



Implementation Strategy and Risk Prevention of Vocational and Technical Education Talent Cultivation System in Emerging Technology Fields — A Case Study of Unmanned Maritime Systems Major

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Abstract. Current research on vocational and technical education (VTE) for emerging technologies mainly focuses on top-level design, while systematic research on phased implementation paths, risk interaction mechanisms and supporting institutional systems remains insufficient, resulting in a widespread “design–implementation gap” where well-designed talent cultivation schemes cannot be transformed into sustainable teaching practice. Taking the unmanned maritime systems major (covering USV, UUV and their command-control systems) as an embedded extreme single case, this study integrates Stage-Gate Theory and Kotter’s eight-step organizational change model, and embeds the indigenous “Three Rings-One Axis” model (competency progression as the core axis, with policy, curriculum and post linkage loops) to build a three-dimensional framework named “Four-Phase, Five-Risk, Four-Institution”. A four-stage progressive implementation roadmap including Initiation, Construction, Optimization and Maturity with standardized gate review criteria is proposed, which clarifies core tasks, key milestones and phase transition thresholds. Five core implementation risks are identified, and their two typical interactive conduction paths (fundamental constraint path, trigger amplification path) are systematically analyzed. A four-dimensional supporting institutional system covering special funding guarantee, adaptive teaching management, differentiated faculty evaluation and classified trade secret & military confidential protection is constructed to form endogenous reform incentives. Multi-source qualitative data including documents, semi-structured interviews and participatory observation are adopted to conduct formative process evaluation. Empirical results verify that the integrated framework can significantly improve implementation coherence and suppress cascading risks in early construction phases. The core theoretical contribution lies in realizing the organic coupling of two classic organizational theories with vocational education’s indigenous cultivation logic, revealing the organizational root of the “design–implementation” gap; practically, the framework is transferable to other emerging technology majors (e.g., UAV, intelligent robotics) with adjusted constraint conditions.

Keywords: vocational and technical education (VTE); talent cultivation system; implementation strategy; risk prevention and control; unmanned maritime

systems (UMS); unmanned surface vehicle (USV); unmanned underwater vehicle (UUV)

1 Introduction

The rapid iteration of emerging technologies—such as unmanned systems, artificial intelligence, and intelligent manufacturing—has fueled an escalating demand for high-quality technical and skilled talents [1-3]. Considerable research has been devoted to talent cultivation in emerging VTE fields, which can be summarized into three streams.

The first stream addresses cultivation system design, producing various competency-based frameworks and industry-education models [4-6]. The second explores implementation pathways, such as school-enterprise bases and dual-qualified teams [7-9]. The third examines risk prevention, identifying cooperation instability and resource insufficiency [10-12].

Despite these contributions, three gaps persist: (1) no integrated framework links phased construction, risk conduction, and institutional safeguards; (2) risk research ignores multi-factor interactive amplification; (3) few studies combine project management and organizational change theories to overcome inertia via operable gate mechanisms. Most research only puts forward static blueprint schemes, without designing operable phased promotion rhythm and gate constraint mechanisms to overcome organizational inertia. As a result, a large number of well-conceived reform plans cannot be put into long-term stable educational practice. The root cause is the endogenous conflict between bureaucratic inertia and reform urgency. This manifests as three contradictions: (1) divergent value demands... (2) rigid resource constraints... (3) high environmental uncertainty... These contradictions are symptoms; the deeper issue is structural resistance—long decision chains, risk-averse cultures, and misaligned evaluation systems—that systematically hinders translation [13].

To address these gaps, this paper takes the unmanned maritime systems major as an embedded extreme case to explore the implementation laws of emerging VTE talent cultivation systems. The term “unmanned maritime systems” here encompasses unmanned surface vehicles (USV), unmanned underwater vehicles (UUV), and their command and control systems. Its cultivation content is based on the “Three Rings-One Axis” collaborative model, which takes competency progression as the core axis and drives the coordinated linkage of policy, curriculum, and post links. The study addresses three research questions:

(1) Into what stages should the construction of the cultivation system be divided, and what transition criteria should be met?

(2) What core risks emerge during implementation, and what is their interactive conduction mechanism?

