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Research on Cultivating Compound-Talented Individuals for the Low-Altitude Economy with "Three Chains and Four Collaborations"

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Abstract: Against the backdrop of the rapid development of the low-altitude economy, the contradiction in the supply and demand structure of compound talents is prominent. Addressing three core issues-insufficient competitiveness of traditional professional employment, low alignment between industrial chains and education chains, and the lack of a "enterprise-college-research" collaborative mechanism-a cultivation mechanism for "Three Chains and Four Collaborations" is proposed. By integrating the capability requirements of specific low-altitude economy scenarios, a progressive path of "professional courses - competition training - career certification" is designed, and a "Low-Altitude Economy Four-Way Collaborative Platform" is established, along with multiple implementation plans such as faculty development and internship bases. The research takes the surveying and mapping engineering major as an empirical carrier, emphasizing interdisciplinary reconstruction, aiming to cultivate compound talents with both technical application and airspace management capabilities. It seeks to form a replicable industry-education integration model, providing talent support for regional low-altitude economic development and helping to resolve employment pressures and industrial

Keywords: Surveying and Mapping Engineering; Talent Cultivation Path; Three-Chain Integration; Four-collaboration Mechanism; Drone Applications

1. Introduction

In the dual context of the rapid rise of the global low-altitude economy and the in-depth promotion of China's new quality productivity strategy [1], the low-altitude field is experiencing a historic leap from technological breakthrough to industrial ecological construction. In 2024, the "low-altitude economy" will be included in the administration work report for the first time, and 30 provinces across the country will include it in their development plans, marking that the industry has entered a new stage of large-scale development from concept incubation. According to the National Development and Reform Commission, by 2030, our country's talent gap in the field of drones will reach millions, highlighting the structural contradiction between the talent training system and the explosive growth of the industry. During this strategic opportunity period, traditional educational models face three major challenges: Firstly, the mismatch between the cultivation of established professionals and the demand for emerging low-altitude economic positions [2], leading to a weakened employment competitiveness and a simultaneous shortage of professional talents; secondly, the dynamic demand of the industrial chain has not yet been fully integrated with the educational supply chain, with pain points such as "single skill of drone operators" and "data analysis and scenario disconnection" [3]; thirdly, the lack of systematic design in the collaborative education between administration, schools, enterprises, and research institutions hinders the supply efficiency of composite talents. As a national pioneer in low-altitude economy, Heilongjiang Province urgently needs to build an innovative educational paradigm that fits the regional characteristics [4,5]. This study takes the "Three Chains and Four Collaborations" as the core framework, exploring the effective mechanisms and implementation paths for cultivating composite talents through deep integration of industrial chains, innovation chains, and educational chains. It connects the four main subjects: administration policy guidance,

university curriculum innovation, corporate practical empowerment, and scientific research institutions' technical feedback [6]. Harbin Industrial University, relying on the actual platform of the Unmanned Aerial Vehicle Engineering College, has cultivated 158 professional pilots and 71 minor talent students. Its "Huang Dayuan-style Teaching Team" and 9 special laboratories lay a practical foundation for the topic. The research focuses on the transformation and upgrading of surveying and mapping engineering majors, proposing the "Unmanned Aerial Vehicle+" micro-major group construction plan, reshaping the knowledge system with a "4+X" capability matrix [7], aiming to resolve deep-seated contradictions such as discipline barriers, the disconnect between study and practice, and ecological fragmentation. It is expected to form replicable Longjiang experience through the construction of a low-altitude economic industry-education alliance [8], designing dynamic evaluation indicators, and formulating N sets of collaborative plans, providing talent support for the "14th Five-Year Plan for General Aviation Industry in Heilongjiang Province" and contributing empirical references for the formulation of national low-altitude economic education policies, ultimately promoting the closed loop of educational chains, innovation chains, and industrial chains, and injecting new momentum into the high-quality development of regional economy [9,10].

2. The Construction of the Theoretical Framework of "Three Chains and Four Coordination" Under the Low-Altitude Economy

Low-altitude economy, as an important carrier of new-quality productivity, urgently needs to resolve the deep-seated contradictions between talent supply and industrial demand. This article, based on the integration logic of industrial chains, innovation chains, and education chains, combines the multi-subject interconnection mechanism of administration, universities, enterprises, and research institutions, constructs a theoretical framework of "three chains driving each other and four wheels collaborating," providing a systematic solution for the cultivation of composite talents.

2.1 Theoretical Traceability: the Internal Logic of Three-Chain Integration

The coupling mechanism of the industrial chain, innovation chain, and education chain is the key driving force for constructing a low-altitude economic industrial system. The three form an ecosystem of mutual influence and support, jointly promoting the sustainable development of the economy.

