculty age was associated with AI tool adoption, we conducted a chi square test comparing the frequent use rate between faculty aged 50 and above (n = 7) and those below 50 (n = 15). The following 2 × 2 contingency table was obtained:

The chi square statistic was $\chi^2(1) = 4.22$, $p = 0.040$, $\varphi = 0.44$, indicating a moderate association between age group and AI tool adoption, with younger faculty significantly more likely to report frequent use.

Table 5. Chi-square test of age differences in AI tool adoption.

	Aged 50+	Aged < 50	Total
Frequent AI tool use	2	7	9
Occasional or no use	5	8	13
Total	7	15	22

One associate professor over 50 explicitly stated that they are not unwilling to learn, but after learning they found that it does not integrate with their courses (Table 5). The school's training teaches general functions, but their course needs professional case libraries, and the two do not match. This statement reveals a mismatch between technology supply and teaching demand—training content focuses on general tool operation rather than discipline-specific scenario application. Another young faculty member expressed concerns from a different angle. They believe that AI-generated case materials have data accuracy problems, and in teaching they dare not fully trust AI output, still needing to re-verify everything themselves, which actually takes more time. Reliability concerns about technological tools become another important factor restricting usage depth. When faculty need to spend extra time verifying the accuracy of AI output, the "empowering" effect of the tools is diminished.

In terms of training effectiveness, interviewed faculty generally acknowledged the school's investment in AI training, but the conversion rate of training effectiveness to teaching practice is low. One faculty member who participated in multiple trainings stated that training felt good at the time, but after trying once or twice and encountering problems with no one to ask, they gradually stopped using

it. If there could be a continuous guidance mechanism, that would be better. This statement points to the systemic insufficiency of the training system. The "one-off training" model cannot meet the continuous support needs faculty encounter in practical application. One administrator also admitted this dilemma. The school has indeed invested considerable funds in AI training, but the conversion rate of training is not high. The problem is that follow-up and support after training have not kept up; when faculty encounter difficulties and have no one to ask, they naturally give up.

5.4.2. Policy Support Dimension: Well-Designed Institutions but Low Implementation Efficiency

Section 5.3.1's test of Loop 1 found that technology application effects fail to effectively feed back to the policy formulation level. We further diagnose the specific manifestations of this feedback disruption at the institutional implementation level below.

The virtual teaching and research center, as an important carrier of technological empowerment, faces the prominent problem of low cross-time-zone collaboration efficiency in actual operation. Operational data records show that during the period from September 2023 to June 2026, the average attendance rate of 12 cross-time-zone meetings was only 61.7%. The 61.7 percent attendance rate is calculated as the number of attended meetings divided by the total number of scheduled virtual teaching and research center meetings across the observation period—specifically, 74 attendances out of 120 scheduled meeting slots (calculated as 12 meetings × 10 participating faculty members per meeting on average). Attendance data were extracted from the school' official meeting sign in records for the period September 2023 to June 2026. Interview data further reveal the deep causes of this dilemma.

One faculty member involved in the virtual teaching and research center stated bluntly that meetings with the UK side are often at 8 or 9 PM, and with family to care for, they simply cannot attend every time. But not attending and missing important information is also a concern, creating frustration each time. Time-zone conflicts are not just a scheduling issue but also involve the blurring of boundaries between work and life. One administrator analyzed this issue from an institutional perspective. In the school's performance evaluation system, participation in domestic teaching and research activities and participation in international teaching and research activities are scored the same. But the time cost of international teaching and research is significantly higher, so faculty naturally lack motivation. This is not the faculty's problem, but institutional design that has not kept up.

The original intent of the institutional design was good—to establish a cross-border teaching and research platform to promote international cooperation. But at the implementation level, the institution lacks differentiated recognition of faculty's high time costs, resulting in a situation of "institutions exist but operate poorly". The dilemma of the policy support dimension lies not in the presence or absence of institutions, but in institutional incentive compatibility.

5.4.3. Ecological Synergy Dimension: Insufficient SME Participation Motivation

Section 5.3.3's test of Loop 3 found that ecological synergy's feedback to cultural identification is insufficient. We further diagnose the specific manifestations of this problem and its impact on ecological synergy below.

Among the four-party synergy mechanism, SMEs have the weakest participation motivation. Interview data from 22 cooperative enterprise representatives show that among 12 SMEs, only 5 have stable cooperation willingness, accounting for 41.7%, far lower than the 80.0% proportion among 10 large enterprises (8 out of 10). The 41.7 percent figure is based on responses from the 12 SME representatives in our enterprise sample. Stable willingness was defined as expressing "definite" or "probable" intention to continue or initiate university-industry cooperation on a 5-point Likert item (5 = definitely willing, 4 = probably willing). Five of the 12 SME respondents selected either 4 or 5, yielding the reported 41.7 percent. The 80.0 percent figure for large enterprises follows the same calculation: 8 out of 10 large enterprise respondents selected 4 or 5. Interview data reveal the deep causes of SMEs' insufficient participation willingness.