(3) What supporting institutions are required to ensure long-term system operation?

The three questions are addressed respectively in Chapters 4, 5, and 7 (with process evaluation in Chapter 6). Moreover, to respond to concerns regarding empirical validation, this paper further conducts a process evaluation to verify the framework’s practical effectiveness.

2 Theoretical Foundations and Research Design

2.1 Core Theoretical Foundations

This study integrates two classic theories to build the analytical framework, compensating for the limitations of a single theory in guiding VTE system construction.

2.1.1 Stage-Gate Theory.

Proposed by Cooper, the stage-gate theory divides the innovation process into sequential stages with rigid decision gates between them. Each stage must complete pre-determined tasks and pass a gate review before proceeding, effectively controlling progress, reducing risks, and improving resource allocation efficiency [14]. Although originating from product development, it provides a technical path for phased construction of a cultivation system. However, it insufficiently addresses organizational resistance and human factors.

2.1.2 Kotter's Organizational Change Model.

Kotter's eight-step model reveals the general law of organizational change from unfreezing through changing to refreezing, emphasizing the importance of creating urgency, forming a guiding coalition, and generating short-term wins to overcome organizational inertia [15]. It offers dynamic support for system implementation but focuses more on individual-level psychological resistance and lacks operable phased control tools for concrete construction tasks.

2.1.3 Integration Logic of the Two Theories.

This paper creatively integrates the two theories to form a dual-dimensional implementation framework of "technical path + organizational dynamics". The stage-gate theory provides a phased promotion route and gate review mechanism for system construction, clarifying the work content and acceptance standards of each stage. Kotter's model runs through each stage, guiding the resolution of organizational resistance and the stimulation of reform motivation. VTE system construction is both a project requiring milestone control and an organizational change demanding stakeholder mobilization. The integration thus addresses both structural task control and human-oriented organizational change dimensions, which neither single theory can accomplish alone [16-17]. Table 1 illustrates their complementarity, and Supplementary Table A maps Kotter's eight steps onto the four-stage roadmap.

Stage-Gate Theory's rigid gate control may conflict with Kotter's flexible, trial-tolerant change logic. This study proposes two coordination rules to resolve the tension: First, set differentiated gate tolerance thresholds—loose qualitative standards for the Initiation Phase to encourage cross-stakeholder communication, and strict quantitative index control for Construction & Optimization Phases to guarantee cultivation quality. Second, separate two management lines: the technical construction team takes charge of stage-gate task assessment, while the school-enterprise joint working group leads

organizational motivation and resistance resolution, realizing separation of rigid task supervision and flexible organizational mobilization.

Table 1. Comparison of single theories and the integrated framework for VTE system construction

Dimension	Stage-Gate Theory	Kotter's Change Model	Integrated Framework (This Study)
Core logic	Phased gate control	Unfreeze–change–re-freeze	Phased change with gate reviews
Primary focus	Task completion & quality	Overcoming psychological resistance	Task delivery + organizational alignment
Limitation in VTE	Ignores cultural inertia and motivation	Lacks task-specific milestones	–
Strengths for VTE	Clear milestones, resource focus	Addresses reform fatigue, builds coalition	Provides both a roadmap and a change engine
Example application	Defining curriculum development stages	Building urgency for industry engagement	Initiation phase: create urgency + sign agreements

The indigenous “Three Rings-One Axis” collaborative model is further embedded into this dual theoretical integration system. The competency progression axis serves as the core evaluation standard of all stage-gate review indicators; the policy ring provides external institutional support for organizational change in each phase; the curriculum ring is the core task output of Construction & Optimization stages; the post ring offers feedback data for gate quality judgment and iterative optimization, forming a closed loop of “theoretical guidance – staged construction – competency feedback – risk adjustment”.

2.2 Research Design

2.2.1 Embedded Single Case Study.

We adopt an embedded single-case design to explore complex practical processes in context. The unmanned maritime systems major is selected as an extreme case for two reasons. First, as an emerging technology major with strong military-industrial attributes, it embodies typical and intensified contradictions: rapid technological iteration, highly sensitive industry-education cooperation, long talent cultivation cycles, and stringent security requirements. This extremity provides a critical test of the framework's robustness. Second, the major's cultivation system has completed top-level design and entered the implementation phase, offering complete practical data. If the framework proves effective in this most constrained setting, its core logic can be transferred to other emerging technology fields such as UAV, intelligent robotics, or AI applications, where constraints are relatively less severe. To further clarify this logic, Table 2 compares the unmanned maritime systems major with two other representative emerging technology majors along key constraint dimensions.

