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Developing an Industry-Aligned Curriculum for Aviation Manufacturing Education

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Abstract: This study examines a curriculum system developed at the College of Aviation Manufacturing Industry at Nanchang Hangkong University through Industry-Education Integration (I-E Integration). Drawing on engineering education principles and reforms in the Mechanical Design, Manufacturing, and Automation program, it aligns course design with industry needs, integrates technological advancements, and embeds production processes. The approach restructures modular course content based on aviation manufacturing technologies, implements project-based learning via a university-enterprise "factory-in-school" training base, and adopts an Outcome-Based Education (OBE) system for evaluation and improvement. This replicable model provides practical insights for industry-focused curriculum development.

Keywords: I-E Integration; Aviation manufacturing curriculum; OBE; Engineering education reform

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1. Introduction

The aviation manufacturing industry, a cornerstone of national strategic development, is experiencing rapid technological advancements, intensifying the demand for highly skilled, application-oriented professionals. At the 2023 National Conference on I-E Integration for the Rail Transit Equipment Sector, China's Ministry of Education emphasized that "I-E Integration is essential for the high-quality development of higher education." As one of the first 20 standardized industry colleges established by the Ministry of Education and the Ministry of Industry and Information Technology, the College of Aviation Manufacturing Industry at Nanchang Hangkong University is strategically located in Jingdezhen High-Tech Industrial Development Zone, a key hub for helicopter research, development, and assembly in China. With programs in Mechanical Design, Manufacturing, and Automation, and Aircraft Manufacturing Engineering, the college aligns directly with the technical needs of leading local enterprises, such as AVIC Changhe Aircraft Industry and Jiangxi Jinghang Aviation Forging and Casting, providing an ideal setting for exploring industry-integrated curriculum development.

Current curriculum systems for aviation manufacturing programs face three critical challenges. First, there is a tension between the rapid pace of technological advancements and outdated teaching content, as new processes, materials, and equipment in aviation manufacturing outstrip the slow update cycles of textbooks. Second, the complexity of engineering practice conflicts with limited teaching resources, as aviation manufacturing involves interdisciplinary knowledge and intricate processes, yet institutions struggle with costly and outdated training facilities. Third, the diverse talent needs of industry—spanning research, process engineering, and quality control—clash with the uniformity of traditional curricula, resulting in graduates whose practical skills fall short of industry expectations and limited employability [1].

To address these challenges, this study proposes an industry-aligned curriculum framework that integrates course design with industry demands, aligns content with technological advancements, and embeds teaching within production processes. It further promotes collaboration between academic faculty and industry experts, integrates institutional and enterprise resources, and aligns student training with industry needs. Using the Mechanical Design, Manufacturing, and Automation program as a pilot, this study draws on over two years of practical exploration to develop a curriculum reform model tailored to the aviation manufacturing industry chain. Unlike prior I-E Integration studies, this research focuses on practical implementation details from an engineering education perspective, including transforming real industry projects into teaching cases, establishing dual-instructor teaching mechanisms, and evaluating the curriculum's effectiveness in fostering engineering competencies. The findings offer actionable insights for curriculum development in similar industry-focused colleges [2].

2. Aviation I-E integration curriculum analysis

2.1. Core characteristics of the industry college curriculum system

The curriculum system of an industry college fundamentally differs from traditional curricula through its deep integration of industry-specific elements. The curriculum of the College of Aviation Manufacturing Industry at Nanchang Hangkong University is not merely an adaptation of existing courses with added industry components but a comprehensive restructuring of course logic and content driven by industry needs. From an educational ecology perspective, this curriculum operates as an open system, continuously exchanging resources, such as equipment and materials (matter), technical expertise and knowledge (energy), and standards and processes (information), with the industry environment to maintain dynamic equilibrium [3]. This system is characterized by three key features:

(1) Demand-driven design

Curriculum objectives are aligned with the talent needs of aviation manufacturing enterprises. Through job role surveys conducted with partner companies, such as AVIC Changhe Aircraft Industry and Jiangxi Jinghang Aviation Forging and Casting, the Mechanical Design, Manufacturing, and Automation program has defined its training focus on process engineering, while also addressing research and development (R&D) and production management. Differentiated course modules were developed for each track. For process engineering, core courses include Mechanical Manufacturing Technology, CNC Technology and Programming, Part Processing and Simulation Design, and Specialized Manufacturing Techniques.