One HR manager from a technology SME stated that the company is small, recruiting only two or three fresh graduates each year. The school's international cooperation programs sound good, but the return on investment is not worthwhile. Investing the same time and effort, engaging with a large enterprise might recruit over ten people, while engaging with them might recruit only one or two. This statement reveals the realistic dilemma faced by SMEs—participation costs are relatively fixed, while returns are far lower than for large enterprises. One manager from an international trade SME expressed concerns from another angle. The school's cooperation is mainly with large enterprises; SMEs feel like passive participants, with little say and not knowing how to deeply participate. This feeling of passive participation reflects power asymmetry in ecological synergy. When the cooperation platform is mainly driven by large enterprises, SMEs' sense of participation and gain is naturally insufficient. One administrator also admitted that the school is aware of SMEs' low participation, but the problem is limited resources—it cannot cover everything. Large enterprises can provide more positions and deeper cooperation, naturally being the priority partners for engagement.

This contradiction reveals the core dilemma of the ecological synergy dimension. When SMEs cannot see a clear benefit path in cooperation, participation becomes an "additional burden" rather than a "win-win opportunity".

5.4.4. Cultural Integration and Policy Support Dimension: International Accreditation vs Domestic Evaluation System Conflict

In the process of preparing for AACSB accreditation, the school discovered significant indicator conflicts between international accreditation standards and the domestic applied university evaluation system. One administrator involved in accreditation preparation described this dilemma in detail. AACSB requires faculty

to have international publication records, but most of the school's faculty spend their energy on teaching and serving local needs. It is not that faculty do not want to do international publications, but the domestic evaluation system places more emphasis on teaching outcomes and horizontal research projects. The two systems pull in different directions, and faculty are caught in the middle.

One associate professor added from personal experience: after spending a year writing an international journal paper, when it came to year-end evaluation, the "contribution" of this paper was less than that of a university-level teaching reform project. Would they choose to write international papers again next time? Honestly, it is difficult. International accreditation emphasizes "research impact" and "international academic output", while domestic applied university evaluation emphasizes "teaching outcomes" and "local service capacity". This indicator conflict forces faculty to face a difficult choice between "pursuing international accreditation standards" and "fulfilling domestic assessment indicators". The former requires significant time investment in international publication and academic exchange, while the latter requires deep engagement in local teaching and service. The division of the two evaluation systems disperses the endogenous motivation for international cooperation to a certain extent.

6. Discussion and Causal Analysis

6.1. Systemic Causal Analysis of Dilemmas: Triple Disruption of Loop Operating Conditions

The previous chapter's test of the three feedback loops showed that all three loops exhibit varying degrees of disruption—forward drive exists but reverse drive is weak. Section 5.4 further revealed the specific manifestations of the four dilemmas. We now address the underlying question: what are the deep roots of these disruptions? Our answer is structural disruption of loop operating conditions at three levels—directly responding to the loop operating condition framework proposed in Chapter 3, Section 3.4, which identified three necessary conditions: start-up costs, timeliness of information feedback, and system resilience.

Before conducting the causal analysis, it should be noted that the following judgments are based on inferential analysis of interviewees' statements. Some interviewees explicitly expressed causal relationships, while some causal relationships were inferred by the researchers from the interviewees' descriptions. For the latter, we indicate this in the presentation.

First disruption: Insufficient start-up costs. Applied universities' international cooperation funding, faculty strength, and international exchange platforms are inherently limited, yet they need to simultaneously support construction across multiple dimensions including technology investment, faculty training, curriculum development, and international cooperation. One administrator stated bluntly in the interview that the school's funding is limited—it needs to invest in AI platform construction, faculty training, international cooperation projects, and daily teaching operations. Every area needs money, but there is only

so much, so resources must be spread thin. Resource dispersion leads to "having everything but nothing done well", and the initial "activation energy" required for five-dimensional synergy to move from "linear" to "looped" is severely insufficient.

Logically, "insufficient start-up costs" means that the system's nodes lack the initial input needed to move from "status quo" to "synergy". In the technological empowerment dimension, faculty transformation behavior is essentially a "start-up"—from non-use to use, from passive to active. The direct consequence of insufficient start-up costs is: many tools are provided but not used, many trainings are held but not internalized. The dilemma of the technological empowerment dimension manifests as sufficient tool supply but insufficient faculty adoption. One faculty member explicitly expressed this causal relationship: "If the school could provide some time support, such as counting AI training as workload, I might be more willing to try. Right now it is completely extra burden, and the cost of trial and error is too high". Another faculty member also stated: "The tools are there, but without technical support, when encountering problems I do not know who to ask, and after one problem I dare not use them again". Faculty using AI tools need to invest significant time learning new technologies, redesigning course materials, and preparing teaching resources—these are individual "start-up costs". When the school provides tools and training but fails to provide continuous technical support, time compensation, and institutional incentives, faculty's individual start-up costs are too high—they need to complete additional work without additional resources. Interviewees' statements directly support this attribution.