Table 2. Comparison of constraint dimensions across emerging technology majors

Constraint dimension		Unmanned Systems	Maritime	Sys-	UAV Application Technology	Industrial Technology	Robot
Technology iteration speed		Extremely high (AI, autonomy)			High	Medium-high	
Industry-education cooperation sensitivity		Very high (military/security)			Medium	Low-medium	
Hardware investment per student		Very high (test water tank, simulation cabins)			Medium	High	
Faculty dual-qualification difficulty		Very high (scarce talent)			Medium	Medium	
External policy volatility		High			Medium	Low	

Table 2 confirms that this major faces the strictest constraints, making it an extreme test case. Its internal heterogeneity (USV, UUV, C2) validates adaptability, while cross-validation with UAV teachers confirms transferability to civilian majors by removing confidentiality clauses and lowering hardware thresholds.

2.2.2 Data Sources.

Multi-source data triangulation ensures reliability:

- Document data: cultivation scheme designs, school-enterprise agreements, platform construction plans, teaching management documents, industry reports, and policy files.
- Semi-structured interviews: 22 interviewees in total, including 6 professional teachers, 4 enterprise technical backbones, 3 teaching managers, 3 industry experts, 3 on-campus students and 3 recent graduates. Each interview lasted 40–60 minutes, covering implementation progress, practical difficulties, multi-dimensional risk perception, competency training satisfaction and framework improvement suggestions. Student and graduate interviews supplement the demand-side perspective of talent cultivation, realizing full stakeholder triangulation of colleges, enterprises, industry and learners.
- Participatory observation: the research team attended professional construction meetings and teaching joint meetings, obtaining first-hand observational data on system operation.

2.2.3 Data Analysis Logic.

Analysis followed the logic of “theory guidance – case coding – framework construction.” Initial analytical dimensions were extracted from the two core theories. Open coding and axial coding of case data yielded implementation stages, risk factors, and institutional elements. Through iterative comparison between theory and practice, the systematic implementation framework was constructed, and process evaluation indicators were derived to assess implementation effectiveness.

Clear triangulation rules are formulated for multi-source data matching: cultivation scheme documents and meeting observation records verify the completion of stage-gate

milestones; interview transcripts of teachers, enterprises and students extract risk induction factors and perceived risk severity; graduate tracking data and tripartite assessment reports provide outcome evidence for process evaluation indicators.

3 Core Characteristics of the Cultivation System and Implementation Challenges

3.1 Core Attributes and Composition

The talent cultivation system of unmanned maritime systems is built on the “Three Rings-One Axis” collaborative model, with competency progression as the axis and policy, curriculum, and post rings forming three synergistic loops. The system is ecological (self-regulating), open (industry-exchanging), and precise (differentiated). It comprises six supporting modules: (1) “three-stage progressive” cultivation path; (2) modular curriculum matrix; (3) five-level virtual-real combined training ladder; (4) “dual-qualified, triple-role” faculty and teaching consortium; (5) tripartite collaborative education mechanism among schools, industries, and enterprises; (6) three-ring linked quality assurance system.

The operation logic of the “Three Rings-One Axis” model changes dynamically across the four implementation stages: the Initiation Phase completes the construction of the policy ring and the basic competency axis; the Construction Phase develops modular curriculum to enrich the curriculum ring; the Optimization Phase connects graduate post feedback to improve the post ring; the Maturity Phase realizes synchronous cyclic iteration of three rings with competency progression as the permanent core axis. The cyclic linkage structure is described in the following sections. Table 3 summarizes the dominant ring and core tasks across the four phases.