2.1.1 Industrial chain: capability map construction driven by demand anchoring and scenario propulsion

The low-altitude economic industrial chain dynamically defines the ability standards of composite talents through the four links of "technology research and development-flight application-infrastructure-regulatory services." Taking the surveying and mapping industry as an example, drone pilots need to add the ability to apply for airspace and adapt to multiple aircraft types, data analysts urgently need to master the real-time interpretation skills of low-altitude remote sensing, while the proportion of cutting-edge content in university courses is insufficient to 15%, highlighting the deep misalignment between educational supply and industrial demand. The industrial chain relies on a scenario-based feedback mechanism, based on real scenarios such as agricultural pest control and power line inspection, to refine the full chain capability map of "data collection → intelligent processing → decision support," providing precise demand input for the education chain. The construction of the Heilongjiang Province drone logistics base explicitly requires talents to have the ability to plan cross-scenario tasks, forcing the reconstruction of educational content. This mechanism ensures that the integration of the three chains is always driven by market demand through dynamic capture of industrial technology iteration, resolving the core contradiction of traditional training lagging behind industrial upgrading.

2.1.2 Innovation chain: a teaching-closed loop of technology transfer and research feedback

The innovation chain focuses on solving the bottleneck in the transformation between "research and teaching," connecting the demand of the industrial chain with the supply of the educational chain through a two-way circular mechanism. On one hand, it promotes the teaching of technology: integrating university research resources and corporate R&D achievements, converting patents and software

copyrights into modular teaching cases. On the other hand, it achieves knowledge standardization, developing lightweight translation tools to lower the threshold for technology learning. The case of the University of Stuttgart in Germany shows that standardized teaching materials have increased students' practical operation efficiency by 40%. The innovation chain ensures the simultaneous evolution of educational content and industrial technology with a closed loop of "scientific research break through→teaching transformation →application feedback → iterative R&D," providing a continuously updated knowledge ammunition depot for the educational chain.

2.1.3 Educational chain: a closed-loop ecological system for cultivating talents through progressive capability enhancement and collaborative empowerment

The educational chain aims to match talents with the industrial chain output, building a closed-loop ecosystem of "three-level ability progression + four-party collaborative empowerment." The three levels of ability cultivation include: the basic level, the application level, and the certification level. In terms of collaborative mechanisms: the administration coordinates resources to establish industry-education alliances; universities develop a micro-major of "drones + surveying and mapping"; enterprises jointly build training bases; research institutions formulate technical teaching standards, thereby forming a positive cycle of "demand → cultivation → output → optimization," ultimately achieving the collaborative coexistence of the educational chain, industrial chain, and innovation chain.

2.2 Mechanism Innovation: Functional Reconstruction of the Four Collaborative Subjects

The "Four Collaborative" mechanism, through role realignment and functional complementarity, solves the problems of subject decentralization and fragmented collaboration, constructs a "1+N" dynamic response system, and provides an execution carrier for the integration of the three chains.

2.2.1 Administration: dual-track drive of top-level coordination and institutional empowerment

As a resource integration hub, the administration drives a collaborative ecosystem through dual-track policy supply and platform construction: On the policy supply side, it formulates the "Special Plan for Training Talent in Low-altitude Economy" and establishes a special fund for industry-education integration to release institutional benefits, relying on the mandatory clause "Establishing no fewer than 20 joint laboratories between enterprises and schools" in the "General Aviation Planning of Heilongjiang Province for the 14th Five-Year Plan," providing legal basis for resource injection; On the platform construction side, it leads the establishment of the "Heilongjiang Province Low-altitude Economy Industry-Education Alliance," coordinating core resources such as airspace open permits, remote sensing data sharing libraries, and drone training equipment, effectively solving the problem of misallocation of resources between schools and enterprises. This dual-track model breaks through institutional barriers with administrative power, laying the institutional infrastructure for the integration of the three chains.

2.2.2 Universities: dual-loop linkage of curriculum reconstruction and ability incubation

Universities anchor on the demand gap of the industrial chain and implement dual-loop linkage of interdisciplinary studies and platform upgrading: By offering a minor in "unmanned aerial vehicles," new courses such as "low-altitude regulations" are embedded into the surveying and mapping curriculum system, raising the proportion of composite courses to 35%; simultaneously, they construct "unmanned aerial vehicle maintenance stations" and "remote sensing data processing centers" to undertake practical projects such as the delineation of rivers and lakes in Jixi City. With the help of this platform, Heilongjiang Institute of Technology has set up unmanned aerial vehicle training as a mandatory module for the surveying and mapping major, promoting a 28% increase in the pass rate of students' practical capabilities, achieving a paradigm shift from "subject-oriented" education chain to "scene capability output."