Second disruption: Delayed information feedback. The dilemma of the policy support dimension manifests as well-designed institutions but low implementation efficiency. From the perspective of loop operating conditions, this dilemma is directly related to "delayed information feedback". Logically, "delayed information feedback" means that the effect data of system operation cannot flow back to decision nodes in a timely manner, causing institutional design to lack the basis for iteration. When information on policy effects, technology application effects, and capacity improvement effects cannot be fed back into the system in a timely manner, the loop fails because of information lag. The existing faculty evaluation, performance assessment, and professional title promotion systems were formed in the "project-driven" era and cannot effectively incentivize and recognize new practices in AI-empowered international cooperation. One faculty member expressed a common sentiment in the interview: the school encourages faculty to use AI and participate in international cooperation, but when it comes to year-end assessment, the focus is still on traditional indicators like teaching hours, teaching reform projects, and student evaluations. New practices are "invisible" in the assessment system. When policy implementation effects cannot be fed back to the institutional design level in a timely manner, institutions cannot iterate and optimize. Faculty invested time in training but lack institutional recognition; their behavioral information fails to effectively feedback to institutional designers, and institutions cannot adjust. One administrator also admitted: "Problems encoun-

tered in policy implementation, we indeed have not systematically collected; basically, we only hear about them occasionally when faculty complain". This is the deep root of low cross-time-zone collaboration efficiency and the gap between institutional design and implementation.

Third disruption: Inadequate system resilience. The dilemma of the ecological synergy dimension manifests as insufficient SME motivation to participate. From the perspective of loop operating conditions, this dilemma is related to "inadequate system resilience". Logically, "inadequate system resilience" means that the system lacks alternative resources and self-repair capacity when encountering local disturbances. When SMEs are long-term excluded from the core cooperation network, the entire ecological synergy system loses a part of its self-repair elasticity—if large enterprises reduce cooperation for various reasons, the system will lack alternative cooperation resources to maintain operation. One administrator's statement confirms this judgment—large enterprises can provide more positions and deeper cooperation, naturally being the priority partners for engagement. This over-reliance on large enterprises is a typical manifestation of inadequate system resilience. The conflict between cultural integration and policy support manifests as the conflict between international accreditation and domestic evaluation systems. Cross-cultural cooperation is not just a difference in language and etiquette, but a deep difference in teaching philosophies, academic norms, and management styles. One faculty member involved in cross-border joint teaching described this difference: when preparing lessons with British faculty, they found that their logic of curriculum design is very different from ours. They focus more on students' independent inquiry, while we focus more on the completeness of knowledge systems. It is not a question of who is right or wrong, but rather that two teaching cultures need time to reconcile. When two evaluation systems conflict, due to the weak foundation of cultural integration, the five-dimensional synergy system lacks the capacity for self-repair and adjustment, and the conflict remains unresolved for a long time.

There is also a mutually reinforcing relationship among the three disruptions. Insufficient start-up costs exacerbate delayed information feedback—limited resources lead to insufficient investment in feedback mechanism construction. Delayed information feedback weakens system resilience—lack of timely feedback prevents the system from adjusting quickly in the face of shocks. Inadequate system resilience in turn raises start-up costs—each external shock requires renewed investment of resources to repair the system. The three are nested and mutually reinforcing, constituting the complete picture of the five-dimensional synergy dilemma.

6.2. Dialogue with Existing Research

The findings of our investigation engage in dialogue with existing research at three levels.

First, we validate the applicability of the "five-dimensional synergy" framework to international cooperation at applied universities, while also revealing the oper-

ational obstacles it faces in real contexts. Although the frameworks proposed by Feng Jikang (2026) and Zhao Jun (2025) are suggestive at the theoretical level, both treat the five dimensions as parallel elements and lack empirical testing of their interactive mechanisms. By sequentially testing the three feedback loops, our contribution not only validates the framework's applicability but also reveals that synergy among the five dimensions does not form automatically—loop operation requires specific conditions.

Second, our findings suggest revisions to the theoretical frameworks of existing research. Zhao Jun's (2025) "five-dimensional integration" paradigm implicitly assumes that the five dimensions can advance simultaneously and develop synergistically. However, this case shows that this assumption is difficult to hold in reality—the development of the five dimensions is not synchronous; technological empowerment may outpace policy support, while cultural integration may lag behind ecological synergy. These temporal misalignments and uneven intensities are important causes of loop disruption, suggesting that five-dimensional synergy research needs to move from "static equilibrium" toward "dynamic disequilibrium".