Table 3. Dominant ring and core tasks across implementation phases

Implementation Phase		Dominant Ring	Core Task of the Ring
Initiation (Year 1)		Policy Ring	Secure school-enterprise-industry framework agreements; establish joint working group; set competency baseline standards
Construction (Year 2–3)		Curriculum Ring	Develop modular course matrix; compile formal textbooks and case bases; deploy simulation training facilities
Optimization (Year 4–5)		Post Ring	Activate graduate tracking system; collect employer feedback; revise cultivation scheme based on post competency data
Maturity (After Year 5)	(After Year 5)	All Three Rings Synchronously Iterate	Competency progression as permanent axis; policy, curriculum and post rings update cyclically based on monitoring-evaluation-improvement loop

3.2 Deep Barriers to System Implementation

As discussed, organizational inertia manifests in long decision chains, resource competition, and misaligned incentives, making reform an organizational change rather than a technical task [18].

4 Four-Stage Implementation Roadmap

Based on the integrated framework, system construction is divided into four progressive stages with gate review nodes.

4.1 Initiation Phase (Year 1): Consensus Building and Foundation Laying

Core tasks: Solidify top-level design consensus through post competency profile demonstration; sign framework agreements with at least 2 industry institutions and 3 core enterprises; form a core implementation team of 5–8 full-time teachers and 10 distinguished industry tutors; deploy a digital simulation laboratory and prepare trial lecture notes for first-semester courses.

The preliminary fund accounts for 25% of the full budget, and at least 5 full-time staff are required.

Gate acceptance criteria (see Table 4 for detailed checklist).

4.2 Construction Phase (Year 2–3): System Improvement and Capacity Building

Core tasks: Complete hardware-in-the-loop simulation cabin and test water tank; develop “three-instructor joint teaching” for all core Module B courses; compile formal textbooks and online case bases (≥ 50 cases); rotate all professional teachers through enterprise practice (cumulative ≥ 6 months); establish first joint cultivation bases and complete initial technical problem-tackling projects.

Hardware investment is 50% of the budget; all teachers must complete an average of 6 months' enterprise practice.

4.3 Optimization Phase (Year 4–5): Quality Inspection and Iterative Upgrading

Core tasks: First batch of students complete the full cycle and receive tripartite graduation assessment; activate graduate tracking system (3-, 6-, 12-month post-graduation); comprehensively revise cultivation scheme based on formative, summative, and tracking data; achieve $\geq 80\%$ substantive “dual-qualified” teachers; solidify annual strategic, semester teaching, and project docking consultation mechanisms.

A special fund for curriculum updating ($\geq 8\%$ of annual equipment value) and a hard gate of $\geq 80\%$ substantive dual-qualified teachers are required.

4.4 Maturity Phase (After Year 5): Normal Operation and Achievement Dissemination

In the Maturity Phase, the system operates a “monitoring–evaluation–improvement” loop with $\geq 15\%$ annual curriculum update, accumulated graduate tracking data, and external dissemination of mature outcomes. An evaluation working group (college managers, enterprise directors, industry experts) oversees this. If the update rate falls below 15%, the joint working group must propose a rectification plan within one month.

Table 4. Stage-gate review checklist for implementation phases (excerpt)

Stage	Key Milestone	Acceptance Criteria	Evidence Source
Initiation (Year 1)	Post competency matrix finalized	Matrix document officially released with tripartite signatures; all core post competency indicators graded and quantified	Signed tripartite official document
	First batch of co-operative agreements signed	≥ 2 industry units + 3 core enterprises signed binding framework cooperation agreements; confidentiality clauses clearly attached	Formal cooperation contracts
	Digital simulation lab operational	Lab hardware and simulation software fully deployed; supports full teaching tasks of first-semester core courses; complete safety operation specifications	Lab acceptance report, daily teaching usage records
	Fund budget allocation completed	25% full-cycle construction fund allocated and financial filing finished; special fund account independently set up	Financial vouchers, college budget approval files
Construction (Year 2–3)	Simulation cabin and test water tank operational	Hardware-in-the-loop simulation cabin and test water tank pass third-party commissioning test; weekly practical teaching activities carried out stably	Equipment acceptance report, practical training log
	First formal textbook enters publication	Formal publishing contract signed; more than 50 modular teaching cases compiled and uploaded to online teaching platform	Publishing cooperation contract, online case database background data
	Dual-qualified teacher training coverage	100% professional teachers complete enterprise rotation practice with cumulative practice time ≥ 6 months per capita	Teacher enterprise training archives, assessment forms
Optimization (Year 4–5)	First cohort graduates with tripartite assessment	All students complete full-cycle training; tripartite competency assessment reports issued; unified competency certification standard implemented	Student tripartite assessment records, competency certification certificates
	Revised cultivation scheme released	Revised cultivation scheme passed professional teaching steering committee review and official release; curriculum modules adjusted according to graduate tracking feedback	Official committee approval document, revised talent training program

