



**AVICO**

# **CODING TRAINING WITH AVIATION TECHNOLOGIES**

---

## **Literature Review**



**Co-funded by  
the European Union**

The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

## Introduction

The rapid expansion of unmanned aerial vehicles (UAVs) in various sectors, from agriculture to logistics and environmental monitoring, has highlighted the necessity for skilled personnel who can design, code, and operate these advanced systems. Coding education, now a fundamental component of digital literacy, plays a critical role in developing the technical expertise needed for UAV operations, particularly in enabling autonomous functionalities, flight control, data processing, and innovative applications of UAVs.

The AVICO project, a collaboration under the Erasmus+ program focusing on vocational education and training (VET), aims to bridge the gap between coding education and UAV technology. By integrating project-based learning and developing specialized curricula that combine both block-based and text-based coding with practical UAV applications, AVICO seeks to enhance the vocational skillsets of students across Europe. This approach not only aligns with European educational policies promoting digital skills but also responds to the growing demand for innovative educational tools and methodologies in UAV training.

This literature review explores the intersection of coding training and UAV technology within the context of vocational education. It aims to analyze the current landscape of coding education, evaluate existing methodologies in UAV training, and identify the challenges and opportunities in preparing students for the evolving technological demands of the UAV industry. By synthesizing research on coding and UAVs, this review will provide insights that support the AVICO project's objectives of fostering innovation and skill development in vocational education across Europe. The review has been prepared by SUA and VUS.

## Unmanned aerial vehicles and their applications

Unmanned Aerial Vehicles represent one of the most rapidly evolving domains within modern digital and automation technologies. Their increasing sophistication results from continuous advancements in embedded systems, sensor technologies and coding frameworks that support autonomous operation, real-time data processing and intelligent decision-making. As UAVs transition from experimental tools to integral components of operational workflows, their role across industry sectors continues to expand. They now contribute not only to technical fields such as environmental monitoring and precision agriculture but also to service-oriented domains including logistics, tourism and public governance.

The growing relevance of UAVs is closely tied to the integration of advanced programming capabilities that enable autonomous navigation, obstacle avoidance, sensor fusion and complex mission execution. These features allow UAVs to perform tasks with high precision, efficiency and safety while reducing human involvement in hazardous, repetitive or data-intensive operations. At the same time, UAVs increasingly function as platforms for STEM education, offering immersive learning opportunities that connect coding concepts with real-world applications.

# 1 Technical Overview

Unmanned Aerial Vehicles, also known as drones, have undergone rapid development in recent years, driven by advances in hardware and software. The integration of sophisticated coding and automation technologies is at the core of UAV innovations, enabling key features such as:

- **Autonomous Navigation:** UAVs rely on advanced algorithms and programming languages such as Python and C++ to execute autonomous flight operations. This allows drones to perform complex missions, including pre-programmed flight paths and real-time route optimization based on environmental inputs [1]. By integrating GPS, inertial measurement units (IMUs), and machine learning (ML) algorithms, UAVs can navigate autonomously across various terrains and environments with minimal human intervention.
- **Obstacle Detection and Avoidance:** UAVs use sensors such as Light Detection and Ranging (LiDAR), ultrasonic sensors, and computer vision systems to detect obstacles and avoid collisions during flight. The coding behind these sensors integrates real-time data with ML algorithms, enabling UAVs to dynamically adjust their flight paths to safely navigate through complex environments [2]. This technology is particularly useful in urban settings and challenging terrains where manual navigation would be difficult or hazardous.
- **Real-Time Data Processing:** UAVs are equipped with cameras, thermal sensors, and other devices that collect large amounts of data in real time. Through advanced coding, UAVs can process these data streams to generate actionable insights, such as detecting temperature anomalies, mapping terrain, or identifying objects of interest. Data analysis frameworks like OpenCV, TensorFlow, and MATLAB are widely used to support these functions, ensuring that UAVs can perform critical tasks such as disaster response, environmental monitoring, and precision agriculture [3].
- **STEM Education Integration:** UAVs have become a valuable tool in STEM (Science, Technology, Engineering, and Mathematics) education, offering hands-on learning experiences that connect theoretical concepts with real-world applications. Programs like the Drone Innovators Program use UAVs to teach students coding, data analysis, and engineering design principles through project-based learning [4]. By simulating complex missions and incorporating coding tasks, such as programming autonomous flight paths and processing real-time sensor data, UAVs help students develop critical skills in areas like Python programming, algorithmic thinking, and problem-solving. This educational integration prepares students for future careers in drone technology and related fields, making UAVs a powerful medium for advancing STEM literacy.