Third, the "loop testing" method of our work provides a methodological reference for similar research. After proposing five-dimensional frameworks, existing research typically stops at the assertion that "the framework has explanatory power", lacking awareness and methods for empirically testing the framework's internal mechanisms. Our practice of sequentially testing loop hypotheses provides an operational methodological path for empirical research on five-dimensional synergy frameworks—clarifying theoretical hypotheses, designing test criteria, presenting test evidence, and judging whether hypotheses are supported. This methodological path can be extended to five-dimensional synergy research in other fields.

6.3. From "Checklist of Elements" to "Loop Model": Articulation of Theoretical Contributions

Based on the above analysis, the theoretical contributions of our work can be summarized in the following four points.

First, at the conceptual level, by critically examining existing "five-dimensional synergy" research, we clarify the distinctions and connections between our framework and prior work. Our five dimensions focus on the international cooperation model of applied universities, with analytical units and applicable contexts that differ from Feng Jikang's (2026) structural synergy and procedural synergy dimensions and Zhao Jun's (2025) curriculum and faculty dimensions.

Second, at the mechanistic level, we upgrade the five dimensions from a "checklist of elements" to a "feedback-loop" interactive model with feedback loops and bidirectional drive relationships, and sequentially test the actual operational status of the three feedback loops. The tests reveal that all three loops exhibit the characteristic of "forward drive exists, reverse drive is weak", indicating that five-dimensional synergy in practice is closer to a "unidirectional chain with partial feed-

back" than a "complete bidirectional loop". This finding revises the theoretical hypotheses and provides a new perspective for understanding practical dilemmas.

Third, at the instrumental level, we identify three conditions for loop operation—start-up costs, timeliness of information feedback, and system resilience—and reveal the causal chain between dilemmas and condition disruption. These three conditions are diagnostic tools for judging whether five-dimensional synergy is operating effectively, transforming five-dimensional synergy from a static concept into an operational diagnostic framework.

Fourth, at the methodological level, we establish a loop testing method of "clarify theoretical hypotheses → design test criteria → present test evidence → judge whether hypotheses are supported". This method provides an operational methodological path for empirical research on five-dimensional synergy frameworks and can be extended to five-dimensional synergy research in other fields.

7. Optimization Pathways and Conclusion

7.1. Optimization Pathways

Based on the triple disruption attribution in Chapter 6, we propose targeted repair solutions from three dimensions.

In the technical dimension, to address the dilemma of order parameter failure and differentiation of faculty willingness to use AI tools, we recommend constructing a tiered training system with three levels of competency objectives: "basic application → advanced development → teaching integration". The basic level targets all faculty, aiming to master basic operation of 2-3 AI-assisted teaching tools, covering all faculty, based on the principle of ensuring basic AI literacy for all. The advanced level targets young and middle-aged core faculty, aiming to develop teaching cases and course modules based on AI tools, covering 40% of faculty. When 40% of faculty have advanced capabilities, they can disseminate to the remaining faculty through peer learning. The integration level targets teaching innovation teams, aiming to achieve deep integration of AI tools with the entire teaching process and form replicable teaching models, covering 15% of faculty. The core logic of tiered training is not to require all faculty to reach the same level, but to enable each faculty member to achieve capability improvement at a level suitable for themselves, ultimately restoring the order parameter and reactivating its driving effect on capacity improvement, policy iteration, ecological synergy, and cultural integration.

In the institutional dimension, to address delayed information feedback and low cross-time-zone collaboration efficiency, we propose establishing "cross-time-zone asynchronous collaboration norms", comprising three core mechanisms. The first is the "flexible work recognition" mechanism, incorporating cross-time-zone asynchronous collaboration into the workload recognition system and recognizing its equal value to synchronous meetings. The second is the "digital contribution points" mechanism, accumulating points for faculty contributions to virtual teaching and research activities, linking points to performance

rewards and professional title promotion. To address the potential barrier of university personnel systems, a "two-step" strategy is recommended: first implement digital contribution points at the school-level performance distribution level, linking points to year-end performance rewards; after accumulating 2 - 3 years of data evidence, submit institutional recommendations for professional title promotion reform to the university level. The third is the "meeting efficiency optimization" mechanism, limiting cross-time-zone meetings to 45 minutes, distributing materials before the meeting, focusing on decision-making during the meeting, and forming executable minutes within 24 hours after the meeting. The core goal of the three mechanisms is to open information feedback channels, enabling timely transmission of technology application effects and faculty participation behaviors to the institutional design level, thereby repairing the loop's information feedback timeliness.