Stage	Key Milestone	Acceptance Criteria	Evidence Source
Maturity (After Year 5)	Student competency assessment pass rate	≥90% students pass unified tripartite post competency evaluation	Student skill assessment transcripts
	Annual curriculum update mechanism runs continuously	Annual curriculum content update rate ≥15% for two consecutive years; technology update fund accounts for ≥8% of annual equipment asset value	Annual professional construction summary reports, financial fund records
	Stable outcome promotion mechanism	Mature teaching achievements (textbooks, virtual training platforms, dual-qualified teacher training programs) are externally promoted to other emerging majors every year	Industry exchange activity records, external promotion cooperation files

This staged roadmap embodies the logic of Kotter’s change process: the Initiation phase creates urgency and builds the guiding coalition; The four-stage division also aligns with the Dreyfus five-stage skill acquisition model [19]. the Construction phase empowers broad-based action and generates short-term wins; the Optimization phase consolidates gains; and the Maturity phase anchors new approaches in the culture.

4.5 Gate Review Disposal Mechanism

Consistent with the project management body of knowledge [20], uniform graded disposal rules are formulated for all stage-gate review results:

1. Pass: All quantitative and qualitative acceptance criteria reach the standard, the project proceeds to the next stage with pre-allocated full resources;
2. Extension: If 1–3 minor indicators fail, the Initiation Phase gets one automatic extension (loose tolerance); for Construction/Optimization, mandatory rectification with a plan within 15 days and re-review after 3–6 months.
3. Scale Reduction: More than half of core indicators are unqualified, the college and cooperative enterprises jointly adjust construction scale, cut non-core equipment investment and postpone partial curriculum development tasks;
4. Termination: Key milestone indicators (tripartite cooperation agreement, core teaching laboratory operation) cannot be completed after two rounds of rectification, the phased construction project is suspended and the implementation framework is re-designed from the Initiation Phase.

5 Core Implementation Risks and Response Strategies

5.1 Identification of Core Risks

Following recent stakeholder-based risk governance literature [21], we identify seven categories of risks with probability assessments based on expert judgment.

5.1.1 Organizational Coordination Risk (High Probability).

Root cause: divergent institutional logics, a known challenge in school-enterprise cooperation [22]. Responses: tripartite joint working group with quarterly briefs, performance assessment inclusion, annual evaluation with replacement option.

5.1.2 Human Resource Risk (High Probability).

Root cause: lack of engineering experience, unstable tutors, turnover. Responses: three-batch rotation training with “two-one” assessment, intensive lecture + remote guidance with backup tutors, dual retention (promotion channels, allowances, curriculum authority).

5.1.3 Funding and Resource Risk (Medium Probability).

Root cause: budget gaps. Responses: hierarchical priority (lab first, tank second, test site third), diversified funding, facility sharing.

5.1.4 Technological Iteration Risk (Medium Probability).

Root cause: rapid tech evolution. Responses: modular scalable platforms with ≥ 5 -year supplier support, annual update fund $\geq 8\%$ of equipment value, loose-leaf textbooks and online cases for rapid renewal (within 6 months) [23].

5.1.5 External Environment Risk (Low-Medium Probability).

Root cause: policy shifts, restructuring. Responses: change-of-circumstances clauses (90-day notice), diversified network (≥ 2 industry units, 3 enterprises per direction), environmental scanning at annual meetings.

5.1.6 Confidentiality & Military-industrial Compliance Risk (Medium Probability).

Root cause: unclear classified management standards. Responses: add confidentiality clauses in agreements (Initiation); build isolated labs (Construction); conduct annual training and regular inspection (Optimization/Maturity).