## 1.1 Applications of UAVs

UAVs have become highly versatile platforms that are transforming numerous sectors through advanced automation, sensing capabilities, and precise mission execution. Their integration into operational workflows is increasingly evident across agriculture, logistics, tourism, public



administration, and environmental monitoring, where they enhance efficiency, reduce operational costs, and enable data-driven decision-making.

### **1.1.1 Agriculture (Precision Farming)**

The integration of unmanned aerial technologies is significantly advancing precision agriculture by enabling farmers to monitor crops, assess soil health, and optimize resource allocation. Equipped with multispectral cameras, drones capture high-resolution imagery that reveals indicators such as plant vitality, moisture distribution, and pest activity. Automated flight paths, real-time data collection, and ML algorithms further support early detection of crop stress and forecasting of harvest timelines [5]. Through AI-driven analytics, these systems promote more efficient use of water and fertilizers, reducing environmental impact while improving overall yields [6].

### **1.1.2 Logistics (Delivery Drones)**

In the logistics sector, aerial delivery platforms have become indispensable for last-mile transport in both urban and remote environments. Delivery drones, programmed to follow predefined routes, autonomously navigate and distribute packages, even across difficult terrain. With built-in obstacle detection and GPS-based guidance, they can avoid air traffic, adjust to weather variations, and autonomously return to charging or docking stations when required [7]. The integration of coding frameworks with logistics software allows real-time route optimization, enhancing the efficiency of delivery networks [3].

### **1.1.3 Tourism (Aerial Photography and Site Management)**

The tourism industry increasingly relies on aerial systems for applications such as aerial photography, site surveillance, and attraction management. Tour operators employ drones to capture immersive, high-quality footage of landscapes, cultural landmarks, and natural attractions. Through advanced programming, these platforms can autonomously follow predefined flight paths, collect high-definition video, and integrate augmented reality (AR) overlays for enriched visitor experiences. Additionally, aerial systems assist in managing high-traffic tourist locations by supporting crowd monitoring, assessing site conditions, and enhancing emergency response coordination [8, 9]. This integration of UAV technology into tourism not only enhances visitor experiences but also optimizes the management of high-traffic tourist destinations.

### **1.1.4 Public Governance (Infrastructure Monitoring and Urban Planning)**

Within public governance, aerial platforms serve as powerful tools for infrastructure inspection, land administration, and urban planning. High-resolution sensors and cameras allow authorities to monitor roads, public lands, and construction sites with improved accuracy. Automated large-area coverage enables real-time data acquisition, supporting informed decision-making for maintenance and long-term planning. These capabilities are particularly valuable in urban planning, where UAVs assist in 3D mapping, tracking urban development, and assist in land-use management. UAVs also enhance land administration by improving the monitoring of infrastructure and supporting sustainable urban growth [10]. Additionally, UAVs play a critical role in disaster management, offering rapid damage

assessments and aiding authorities in more effective emergency responses.

### 1.1.5 Environmental Monitoring (Wildlife Tracking and Disaster Response)

Environmental monitoring has greatly benefited from aerial systems that enable non-intrusive observation of wildlife, ecosystem changes, and environmental risks. Thermal and multispectral imaging supports wildlife population tracking, habitat analysis, and the detection of poaching or deforestation activities [3]. In disaster situations, drones offer rapid situational awareness by mapping affected areas, locating survivors, and delivering essential supplies to regions unreachable by ground teams [11]. These capabilities are further enhanced by adaptive autonomy algorithms that allow drones to dynamically adjust flight paths and data-collection parameters in response to changing environmental and operational demands.