(2) Technological relevance

Course content closely tracks advancements in aviation manufacturing technology. For instance, while traditional curricula emphasize metal machining processes for helicopter rotor production, the increasing use of composite materials in aviation prompted the inclusion of Composite Materials Technology as a core course. Technical experts from AVIC Changhe's composite materials workshop contribute to the practical component of Composite Materials Technology Course Design, incorporating cutting-edge techniques such as automated tape laying and autoclave molding.

(3) Authentic practice

Teaching is grounded in real-world production environments and projects. The university's partnership with AVIC Changhe established a "factory-in-school" training base, enabling students to learn in authentic settings, such as helicopter assembly lines and CNC machining centers. For example, the Digital Assembly course utilizes the Z-10 helicopter tail boom assembly line as a teaching site, transforming production documents like process cards and quality inspection forms into instructional materials [4].

2.2. Aviation manufacturing curriculum mapping

Table 1. Aviation industry knowledge-curriculum mapping

Knowledge level	Knowledge content	Corresponding course modules	Teaching implementation Method
Foundational Theory Layer	Engineering Mechanics, Materials Science, Mechanical Principles, etc.	Fundamental Professional Courses (Engineering Mechanics, Aviation Materials and Heat Treatment, Mechanical Principles)	Theoretical Instruction + Basic Experiments
Specialized Technical Layer	Aviation Parts Machining, Assembly, Inspection, etc.	Core Professional Courses (Composite Materials Technology, CNC Technology and Programming)	Case-Based Teaching + Virtual Simulation
Process Application Layer	Enterprise-specific Processes, Tooling, Standards, etc.	Professional Orientation Courses (Machining Process Design and Simulation, Non-Traditional Machining Technologies)	Enterprise Mentor Guidance + On-Site
Innovation and R&D Layer	New Materials, New Processes, Intelligent Manufacturing, etc.	Professional Development Courses (Aviation Intelligent Manufacturing Equipment Technology, Scientific Innovation Practice)	Production Training Project-Driven Approach + Research Feedback Integration

Aviation manufacturing is characterized by a long, technology-intensive industry chain with a hierarchical and dynamic knowledge structure. Based on an analysis of the Jingdezhen aviation industry cluster, we categorized the industry's knowledge into four levels and established a mapping relationship with the curriculum system, as presented in **Table 1**.

This knowledge stratification approach departs from the traditional discipline-based curriculum organization, establishing an industry chain-oriented course structure. For instance, in the "CNC Machining of Aircraft Components" course, we have moved beyond isolated instruction of discrete knowledge points such as CNC programming, tool selection, and process planning. Instead, we adopt the actual manufacturing process of helicopter hub components from Changhe Aircraft Industries Corporation as the instructional framework, systematically integrating relevant knowledge and skills to form comprehensive learning projects.

2.3. Dynamic curriculum development mechanism

The rapid knowledge evolution in aerospace manufacturing necessitates dynamic curriculum adaptation.

We have established a four-step knowledge development mechanism: technology tracking → knowledge deconstruction → pedagogical transformation → feedback optimization [5].

(1) Technology Tracking Mechanism

Faculty conduct semesterly technical research at partner enterprises and participate in innovation projects. For example, after Changhe Aircraft introduced robotic automated drilling-riveting systems in 2024, the technology was promptly incorporated into the Industrial Robotics Technology and Applications course.

(2) Knowledge Deconstruction Methodology

Complex technologies are decomposed into teachable units. Composite blade manufacturing, for instance, is deconstructed into modules, material selection, ply design, mold preparation, curing processes, and quality inspection, each mapped to instructional units with tailored theoretical content, virtual simulations, and hands-on training.

(3) Pedagogical Transformation Pathways

Industrial knowledge transforms into teaching resources through three pathways: integrating aviation standards into curricula to synchronize with industry norms; converting production cases into training projects like helicopter drive shaft analysis; and translating technical challenges into graduation projects such as rotor edge-trimming optimization. This mechanism maintains teaching relevance while enhancing practical cultivation.

(4) Feedback Optimization System

Annual employer evaluations and graduate tracking inform curriculum adjustments. For instance, 2023 feedback revealed gaps in 3D modeling and engineering drawing conversion, prompting the addition of Model-Based Definition (MBD) content in Computer-Aided Design and Drafting.

This mechanism ensures synchronization with industrial advancements, creating a virtuous cycle: industry demands → curriculum updates → talent development → industrial service [6]. Two years of data show that students in reformed courses exhibit 25% higher employer satisfaction and significantly improved problem-solving skills and job adaptability.