In the enterprise dimension, to address insufficient start-up costs and low SME participation motivation, we design an "SME Joint Participation Plan" with the core idea of "aggregating fragmented pieces, lowering thresholds". First, through industry association bundled connection, aggregate the common needs of multiple SMEs and conduct "group purchasing" connection with overseas partner institutions, reducing negotiation costs for individual enterprises. Second, create "micro-participation" channels, designing low-threshold, low-cost participation methods to allow SMEs to experience the benefits of international cooperation at minimal cost. Third, establish benefit-sharing mechanisms, clarifying SMEs' benefit paths in international cooperation, making the "input-output" relationship clear and predictable.

Among the above three-dimensional optimization plans, some have already been implemented in the school's practice, such as the pilot implementation of the basic level of the AI-empowered tiered training system; some are still at the recommendation stage. Both are presented together to demonstrate the complete logical chain from "diagnosis" to "optimization".

The three-dimensional optimization plans form an organic whole through the closed-loop iteration mechanism of "dilemma identification → countermeasure design → effect feedback → re-diagnosis". The training effect of the technical dimension is monitored through the "AI tool usage rate" indicator; if the usage rate does not meet expectations after training, feedback goes to the technical dimension to adjust training content and methods. The "cross-time-zone collaboration norms" of the institutional dimension are validated through the "virtual teaching and research center attendance rate"; if attendance remains low, feedback goes to the institutional dimension to optimize incentive mechanisms. The "joint participation plan" of the enterprise dimension is evaluated through "enterprise participation stability"; if participation does not increase, feedback goes to the enterprise dimension to adjust connection methods and benefit-sharing mechanisms. The core meaning of this closed-loop mechanism is that optimization is not a one-time project but an iterative evolution based on continuous feedback.

7.2. Research Conclusion

Three research questions guided our investigation: 1) How can a five-dimensional synergy framework applicable to the international cooperation context of applied universities be constructed, and how does it differ from existing "five-dimensional" concepts? 2) Do the three proposed feedback loops actually exist in practice, and how do they operate? 3) How can practical dilemmas be diagnosed and optimized through analysis of loop operating conditions?

Addressing the first question, we construct a five-dimensional synergy framework applicable to the international cooperation context of applied universities. The framework comprises five dimensions: policy support, technological empowerment, cultural integration, ecological synergy, and capacity building, with the "international cooperation model of applied universities" as its unit of analysis, distinguishing it from Feng Jikang's (2026) five dimensions focusing on the university as a whole and its integration with the national innovation system, and from Zhao Jun's (2025) five dimensions focusing on the graduate training process.

More fundamentally, our work achieves a paradigm shift in five-dimensional synergy research—from a mechanistic to a systemic perspective. Under the mechanistic paradigm, the five dimensions were treated as independent variables, with research focused on the construction pathways of each dimension. Under the systemic paradigm, the five dimensions are understood as interconnected elements of a dynamic system, with research focused on feedback loops and coupling mechanisms among dimensions. This paradigm shift transforms five-dimensional synergy from a "classification tool" into an "analytical instrument"—it no longer merely describes five dimensions, but diagnoses the operational state of the system. On this basis, we introduce an integrated perspective drawing from synergetics and system dynamics, understanding the five dimensions as a closed-loop system composed of three feedback loops, and identifying three conditions for effective loop operation—start-up costs, timeliness of information feedback, and system resilience.

Addressing the second question, we sequentially tested the existence and operational status of the three feedback loops in practice. The test results show that all three loops receive partial data support, but all exhibit varying degrees of disruption. Loop 1 exhibits the unidirectional characteristic of "policy drives technology but technology fails to feedback to policy"; Loop 2 exhibits the characteristic of "supply-driven but stalled transformation"; Loop 3 exhibits the characteristic of "surface-level integration easy, deep synergy difficult". The common characteristic of the three loops is that forward drive is relatively established but reverse drive is significantly weaker, meaning that the operation of five-dimensional synergy in practice is not an ideal "bidirectional loop", but rather a state of "unidirectional chain with partial feedback".

The concept of the "incomplete loop" is the core theoretical contribution of our work. It reveals a general principle of synergistic systems: under conditions of resource constraint, the operation of a synergistic system is not an ideal "bidirec-

tional closed loop" but rather a "unidirectional chain with partial feedback". This implies that the optimization of synergy should not pursue a "perfect loop" but should focus on repairing the critical breakpoints in "reverse drive". The "incomplete loop" concept provides a new theoretical perspective for understanding the operational logic of synergistic systems under conditions of limited resources.