2.2.3 Corporation: a two-way closed loop of scenario feedback and standard co-creation

Corporations leverage their advantages at the industrial end to build a two-way closed loop of project feedback and standard co-creation: On the project feedback side, they provide 12 practical cases such as power line patrol and emergency logistics and develop flipbook-style teaching materials; On the standard co-creation

side, they jointly formulate a certification standard for a composite position of "flying hand + data analyst," and design a skill matrix covering 8 core capabilities such as airspace application and operation of multiple aircraft types.

2.2.4 Research institutions: a dual synergy of knowledge transformation and frontier driving

Research institutions focus on the bottleneck of technology transformation and achieve a dual synergy of knowledge transformation and frontier driving: in the knowledge transformation wheel, transform spatial management algorithms and remote sensing interpretation technology into teaching case packages; in the frontier driving wheel, introduce new technologies such as digital twins through the establishment of low-altitude economy workshops. The Fraunhofer Institute in Germany has empirically shown that this dual-wheel mechanism shortens the lag period of technical teaching to 6 months.

3. Systematic Design of Compound UAV Talent Training Path

The explosive growth of the drone industry has put forward new requirements for talent capabilities: not only expertise in the aircraft itself but also the ability to deeply integrate into vertical industry scenarios. Based on industry demand analysis, constructing a "4+X" core capability matrix and designing a full-chain implementation path is the key to cultivating high-quality composite talents.

3.1 Core Competency Matrix: "4+X" Dynamic Skill Model

3.1.1 4 Core capabilities

Firstly, a deep understanding of the drone hardware system is required, including a thorough grasp of the structural principles of mainstream models such as multi-rotors, fixed-wing, and VTOL fixed-wing, proficiency in the assembly process and calibration technology of precision components, and familiarity with the hardware troubleshooting process for common faults; on this basis, it is necessary to establish a comprehensive maintenance and support capability, master daily maintenance procedures and preventive maintenance strategies, and be skilled in the deep repair and replacement technology of key components to ensure the long-term reliable operation of the equipment; after mastering the flight technology, it is necessary to refine solid flight control skills, extending from basic manual control to automatic route planning and precise takeoff and landing in complex environments, possessing the ability to adapt to multiple aircraft types and payloads, and focusing on improving emergency handling skills in complex electromagnetic environments or severe weather conditions; finally, by maximizing the performance of hardware and software through system debugging capabilities, master flight control parameter adjustment, sensor calibration and fusion, data link optimization, and the integration and debugging of mission payloads to ensure that the entire drone system works together to achieve optimal performance.

3.1.2 X-class scenario capabilities

Combining professional skills, it is necessary to possess strong data analysis capabilities in surveying and mapping, be proficient in the acquisition processes of key data such as oblique photography and laser point clouds, and skillfully use professional software like Pix4D and Context Capture to complete core tasks such as aerial triangulation, real-world 3D modeling, orthophoto generation, and earthwork calculation. It is also essential to deeply understand the key factors for precision control in surveying and mapping results to ensure accurate and reliable data output. On this basis, it is necessary to be expert in the practical application of airspace regulations, thoroughly interpret the national "Interim Regulations on the Flight Management of Unmanned Aerial Vehicles" and local regulations, and skillfully operate airspace management systems like UTMISS for compliant airspace applications, flight plan reporting, and real-time dynamic surveillance. Additionally, the ability to conduct risk assessments and formulate emergency response plans is required, providing a solid guarantee for safe and legal flights. It is also necessary to have cross-platform collaboration and closed-loop management capabilities for specific scenarios. In the field of agricultural plant protection, the ability to interpret multispectral data to generate NDVI vegetation index maps, accurately identify pest and disease or fertility difference areas, and plan the optimal spraying path accordingly is required. This also involves data interaction with ground agricultural machinery or agricultural Internet of Things platforms to complete a closed-loop precision agricultural management. This

capability framework has high scalability, allowing for the dynamic addition of other core skills for different scenarios, such as using infrared thermal imaging to identify equipment defects in power line inspections or achieving rapid 3D modeling in emergency detection.

3.2 Three-Dimensional Integrated Implementation Path

3.2.1 Deep reconstruction of the curriculum system

Break through traditional professional barriers and systematically add cross-disciplinary and cutting-edge courses such as "Unmanned Aerial Vehicle Intelligent Networking and Cooperative Control" and "Intelligent Interpretation of Remote Sensing Images." Develop "loose-leaf" teaching materials for easy integration of the latest technical standards and industry cases. Construct a "step-by-step" training system: 1st stage - indoor-simulator basic operation, miniature drone disassembly and assembly; 2nd stage - closed-site operation of multi-aircrafts, basic payload debugging; 3rd stage - complex environment flight in real scenarios, execution of typical industry tasks; 4th stage - on-the-job practice - participate in the full process of real projects of enterprises.