3. Curriculum system and industry needs docking mechanism

3.1. Precise docking between curriculum setting and industry needs

Industry needs serve as the logical starting point for constructing the I-E Integration curriculum system. We adopt a “three-dimensional” needs analysis method to ensure the curriculum setting resonates at the same frequency with the development of the aviation manufacturing industry:

(1) Macro dimension: Focuses on national aviation industry development strategies and regional economic planning, such as the key development directions (helicopters, UAVs, etc.) clearly defined in “Jiangxi Province’s ‘14th Five-Year’ Plan for High-Quality Development of Aviation Industry”;

(2) Meso dimension: Analyzes the technology roadmap of Jingdezhen aviation industry cluster, such as Changhe Aircraft Company’s technology upgrade plans in intelligent manufacturing and composite material applications;

(3) Micro dimension: Investigates the specific competency requirements of partner enterprises’ positions, extracting core competency indicators by analyzing job descriptions for positions like process engineers and quality inspectors.

Based on the needs analysis, we reconstructed the curriculum system framework for the Mechanical Design, Manufacturing, and Automation major. This framework adopts a flexible “platform + module” structure, including four parts: general education platform, professional foundation platform, professional direction modules, and extension elective modules.

Among them, the professional direction modules directly dock with key links of the aviation manufacturing industry chain, setting up three directional course groups: “Precision Manufacturing of Aviation Parts,” “Aviation Materials and Process Direction”, and “Intelligent Aviation Manufacturing Direction,” allowing students to flexibly choose according to their career planning.

The dynamic adjustment mechanism of curriculum design is key to ensuring alignment effectiveness [7]. The college has established a professional development committee composed of internal and external experts, which holds annual meetings to review curriculum design and promptly respond to industry changes. For example, with the advancement of aviation intelligent manufacturing, the course “Aviation Intelligent Manufacturing Equipment Technology” was added in 2024, while the class hours for “Mechanical Manufacturing Technology” were reduced. In response to employer feedback about graduates’ insufficient project management skills, an elective course titled “Aviation Engineering Project Management” was added to the extended module.

3.2. Seamless integration of course content with technological advancements

Given the rapid iteration of aviation manufacturing technologies, course content must establish channels for swift updates [8]. We have developed a “Four-Step Transformation Method” to convert cutting-edge enterprise technologies into teaching materials: technology screening → pedagogical adaptation → resource development → classroom implementation. Taking the robotic automatic drilling and riveting system introduced by Changxing Company as an example, enterprise engineers and instructors first collaboratively identified key technical points suitable for teaching (e.g., visual positioning, process parameter optimization). The teaching team then decomposed these technical points into three levels—basic theory, core technology, and extended application—corresponding to the teaching requirements of different courses. Next, supporting virtual simulation experiments and hands-on training projects were developed. Finally, instruction was delivered through joint enterprise-college teaching.

The core of course content integration lies in overcoming the bottleneck of textbook updates. We adopted a “modular textbook + digital resources” hybrid strategy: core course materials use a modular format for easy updates, while complementary AR/VR teaching resources visually demonstrate complex processes. For instance, the “Helicopter Structural Assembly Technology” course developed an AR-based assembly process guidance system. By scanning physical models with tablets, students can overlay assembly sequences, process requirements, and common issues, significantly improving learning outcomes [9].

To address tacit knowledge unique to aviation manufacturing (e.g., experienced technicians’ know-how), we facilitate knowledge transfer through “Enterprise Mentor Workshops.” Each semester, technical experts from enterprises are invited to conduct case-based workshops on hard-to-codify practical experience. For example, a senior technician from Changfei Company led a workshop on “Helicopter Transmission System Assembly Adjustment Techniques,” transforming vibration control methods accumulated over the years into teachable content, which was highly praised by students.

3.3. Deep alignment of teaching processes with production processes

To effectively implement I-E Integrated courses, it is essential to transcend the limitations of traditional classroom settings and establish diversified teaching scenarios [10]. We have developed a "Tri-Classroom Synergistic" teaching chain consisting of campus-based classrooms for theoretical foundations, factory-based classrooms for skills training, and online classrooms for extended learning. Among these, factory classrooms serve as the pivotal platform for bridging education with production. The college has established dedicated teaching zones at Changfei Company's production facilities, equipped with multimedia teaching tools, materializing the educational philosophy where "workshops become classrooms, workstations transform into desks, and products serve as teaching aids."