Addressing the third question, we reveal that the four dilemmas in practice—insufficient technology transformation, low cross-time-zone collaboration efficiency, weak SME participation, and conflict between international accreditation and domestic evaluation indicators—can all be attributed to disruption of loop operating conditions: insufficient start-up costs, delayed information feedback, and inadequate system resilience. The optimization pathways point to specific repair paths for these three disruptions: tiered training to restore the order parameter, cross-time-zone collaboration norms to facilitate information feedback, and SME joint programs to reduce start-up costs.

The practical contribution of our work is not a set of "best practice solutions", but a "diagnosis-optimization methodology". Unlike the traditional "benchmarking approach"—which seeks a successful model to imitate—the methodology provided herein proceeds as follows: first diagnose the loop breakpoints in one's own system, then implement targeted repairs for those breakpoints. The core advantage of this methodology lies in its respect for the differences in institutional environments and resource endowments among universities—it is not about "learning from others", but about "understanding the problems of one's own system". Other universities can apply our five-dimensional synergy analytical framework to diagnose their own international cooperation dilemmas, use the three loop conditions for causal analysis, and draw on the optimization pathway design to develop improvement plans suited to their own conditions. The framework is replicable, but specific plans must be tailored to each institution.

Based on the above analysis, three core conclusions are drawn. First, five-dimensional synergy does not come about automatically and is not a static framework; its operation requires specific conditions. The absence of any of the three conditions will degrade the synergy loop. Second, the operational state of five-dimensional synergy in practice is the "incomplete loop"—forward drive exists but reverse drive is weak. This positioning is neither a negation of the theoretical framework nor a simple affirmation of practice, but rather a description of the real relationship between the two. Third, practical dilemmas are catalysts for theoretical deepening rather than evidence of model failure. The dilemmas encountered by the School of Economics and Management at Beijing Institute of Petrochemical Technology in five-dimensional synergy practice precisely reveal the key obstacles that five-dimensional synergy must overcome in moving from "checklist of elements" to "mechanistic loop".

7.3. Research Limitations and Future Directions

Several limitations of our work should be acknowledged.

First, our analysis is based on a single case, following the logic of analytic generalization. The conclusions have direct reference value for Beijing municipal applied universities, but their applicability to other regions or other types of universities requires further validation. As noted in Section 4.2, the boundary conditions of our study—Beijing municipal applied universities with similar resource endowments and policy environments—should be considered when assessing the transferability of findings. Future research could select applied universities in other regions (such as the Yangtze River Delta and Guangdong-Hong Kong-Macao Greater Bay Area) for cross-case comparisons to test the boundary conditions of our findings.

Second, interview data are subjective reports and may contain recall bias and social desirability bias, although we have controlled for these through triangulation and member checking. The small sample of administrators may limit the completeness of the management perspective. Future research could introduce longer-term follow-up observation and more objective operational data.

Third, the effectiveness of the optimization pathways requires longer-term follow-up validation. Future research could conduct 3-year follow-up evaluations of the optimization pathways proposed herein.

Fourth, the judgment of "technological empowerment" as the order parameter is based primarily on theoretical deduction. Future research could further test through cross-case comparisons whether technological empowerment exhibits order parameter characteristics across different types of universities.

Fifth, our "loop testing" method is still in the exploratory stage, and the design of test criteria needs further refinement and standardization.

Sixth, in the causal attribution of Section 6.1, some causal relationships are based on inference rather than direct statements from interviewees, which is a limitation of our approach. Future research could use more refined interview designs to directly ask interviewees about their views on causal relationships, thereby strengthening the evidence for causal attribution.

Funding

Beijing Education International Exchange Association 2025 General Research Project: "Research on International Cooperation Models for Talent Development in Economics and Management in the Context of Artificial Intelligence" (Grant No. YBGD202515).

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix A: Faculty Interview Guide

I. Interview Basic Information

- Interviewee: _____
- Title: ☐Professor ☐Associate Professor ☐Lecturer ☐Teaching Assistant
- Department: _____
- Years of Teaching: _____
- Interview Date: _____
- Interview Location: _____

II. Interview Opening

Dear Professor/Teacher:

Thank you for taking the time to participate in this interview. This research aims to understand the implementation of the "five-dimensional synergy" framework in international cooperation and talent development at the School of Economics and Management of Beijing Institute of Petrochemical Technology. Your honest opinions and valuable experience will provide important evidence for this study. The interview content will be used solely for academic research, and your personal information will be strictly confidential. The interview will take approximately 40 - 60 minutes.

III. Interview Questions

(1) Policy Support Dimension

1. How do you evaluate the school's current policy support for internationalized teaching and AI-empowered teaching? (Probe: In terms of funding, institutions, incentive measures, etc., what do you think is done well? What is still insufficient?)
2. Are you aware of the school's policy on incorporating AI literacy into faculty assessment? What impact has this policy had on your teaching work?
3. Do you think the current faculty evaluation and professional title promotion system can effectively incentivize faculty to participate in international cooperation and AI teaching innovation? Why?

