



# Research on the Construction of Undergraduate UAV Practical Courses

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**Abstract.** In response to the current application of unmanned aerial vehicles (UAVs) in many fields and the development needs of the low-altitude economy, this paper deeply explores the construction objectives, teaching content, teaching methods and practices of UAV practical courses at the undergraduate teaching stage, analyzes the problems encountered in the course implementation process, and puts forward targeted improvement measures. Through a comprehensive analysis of the course, this paper aims to provide a reference for cultivating UAV professionals who can meet the needs of modern scientific and technological development, and promote the high-quality development of UAV practical teaching.

**Keywords:** UAV practical education, undergraduate curriculum construction, UAV teaching module design.

## 1 Introduction

In recent years, the diverse applications of drones have elevated the importance of drones to a new level, showcasing their multifaceted operational capabilities. For example, drones are used to provide reconnaissance intelligence information, which has changed traditional reconnaissance methods. In offensive operations, suicide drones can precisely strike targets; for example, loitering munitions offer high operational effectiveness at relatively low costs, thereby altering the balance of power. In the civilian sector, with the rapid development of the low-altitude economy in recent years, drones have been widely adopted in various fields such as agriculture, public security, surveying and mapping, and transportation, significantly increasing the demand for drone operators. As drone technology continues to advance, drone pilots are no longer merely operators who control aircraft—they have become planners and managers of flight missions. Consequently, the requirements for drone pilots have expanded beyond basic flight operation skills to include the execution of flight missions, analysis of flight data, and management of flight safety. At this stage, drone flight control systems are becoming increasingly intelligent. As a result, drone operators' job responsibilities are shifting

from mere flight operations to the planning and management of flight missions, requiring them to possess higher-level skills in mission management, data analysis, and emergency response. With the ever-expanding application of drones, the demand for professionals with specialized drone operation skills and knowledge is rapidly growing.

To meet this demand, numerous universities and vocational colleges have begun offering drone-related courses. Among these, practical drone courses—critical for developing drone operators' hands-on capabilities and problem-solving skills—have become particularly important. Recent years have witnessed a growing emphasis on integrating theory and practice in UAV education to meet the demands of an increasingly intelligent and interdisciplinary technological landscape. Zhang et al. [1] developed a comprehensive practical teaching system for quadrotor UAV experiments, demonstrating how structured hands-on activities can reinforce theoretical understanding and enhance student proficiency. Similarly, Li et al. [2] addressed the cultivation of practical abilities among UAV professionals under the backdrop of intelligence-driven applications, advocating for curricula that align with real-world operational challenges. Educational environments tailored for UAV learning have also been explored; Sedláček et al. [3] designed a supportive ecosystem that blends simulation and physical experimentation, while Giurato et al. [4] and Abarca et al. [5] implemented multidisciplinary and interdisciplinary UAV courses that foster collaboration across engineering domains. Pedagogical innovations such as challenge-based learning, as employed by Félix-Herrán et al. [6], further promote competency development through immersive, project-oriented tasks. To bridge theory and practice more effectively, Arsat et al. [7] utilized drone flight simulators in a pilot study, showing their potential as accessible training tools. Meanwhile, Sadraey [8] critically examined the techniques and inherent challenges in UAV design education, calling for adaptive teaching strategies. Most recently, Chatzopoulos et al. [9] introduced an open-source, low-cost drone platform grounded in the engineering design process, offering a scalable and affordable solution for higher education settings like mechatronics courses. Collectively, these studies highlight a clear trend toward experiential, interdisciplinary, and cost-effective approaches in UAV education, aiming to equip students with the technical and problem-solving skills required in modern aerospace and robotics industries. This study aims to comprehensively and systematically explore the organizational approaches and teaching strategies for drone practice courses. By analyzing the experiences and challenges encountered during course implementation, it focuses on the critical needs of building a new generation of drone capabilities—particularly in light of diverse typical application demands from both military and civilian sectors as well as the overarching trend toward intelligent development.

So the main contribution of this paper is proposing the content of the teaching system and the practical methods for drone practice courses. The structure of the article is as follows. In Section 2, this paper designs a teaching content system for the drone practice course. In Section 3, combined with the teaching content and objectives, we introduce the teaching methods used in the course.

## 2 Design of the Practical Curriculum System for UAV

Currently, with the rapid development of emerging technologies such as artificial intelligence and unmanned systems, the development of unmanned aerial vehicles is accelerating its evolution toward intelligence, distribution, and high tempo. From the perspective of talent cultivation orientation, both military and civilian fields have raised higher requirements for UAV professionals.