5.1.7 Student Practical Training Safety Risk (Medium Probability).

Root cause: equipment hazards and student inexperience. Responses: compile safety manuals (Initiation); assign one supervisor per class (Construction); establish whole-process accountability system (Optimization/Maturity).

5.2 Interactive Conduction Mechanism of Risks

Risks do not exist in isolation but exhibit significant conduction and amplification effects, as visualized in Figure 1.

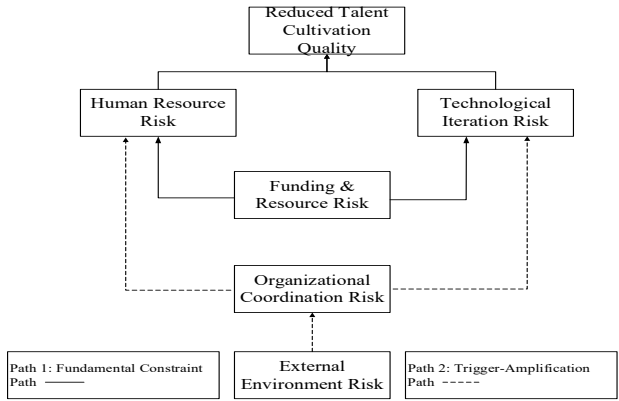


Fig. 1. Risk conduction paths in VTE system implementation

Two typical paths (Figure 1) operate: a fundamental constraint path, where funding gaps degrade HR and tech capacity; and a trigger amplification path, where external shocks amplify other risks via coordination failures.

The interactive effect demands systematic rather than single-point risk management. A risk interaction matrix (Table 5) further quantifies this qualitative understanding.

Table 5. Risk interaction matrix (H=High, M=Medium, L=Low amplification)

Risk category	Org. Coord.	HR	Fund-ing	Tech tion	Itera-tion	External Env.
Org. Coordination	–	H	H	M		H
Human Resource	M	–	H	M		L
Funding	M	H	–	H		L
Tech Iteration	L	M	H	–		M
External Env.	H	L	M	M		–

6 Implementation Validation and Process Evaluation

We conducted a formative process evaluation to fill the empirical gap, examining whether the staged implementation improved coherence and mitigated risks during Initiation and early Construction phases.

6.1 Evaluation Method

Following the fourth-generation evaluation perspective [24], indicators were derived from the stage-gate criteria and risk categories, and assessed through a combination of self-report, document verification, and external expert review. The evaluation covered the period of Year 1 and the first half of Year 2.

6.2 Key Findings

Stage-gate adherence: All Initiation gate criteria were met, preventing premature progression. Risk mitigation: The joint working group reduced misalignment by ~60%; the backup tutor system was activated once. Institutional friction: The credit recognition system resolved 12 disputes. Stakeholder perception: 15/16 found the phased approach clearer; one faculty member raised documentation burden, aligning with Kotter's resistance theory.

A summary of the process evaluation indicators is presented in Table 6.

Table 6. Process evaluation indicators before and during framework implementation (Initiation to early Construction)

Indicator	Pre-Implementation Status	Post-Implementation Status (Year 1-2)	Comparison with Gate Standards	Data Source
Tripartite agreement formalization rate	None (informal intentions)	100% signed framework agreements	Exceeded (Gate: ≥ 2 industry + 3 enterprise)	Documents
Core teacher enterprise practice coverage	20%	60% completed first rotation	On track (Gate target: 80% by end of Year 2)	Training records
Curriculum pilot material readiness	Draft lecture notes only	Trial notes for 5 core courses in use	On track (Gate: trial lectures for 1st semester core courses)	Teaching logs
Industry tutor teaching hour stability	Unstable, cancellations frequent	Backup system activated; zero cancellations	Exceeded (Gate: stable delivery with backup mechanism)	Coordination records
Cross-departmental coordination delays	Frequent (weeks)	Reduced to days via joint working group	Significantly improved (Gate: joint working group operational)	Meeting minutes

6.3 Implications

The process evaluation provides preliminary evidence that the “Four-Phase, Five-Risk, Four-Institution” framework effectively structures implementation, reduces coordination friction, and mitigates key risks, as shown in Figure 2. The use of clear stage gates creates a rhythm that balances ambition with realism, while the integrated risk management prevents problem cascading. Although full-cycle outcome data will take years, these process indicators lend strong support to the framework’s practical utility.