(2) Technological Empowerment Dimension

4. Do you use AI-assisted teaching tools in your daily teaching? (Probe: What tools do you use? How frequently?)
5. If you do not use or rarely use AI teaching tools, what are the main reasons? (Probe: Is it a technical threshold issue? Time issue? Or do you feel it is disconnected from actual teaching needs?)
6. What AI teaching training or support has the school provided? How effective do you think these trainings are? (Probe: Can you sustain the application after training? Why or why not?)

(3) Cultural Integration Dimension

7. Have you participated in the school's internationalized course teaching or cross-cultural teaching programs? (Probe: How did you feel? What

difficulties did you encounter?)

8. How do you evaluate the actual effectiveness of the school's cross-cultural curriculum system (8 bilingual/English-taught courses)? (Probe: What is the level of student acceptance and participation?)

(4) Ecological Synergy Dimension

9. Have you participated in cooperative projects with enterprises or university-industry collaborative teaching activities? (Probe: What is the cooperation model? How effective is it?)
10. How do you evaluate the level of enterprise participation in the school's international cooperation and talent development? Is communication and collaboration between enterprises and the school smooth?

(5) Capacity Building Dimension

11. Do you have overseas study or visiting scholar experience? What support did the school provide? (Probe: How have these experiences impacted your teaching and research?)
12. In the AI era, what internationalization competencies do you think economics and management faculty most need to enhance?

(6) Open Summary

13. From your observation, what are the most prominent problems in the school's international cooperation and AI-empowered teaching? What suggestions do you have?
14. Is there anything else you would like to add?

Appendix B: Administrator Interview Guide

I. Interview Basic Information

- Interviewee: _____
- Position: _____
- Area of Responsibility: _____
- Years in Position: _____
- Interview Date: _____
- Interview Location: _____

II. Interview Opening

(Same as above)

III. Interview Questions

(1) Policy Support and Top-Level Design

1. What are the strategic objectives regarding international cooperation in the school's "14th Five-Year Plan"? What is the current progress?
2. How does the school incorporate AI literacy into faculty assessment? What challenges has this policy encountered from design to implementation?
3. Do you think the school's current institutional design can effectively guarantee the operation of "government-enterprise-university-overseas" four-party synergy?

(2) Technological Empowerment and Resource Allocation

4. What resources has the school invested in AI teaching tools and smart teaching platforms? What is the current utilization rate?
5. How do you evaluate the differentiation of faculty willingness to use AI tools (with older faculty showing higher resistance)? How does the school plan to address this?
6. How effective is the operation of the cross-border virtual teaching and research center? Where do you think the crux of the low cross-time-zone collaboration efficiency lies?

(3) Ecological Synergy and University-Industry Cooperation

7. How effective is the operation of the four-party joint meeting mechanism? What is the participation level of government departments, enterprises, and overseas institutions?
8. What is your view on the problem of insufficient SME motivation to participate in international cooperation? What strategies does the school have?
9. What is the cooperation model between the school and overseas institutions such as the University of Dundee, University of Stirling, and University of the West of Scotland? What are the main challenges in cooperation?

(4) International Accreditation and Institutional Conflict

10. In the process of promoting AACSB accreditation, what difficulties has the school encountered? How can the conflict between international accreditation standards and the domestic evaluation system be resolved?

(5) Capacity Building and Future Directions

11. What measures has the school taken to enhance faculty internationalization capabilities? How effective are they?
12. What do you think is the biggest bottleneck in the school's practice of the five-dimensional synergy framework?
13. What are your visions for optimizing the school's international cooperation model in the future?

Appendix C: Enterprise Representative Interview Guide

I. Interview Basic Information

- Interviewee: _____
- Position: _____
- Company Name: _____
- Company Size: ☐Large (≥500 employees) ☐Medium (50 - 499 employees) ☐Small (<50 employees)
- Industry Type: ☐ Technology Innovation ☐ International Trade ☐ Financial Services ☐Other
- Interview Date: _____
- Interview Location: _____

II. Interview Opening

(Same as above)

III. Interview Questions

(1) Talent Demand and Capability Expectations

1. When recruiting economics and management graduates, what competencies does your company value most? (Probe: How important are AI literacy, data analysis capability, and cross-cultural communication capability?)
2. In what competency areas do you think current university-trained economics and management graduates fall short of enterprise actual needs?

(2) Current Status of University-Industry Cooperation

3. What forms of cooperation does your company have with the School of Economics and Management at Beijing Institute of Petrochemical Technology? (Probe: How long has the cooperation lasted? How effective is it?)
4. How do you evaluate the school's "government-enterprise-university-overseas" four-party synergy mechanism? What is your company's role and level of participation?
5. If your company is an SME, what are the main concerns and barriers to participating in university-industry cooperation?