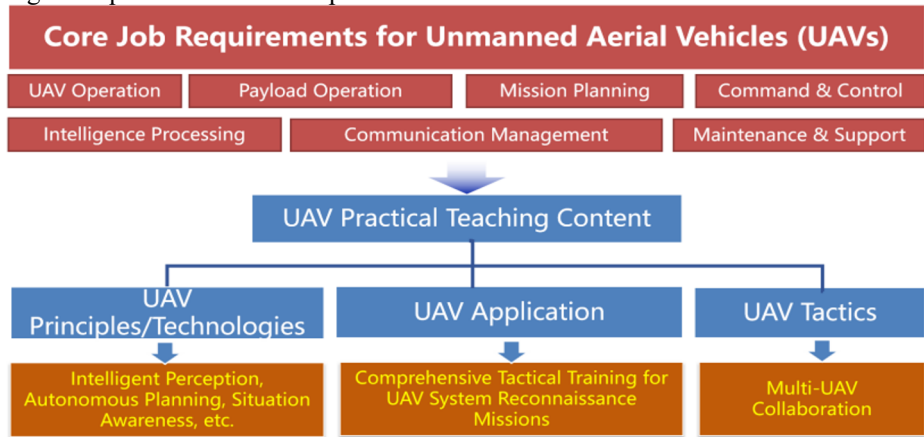


Fig. 1. Curriculum System Design Framework Diagram

To this end, the curriculum design shall take the demands of practical post capabilities as the fundamental driving force, regard intelligent autonomy as the core driver, and closely align with the Observe–Orient–Decide–Act (OODA) loop theory, as shown in Figure 1.

### 2.1 Course Development Objectives

Closely aligned with the evolutionary trend of intelligence and the urgent demand for new-type talents in posts, this UAV practical curriculum takes "integration of technology and operation, linkage of post and training" as the core teaching philosophy, and systematically constructs a three-in-one new practical teaching paradigm of "teaching - training - competition". The curriculum not only focuses on cultivating basic UAV platform operation capabilities, but also emphasizes the tempering of advanced competencies such as intelligent perception, autonomous decision-making, and collaborative action in complex environments. Deeply integrating the Observe–Orient–Decide–Act (OODA) loop, the curriculum guides students to accelerate decision-making cycles and optimize tactical responses in dynamic, confrontational, and uncertain environments. Meanwhile, relying on on-campus comprehensive practical training, red-blue confrontation exercises, and high-level intelligent unmanned system competitions, an immersive growth path of "learning by doing, competing by practicing, and innovating by competing" is built to effectively stimulate students' tactical imagination and technological innovation capabilities. Ultimately, the curriculum is committed to realizing

students' capability leap from "daring not to fly and being unable to use" to "flying stably and using proficiently", and further to "thinking deeply and daring to innovate". It comprehensively cultivates new-quality UAV talents who understand both technology and tactics, and are capable of both operation and innovation, truly bridging the "last mile" from college classrooms to future posts.

## 2.2 Design of Teaching Content

To achieve a leap in capabilities from basic understanding to tactical innovation, it is necessary to break away from the traditional fragmented curriculum that emphasizes theory over practical application. This system uses the OODA (Observe, Orient, Decide, Act) loop as its internal logical framework, dividing teaching content into three interconnected and progressively deepening modules.

(1) UAV Theory (Principle Level): This module focuses on the fundamental scientific principles and key technical mechanisms of UAV systems, serving as the theoretical foundation for all subsequent practical skills.

(2) UAV Practical Operations (Technical Level): Building upon the understanding of principles, this module employs intensive, standardized, and scenario-based flight training to develop trainees' proficiency in UAV platform operation and emergency response capabilities.

(3) UAV Application Design (Application Level): This stage emphasizes the transition from "knowing how to fly" to "knowing how to use," requiring trainees to design comprehensive UAV mission solutions based on specific operational scenarios.

**UAV Theory (Principle Level).** This module focuses on the fundamental scientific principles and key technical mechanisms of UAV systems, forming the theoretical foundation for all subsequent practical capabilities. The course thoroughly analyzes the aerodynamic essence of UAV flight, clarifying the dynamic equilibrium relationships among lift, gravity, thrust, and drag. It systematically explains the UAV's core subsystems: airframe structure, power system (including engine, propellers, and energy modules), flight control system (integrating multi-source sensors such as IMU, GPS, and barometers), communication system (remote control link and high-definition video transmission), and diverse mission payloads (optical-electrical, surveying and mapping, and strike equipment), revealing their collaborative working mechanisms and performance constraints. It guides trainees to establish a comprehensive cognitive framework linking physical principles to system design, laying an irreplaceable theoretical foundation for subsequent operational training, mission planning, and tactical innovation.

**UAV Practical Operations (Technical Level).** This module systematically cultivates trainees' UAV operation and emergency response capabilities through a three-dimensional integrated training system of "assembly and debugging - simulation flight - real-flight operations." In the assembly and debugging phase, trainees work in teams to complete the full-system assembly of small UAVs, including airframe structure construction, integration of the power system (motor and propeller installation), core flight

controller debugging (IMU calibration, GPS signal testing), and communication link verification, mastering system integration skills and fault diagnosis methods from individual components to the complete aircraft. In the simulation flight phase, leveraging a high-fidelity realistic simulation platform, complex electromagnetic environments and diverse mission scenarios (e.g., urban area reconnaissance) are constructed to train trainees in dynamic parameter adjustment, flight mode switching (manual/semi-automatic/automatic), and emergency decision-making under sudden conditions such as signal interference and power failure. In the real-flight test phase, a three-stage training method of "basic - advanced - confrontation" is adopted, gradually transitioning from routine takeoff and landing to tactical maneuvers such as low-altitude penetration and formation coordination, strengthening trainees' visual operation and on-the-spot handling capabilities under complex environmental conditions.