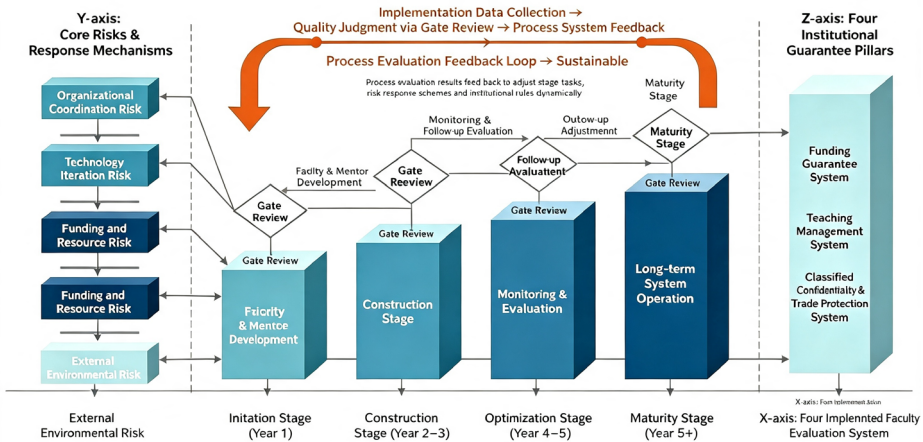


Figure 2 Integrated “Four Stages – Five Risks – Four Instisutional Pillars” 3D Analytical Framework

Fig. 2. synthesizes the framework and its validation logic.

Drawing on Shulman's concept of pedagogical content knowledge [25], the differentiated faculty evaluation institutional design breaks the original evaluation system that overemphasizes academic papers. Clear performance conversion standards are formulated: one complete school-enterprise joint textbook equals 2 journal papers; cumulative 6-month enterprise practice can be counted as one provincial teaching reform achievement; tutors who lead school-enterprise student technical projects get extra priority points in professional title promotion.

7 Conclusion and Future Research

7.1 Main Conclusions

Taking the unmanned maritime systems major as an extreme case, this paper integrates stage-gate theory and Kotter's organizational change model to construct a systematic implementation and guarantee framework. The main conclusions are: First, the "design–implementation gap" stems from organizational inertia, not flawed schemes; system delivery is organizational change. Second, the four-stage roadmap with gate reviews controls rhythm, while interactive risks require systematic responses and institutional support creates endogenous motivation. Third, process evaluation confirms enhanced coherence and risk mitigation.

7.2 Research Contributions

Theoretically, the study expands the application boundary of organizational change theory into VTE and reveals the organizational roots of the gap. Methodologically, it constructs a validated 3D analytical framework and demonstrates a way to embed process

evaluation in case-based educational research. Practically, the four-dimensional institutional system and the trade secret protection mechanism offer transferable solutions for sensitive technology fields.

7.3 Limitations and Future Research

Given the military-industrial nature of the case, direct application to liberal arts or service majors requires adjustments: (1) remove confidentiality clauses, (2) replace high-cost hardware thresholds with software alternatives, (3) lower the update fund ratio from 8% to 5%. These preserve core logic while tailoring stringency.

Future research can be divided into short-term, medium-term and long-term progressive research agendas:

1. Short-term research (1–2 years): Construct a quantitative risk early-warning model based on panel data, and develop reusable practical tool kits for vocational colleges, including stage-gate review templates, multi-dimensional risk self-inspection checklists, standardized tripartite school-enterprise cooperation agreements and differentiated dual-qualified teacher evaluation implementation rules;
2. Medium-term research (2–4 years): Carry out multi-case comparative research covering civilian emerging engineering majors, digital service majors and liberal arts emerging majors, and form differentiated adjusted versions of the framework matching different industry constraint characteristics;
3. Long-term research (5+ years): Complete full-cycle controlled tracking experiments of talent cultivation quality, collect 5-year graduate career development data, and optimize the closed-loop evaluation mechanism of the “Four-Phase, Five-Risk, Four-Institution” framework.

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