Project-driven learning effectively integrates teaching with production processes through a structured "Three-Phase Project" system. The system begins with basic projects targeting skill-specific training, such as CNC milling programming, followed by comprehensive projects involving complete part processing like helicopter connector manufacturing, and culminates in innovation projects addressing real-world technical challenges, including process optimization. All projects are derived from actual enterprise needs and jointly supervised by industry and academic mentors. For instance, the 2024 comprehensive project "Optimization of Helicopter Main Reducer Bracket Processing Technology" resolved a production issue at Yatai Company. The student-proposed fixture improvement solution was adopted, achieving approximately 10% annual cost savings.

To ensure seamless coordination between teaching and production, we implemented flexible management mechanisms featuring adaptive scheduling that aligns internship periods with enterprise production cycles to avoid operational peaks, a dual-mentorship system pairing enterprise professionals for practical training with academic instructors for theoretical guidance, and a credit recognition framework that converts industry-acquired certifications into academic credits, all designed to maintain educational quality while supporting uninterrupted production, thereby achieving mutual benefits for both institutions and enterprises.

The alignment of teaching and production processes has significantly enhanced students' engineering practice capabilities. Statistics show that students participating in factory classrooms improved their engineering blueprint reading accuracy from 72% to 93%, and the excellence rate in process plan evaluation rose from 65% to 85%. Post-graduation job adaptation periods were shortened by an average of 2–3 months. This deep integration model also provides enterprises with talent pipelines and technical innovation insights. Changfei Company has incorporated the industrial college into its "Technician-Process Engineer" training system, establishing a stable talent supply channel.

4. Building a support system for curriculum implementation

4.1. Collaborative integration of faculty and industry experts

A high-quality teaching faculty is the core guarantee for implementing I-E Integration courses. The College of Aviation Manufacturing Industry has innovatively established a dual-qualified faculty development mechanism featuring two-way mobility and tripartite evaluation. Two-way mobility refers to the regular exchange of teachers entering enterprises and engineers entering classrooms, with the requirement that professional teachers accumulate no less than six months of enterprise practice every five years, while enterprise technical experts undertake no fewer than 16 practical teaching hours annually. A tripartite faculty evaluation system involving the school, enterprises, and students has been implemented, assessing not only teaching and research performance but also contributions to solving real enterprise problems [11].

The integration of faculty takes diverse forms. The college implements the "Five Ones" initiative: each professional teacher is required to connect with one enterprise workshop, participate in one technical project, pair with one enterprise mentor, develop one I-E Integration course, and guide one group of students in enterprise practice. For example, the mechanical manufacturing teaching team established a fixed partnership with Yongxin Company's CNC machining workshop, jointly developing the "Five-Axis Machining Technology for Aviation Parts" course. Fifty percent of the course's content is taught by enterprise process engineers, with teaching materials directly derived from real-world cases such as the machining of helicopter rotor clevises. Additionally, the college has recruited three senior engineers and technical experts from enterprises as industry professors, who not only teach but also participate in talent cultivation processes, including program development and laboratory construction.

To enhance collaborative teaching effectiveness, a joint teaching-research system was established. Enterprise and academic teachers co-design teaching projects, develop resources, and discuss methodologies. Particularly in practical training courses, a three-stage teaching method is adopted: "enterprise mentor demonstration → academic teacher explanation → student hands-on practice," ensuring the organic integration of theory and practice. This deep collaboration not only improves teaching quality but also fosters mutual understanding and integration of school-enterprise cultures.

4.2. Optimized integration of teaching resources and enterprise resources

I-E Integration courses require breaking the boundaries between academic and enterprise resources to build a shared ecosystem. The college and partner enterprises jointly established a "Three Databases, Two Platforms" resource system: Course Case Database (collecting over 30 typical enterprise production cases); Process Standard Database (integrating over 20 national, industry, and enterprise standards for aviation manufacturing); Virtual Simulation Database (developing 5 VR/AR training projects); Collaborative Management Platform (coordinating teaching schedules, internship management, and quality monitoring); Resource Sharing Platform (combining academic theoretical resources with enterprise practical resources). This system systematically integrates scattered resources, improving efficiency.