**UAV Application Design (Application Level).** This module focuses on cultivating trainees' UAV system design and application capabilities for tactical-level reconnaissance missions through a full-chain training process of "requirements analysis - platform selection - payload configuration - data processing - intelligence transformation," enabling trainees to master reconnaissance solution design capabilities tailored to near-real scenarios. The course emphasizes in-depth analysis of the tactical application characteristics of fixed-wing UAVs in urban environments. For vehicle target reconnaissance, it systematically explains deep learning-based automatic detection and tracking algorithms for moving targets (e.g., YOLO, SORT) and motion trajectory prediction techniques. Through a high-fidelity simulation training environment, trainees practice designing a four-stage reconnaissance process: "wide-area scanning - target acquisition - continuous tracking - behavior analysis," mastering parameter optimization methods to improve target recognition accuracy under complex urban background interference (e.g., frame rate settings, resolution adjustment, image enhancement processing).

### 3 Design of Teaching Methods

To effectively support the talent development goal of "being able to fly, knowing how to apply, and daring to innovate," this course innovatively adopts a dual-driven teaching model of "interest stimulation + role immersion."

(1) This course constructs a low-cost and high-efficiency stepped training mechanism. To address the common psychological barriers of beginners, such as fear of crashing and reluctance to perform actual flights, the course establishes a training system featuring "one drone per trainee, simulation-first practice, and low-cost trial-and-error". Each trainee is equipped with a small-scale teaching-oriented fixed-wing UAV, and combined with high-fidelity flight simulation software (e.g., DJI Flight Simulator, PX4 SITL, etc.), the progressive training path of "simulation prior to real flight, and individual practice prior to collaborative operation" is realized. A database of typical fault cases (e.g., GPS signal loss, motor failure, communication interruption, etc.) is embedded in the training process. Through the six-step closed-loop process of "task introduction — operational practice — error exposure — instructor feedback — independent

optimization — group reflection", trainees are guided to achieve the full-process capability improvement of "entry-level proficiency → error correction → optimization → reflection → refinement → competence enhancement" in a safe, economical, and repeatable training environment.

(2) The course develops a comprehensive training platform integrating virtual and real environments. Leveraging medium-to-large-sized UAV actual equipment platforms, the course has developed a dual-seat, high-fidelity simulator system equipped with both a command station and a control station, establishing a three-tiered progressive training process of "simulation—actual equipment—real application." In the initial stage, trainees conduct high-risk training such as route planning and emergency response in the simulator. In the intermediate stage, they transition to practical training involving ground taxiing, low-altitude fly-throughs, and payload operations using actual equipment. In the advanced stage, near-real scenarios such as formation coordination and reconnaissance-strike integration are incorporated. By ensuring seamless data exchange between virtual and real environments, consistent operational logic, and unified evaluation standards, the course ensures that trainees become proficient in simulation, validated in actual equipment, and elevated through near-real scenarios.

(3) This course establishes an immersive research and learning platform rooted in military-industrial enterprises, and opens up a talent cultivation channel integrating industry and education. In collaboration with leading domestic UAV R&D institutions, the course regularly organizes trainees to carry out immersive research activities in corporate R&D centers, final assembly workshops, and flight test bases. By closely observing the assembly processes, flight control debugging, and mission payload integration of typical models such as the CH-4 UAV, combined with on-site explanations by engineers and hands-on post experience (e.g., ground station operation, mission planning software application), trainees can intuitively understand the complete equipment life cycle. These research activities not only strengthen the cognition of professional skills, but also expand industrial horizons, stimulate professional identity and a sense of mission for engaging in national defense science and technology undertakings, and effectively achieve the triple talent cultivation goals of "skill enhancement – horizon expansion – career initiation".

## 4 Conclusion

Against the backdrop of the strategic application of UAVs and the talent demand transformation driven by the development of the civil low-altitude economy, this paper addresses the pain points of traditional UAV teaching—overemphasis on theories over practical capabilities and the disconnection between technical skills and tactical applications. Taking the OODA loop theory as the core, this study constructs a closed-loop teaching system featuring four integrated dimensions: "theoretical foundation laying, technical support, application integration, and tactical innovation". This paradigm effectively enables trainees to achieve a capability leap from "basic operational proficiency" to "skilled application" and further to "independent innovation", thereby

providing a feasible model for cultivating interdisciplinary UAV talents with integrated technical operation and tactical command capabilities.

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