(3) International Cooperation and Talent Demand

6. Does your company have international business or internationalization plans? What special requirements does this place on talent?
7. How do you think universities should cultivate economics and management talent with international perspectives and cross-cultural competencies?

(4) Optimization Suggestions

8. From the enterprise perspective, what suggestions do you have for the school's international cooperation and talent development model?
9. What kind of university-industry cooperation model is most attractive to your company?

Appendix D: Student/Graduate Interview Guide

I. Interview Basic Information

- Interviewee: _____
- Status: ☐Current Student (Grade: _____) ☐Graduate (Year of Graduation: _____)
- Major: _____
- Participated in International Cooperation Programs: ☐Yes ☐No
- Interview Date: _____
- Interview Location: _____

II. Interview Opening

(Same as above)

III. Interview Questions

(1) Learning Experience and Capability Growth

1. Have you taken the school's internationalized courses (bilingual/English-taught)? How did you feel? How did they help your learning?
2. Have you encountered AI tools in your course learning? Has the school's teaching helped you improve your AI literacy?
3. In what aspects do you think the school's teaching has helped you improve your international perspective and cross-cultural communication ability?

(2) International Exchange and Cross-Cultural Experience

4. Have you participated in international exchange programs (such as overseas exchange, short-term study visits, multinational enterprise visits, etc.)? How was the experience?
5. How do you evaluate the school's "International Education Awareness Month" and related activities?

(3) University-Industry Cooperation and Internship Practice

6. Have you had corporate internship experience? In your internship, what gaps did you find between the school's training and enterprise needs?
7. Have you participated in cooperative projects between the school and enterprises? How did such experiences help your growth?

(4) Graduate Employment and Capability Evaluation

8. (Graduates) What is your current occupation? How has your learning experience at the school helped your career development?
9. (Graduates) In your workplace, what competencies do you think are most important? How well did the school cultivate these competencies?

(5) Optimization Suggestions

10. What suggestions do you have for the school's international cooperation and talent development?

Appendix E: Interview Data Coding Examples

Thematic analysis was employed for the interview data, with the coding process following a six-step procedure: familiarization with data, initial coding, theme generation, theme review, theme definition and naming, and report writing. The coding work was independently completed by 2 researchers, with inter-coder reliability Kappa coefficient of 0.87, indicating good coding reliability. Coding examples are shown below:

Original Interview Statement	Open Coding	Axial Coding	Selective Coding
"The school encourages faculty to use AI and participate in international cooperation, but when it comes to year-end assessment, the focus is still on traditional indicators like teaching hours, teaching reform projects, and student evaluations. New practices are 'invisible' in the assessment system".	New practices not recognized in old assessment system	Institutional design disconnected from new practices	Policy Support Dimension Dilemma

Continued

"Meetings with the UK side are often at 8 or 9 PM, and with family to care for, I simply cannot attend every time. But not attending and missing important information is also a concern, creating frustration each time".	High time cost of cross-time-zone meetings	Low cross-time-zone collaboration efficiency	Policy Support Dimension Dilemma
"If the school could provide some time support, such as counting AI training as workload, I might be more willing to try. Right now it is completely extra burden, and the cost of trial and error is too high".	Lack of time compensation and incentive mechanisms	Individual start-up costs too high	Insufficient Start-up Costs
"The tools are there, but without technical support, when encountering problems I do not know who to ask, and after one problem I dare not use them again".	Lack of continuous technical support	Technology transformation lacks guarantees	Insufficient Start-up Costs

Appendix F: Interview Research Validity and Reliability Assurance

The quality of interview research was ensured through the following methods:

1. Triangulation. Comprehensively using interviews, documents, and observation to cross-validate findings and avoid bias from a single data source.

2. Member Checking. Providing preliminary analysis results to some interviewees for confirmation to avoid researcher misinterpretation.

3. Thick Description. Providing sufficient background information and detailed descriptions when presenting findings so that readers can judge the applicability of the conclusions.

4. Theoretical Saturation Testing. Continuously assessing during the interview process whether new interviews still provide new information. When three consecutive new interviewees provided no new thematic information, theoretical saturation was deemed reached and sampling stopped.

5. Inter-coder Reliability. Two researchers independently coded 20% of the interview texts, achieving 86.7% coding agreement (Kappa coefficient = 0.87), with disagreements resolved through discussion.

6. Research Ethics. Before all interviews, researchers explained the research purpose, data usage, and anonymization procedures to interviewees and obtained their oral consent. Interview data were used solely for academic research, and no personally identifiable information appears in the report.