Practical training base construction is a key aspect of resource integration. The "Aviation Manufacturing Training Center," co-built with Yatai Company, follows a "productive training" concept, serving both teaching needs and actual production tasks. The center includes CNC machining, composite material forming, and aircraft assembly training zones, equipped with advanced machinery such as DMG MORI five-axis machining centers and automated fiber placement machines, mirroring real production environments. Training programs follow a progressive "simple-to-complex, virtual-to-real" approach: lower-year students practice basic operations on virtual simulation systems, while upper-year students engage in real production tasks. This model ensures both safety and authenticity.

4.3. Comprehensive integration of student development and enterprise needs

The college has developed a comprehensive Three-Level Alignment mechanism to cultivate high-quality applied talents through I-E Integration. This framework first aligns educational standards with aviation industry vocational requirements, enabling students to earn both academic degrees and professional certifications in fields like CNC Machining of Aviation Parts. Second, it matches learning processes with real enterprise workflows through courses that replicate actual production processes, including task allocation and quality control. Third, it adopts comprehensive industry assessment criteria that evaluate not only product specifications but also production efficiency and cost-effectiveness.

To ensure continuous industry engagement throughout students' academic journey, the institution implements a structured Four-Year Continuous practice system. The first year focuses on career awareness through enterprise visits and expert lectures. The second year develops basic professional skills through job shadowing and workflow observation. The third year provides deeper professional immersion through rotational internships and project participation. The final year emphasizes comprehensive application via full-time internships and capstone projects that address real industry challenges. This progressive approach systematically bridges the gap between academic preparation and professional requirements.

This progressive system helps students adapt to enterprise environments, achieving quasi-employee competency. For instance, 85% of the 2025 graduating class's capstone projects addressed real enterprise needs, with 23% of solutions shortlisted for enterprise application, generating potential economic benefits. Notable examples include:

(1) Process Optimization: One graduate optimized the precision machining process for a UAV landing gear support arm, reducing deformation from 0.15 mm to under 0.05 mm and cutting machining time by 25%. The solution was adopted for mass production and incorporated into the Mechanical Manufacturing Technology curriculum.

(2) Smart Manufacturing: Another graduate developed an "AI-Based Defect Detection Algorithm for Composite Blade Layup," achieving 96.7% accuracy (11% higher than traditional methods) in Jinghang Aviation's quality inspection system.

This "real-problem, real-solution" capstone model delivers both educational and economic value. Enterprises gain actionable solutions while pre-screening potential hires. 38% of 2025 graduates working on enterprise projects received priority employment offers, creating a "graduation-to-employment" pipeline. These cases, after didactic refinement, have also updated four professional courses, forming a closed-loop knowledge transformation: production problems → capstone projects → teaching cases.

5. Practical outcomes and promotional value of the curriculum system

After two years of implementation, the "Three Alignments and Three Integrations" curriculum system has achieved remarkable results: students' engineering practice proficiency rate increased to 91%, enterprise-project-based graduation theses accounted for 85%, and competition awards grew by 120% [12]. Employer satisfaction scores rose from 64 to 86 (scale: 0-100), while graduates' job adaptation period shortened to three months. The proportion of dual-qualified teachers grew from 40% to 85%, with annual enterprise training exceeding 100 participants. To address challenges in industry-academia collaboration, curriculum updates, and faculty development, measures such as establishing win-win mechanisms, dynamic course inventories, and innovative personnel systems were implemented, expanding partner enterprises from 3 to 12 and forming a 20-member industry-academia integrated teaching team.

The system's innovative value manifests in three dimensions: methodologically, it created a closed-loop "industry-knowledge-teaching chain" mapping model and a replicable four-step curriculum development approach; institutionally, it established a sustainable co-construction and sharing mechanism between schools and enterprises; practically, it developed a new education paradigm featuring precise alignment between specialized program clusters and industrial chains. Looking ahead, the system will focus on three development priorities: integrating cutting-edge digital technologies for intelligent teaching reform, localizing international certification standards, and building modular personalized course systems, while planning to expand the model to 18 aviation vocational colleges in Jiangxi Province as demonstration sites.

6. Conclusion

The College of Aviation Manufacturing Industry's "Three Alignments, Three Integrations" curriculum system demonstrates that deep coupling of educational and industrial elements is essential for cultivating high-quality applied talents meeting aviation industry needs. This model not only serves aviation manufacturing but also provides a reference for other advanced equipment manufacturing disciplines. As national I-E Integration policies advance, industry colleges will become vital talent cultivation bases, requiring ongoing innovation in curriculum system development.

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