3.2.2 Strong support from the practical platform

The lab is not only equipped with industrial-grade drones, high-performance workstations, and detection calibration equipment, but should also connect to a real industry data platform to simulate production environments. Establish an authoritative "Pilot Certification Center" and strictly train and assess according to the Civil Aviation Administration of China (CAAC) license standards, ensuring the cultivation of more than 5 highly qualified pilots with CAAC licenses annually.

3.2.3 Science-based evaluation drives improvement

Establish a multi-dimensional, quantifiable evaluation system, with dynamic feedback on the quality of training as shown in Table 1:

Table 1. Evaluation System

Evaluation dimension	Core indicators	Weight	Measurement instructions
Talent suitability	Graduate job competency rate	30%	Rate of good evaluations by the company after 6 months of employment
Technology conversion rate	Number of technical solutions implemented	25%	Number of achievements in generating economic benefits or solving practical problems
Industrial contribution	Number of companies served annually	20%	Grade of cooperative enterprises, project amount
Teaching effectiveness	Pass rate of industry qualification certifications	25%	Pass rate of authoritative certifications such as CAAC license, AOPA, etc

4. Empirical Cases: the Deep Integration Practice of Surveying and Mapping Engineering

Taking the surveying and mapping engineering major as a pilot, it took the lead in implementing the reform of "three chains and four collaborations", which achieved remarkable results and provided a replicable model for the training of compound talents.

4.1 Breakthrough Training Model Innovation

"2.5+0.7+0.3+0.5" advanced program: 2.5-year thick foundation: systematic learning of surveying and mapping basics, UAV technology principles, programming basics; 0.7 years of strong skills: settle in cooperative enterprises, participate in real surveying and mapping projects under the guidance of engineers, and master UAV aerial survey field planning, data acquisition and preliminary processing. 0.3 years of research and innovation: join the scientific research team of faculty or enterprise R&D department of the college, and participate in projects such as "intelligent route planning of UAVs with complex terrain" and "multi-source remote sensing data fusion" to cultivate the ability to solve complex problems; 0.5 years of fine positions: According to the previous performance and interests, they will be diverted to positions such as surveying and mapping engineers, data processing engineers, and UAV operation and maintenance engineers for internships to achieve seamless connection with employment. An average of 5 surveying and mapping students have systematically mastered UAV control, aerial survey data processing and industry application knowledge through the minor, and become "surveying and mapping + UAV" dual talents, and their employment

competitiveness has been significantly improved.

4.2 Transformation and Application of High-Value Achievements

Based on the accumulation of real projects, teachers and students jointly developed two special teaching resources: "Low-altitude Remote Sensing Data Interpretation Case Library" and "UAV Surveying and Mapping Engineering Practice Guidance Manual". The case library covers various scenarios such as terrain surveying and mapping, real estate rights confirmation, and disaster monitoring, including raw data, processing processes, common problems, and industry standards. Thanks to solid practical training, students in the direction of "UAV + Surveying and Mapping" are deeply involved in the river and lake demarcation project of Jixi City. By using UAV aerial surveys to generate high-precision orthophotos and digital surface models, the data collection and initial screening work that traditional manual delimitation takes months to complete is compressed to a few weeks, and the overall data processing efficiency is increased by more than 40%. The project has not only become a model of information management of local river and lake chief system, but also directly confirms the great value of compound drone talents in improving public service efficiency.

5. Conclusion

Based on the contradiction between the explosive growth of the low-altitude economy and the structural shortage of talents, this paper innovatively proposes the "three chains and four collaboration" talent training model, which systematically solves the core bottleneck of traditional education lagging behind industrial upgrading through the anchoring of industrial chain demand, the feedback of innovation chain technology, the progressive integration of education chain capabilities, and the four-party collaborative reconstruction of administrations, universities, enterprises and scientific research institutions. With the surveying and mapping engineering major as the empirical carrier, the "4+X" dynamic capability matrix and the advanced path of "course-training-certification" are designed, and the "UAV +" micro-professional group and the industry-education alliance platform are constructed, which significantly improves students' compound ability of technology application and airspace management. Empirical evidence shows that this model has increased the compliance rate of talents' actual combat ability by 28%, increased the data processing efficiency by more than 40%, and spawned special teaching resources such as the "Low-altitude Remote Sensing Interpretation Case Library", which has successfully supported the river and lake demarcation project in Jixi City. Its value lies in the formation of a replicable "three-chain closed-loop, four-wheel drive" education paradigm, which not only provides precise talent supply for the regional low-altitude economy, resolves the dual pressure of the job market and industrial upgrading, but also contributes a generalizable "Longjiang experience" to the innovation of the integration mechanism of industry and education under the strategy of new quality productivity, and ultimately promotes the sustainable and coordinated development of the education chain, innovation chain and industrial chain.

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