## 1.2 Concluding Remarks

In summary, UAVs are making significant contributions across a wide range of industries due to their versatile capabilities and the integration of advanced coding technologies. Their influence spans domains such as precision agriculture, logistics, tourism, public governance, and environmental conservation, where they streamline operations, reduce manual workload, and enable more data-driven decision-making. From improving agricultural productivity and enhancing tourism experiences to supporting public infrastructure management and ecological monitoring, UAVs are becoming indispensable tools for modern industry. The role of coding in enabling automation, real-time data processing, and complex decision-making systems is crucial for the continued growth, reliability, and innovation of UAV applications, ensuring that these technologies remain central to future industrial and societal advancements.

## 2 Defining Essential Skills

The integration of coding into UAV applications requires a diverse set of technical, analytical, and problem-solving competencies. These competencies are fundamental for the efficient development, deployment, and management of UAV systems, supporting their expanding use in sectors such as agriculture, logistics, tourism, and public-sector governance [12, 7, 9, 10]. Through these capabilities, UAV technologies are reshaping how data is collected, processed, and utilized across industries, leading to improved productivity, enhanced monitoring and surveillance, and more informed decision-making.

Key skills necessary for the development and application of UAV technology include:

- **Digital Literacy:** The ability to utilize UAV technologies, including IoT devices, GPS, and data analytics systems, is crucial for drone operations, data collection, and real-time processing in fields like agriculture and logistics [13].
- **Programming Proficiency:** Expertise in Python and C++ is vital for UAV development, including controlling flight systems, automation, and data processing. Python is widely used for scripting and data-heavy applications, while C++ is critical for real-time control and system performance [14].

- **System Integration Skills:** Effective UAV coding relies on the seamless integration of hardware components, including sensors, GPS modules, and communication interfaces. Developers must also be familiar with communication protocols such as Micro Air Vehicle Link (MAVLink) and frameworks like the Robot Operating System (ROS) to ensure interoperability and reliable system performance [3].
- **Data Analysis and Interpretation:** UAVs generate large data sets from sensors and telemetry, requiring proficiency in data analysis tools like Python's Pandas and ML libraries to derive actionable insights for navigation and performance optimization [15].
- **Problem-Solving and Debugging:** UAV coding involves real-time systems where errors and performance issues can occur. Strong problem-solving skills and familiarity with debugging tools and simulators are necessary to maintain safe and efficient UAV operations [2].

## 2.1 Digital Literacy

Digital literacy in the context of UAV applications refers to the ability to effectively use UAV technologies, including IoT devices, GPS, and data analytics systems, to support drone operations, data collection, and real-time processing. This skill is essential for managing UAVs in various fields such as agriculture and logistics, where precise data handling and interpretation are required. This includes:

- **IoT and UAV Integration:** UAV operators must be skilled in utilizing IoT devices to gather real-time data from sensors embedded in drones. These systems help monitor environmental conditions, provide real-time feedback, and enable advanced applications like precision agriculture [13]. Additionally, UAV-based education programs that integrate IoT devices and GPS into student projects significantly improve digital literacy, fostering hands-on experience in real-time data gathering and navigation [16].
- **Data Processing and Software Tools:** Proficiency in software tools that handle GPS and real-time analytics is crucial. Operators should be familiar with tools that integrate flight data, environmental factors, and mission goals for tasks such as drone-based mapping or surveillance [1].
- **Technical Proficiency in UAV Systems:** Beyond software, digital literacy also includes operating the UAV's hardware, managing flight control systems, and maintaining onboard sensors to ensure efficient data collection and overall performance [13].

Digital literacy is foundational to the effective use of UAVs, enabling operators to manage data-driven workflows with greater precision and reliability. It supports the seamless integration of real-time data into decision-making processes, thereby improving the efficiency of UAV-based tasks such as precision agriculture and automated logistics [13].

## 2.2 Programming Proficiency

Programming proficiency is foundational to the development and operation of UAVs, enabling precise control of flight systems, automation processes, real-time data handling, and integration with broader technological ecosystems such as the Internet of Things (IoT). Programming languages such as Python and C++ play particularly pivotal roles, supporting

both high-level scripting tasks and low-level real-time control functions. Mastery of these programming tools equips UAV developers to design sophisticated autonomous systems capable of executing complex missions across domains ranging from environmental monitoring to logistics and public-sector governance.

Below are the key aspects of programming proficiency in UAV development:

- **Python for UAV Applications:** Python is widely recognized as a versatile, high-level programming language used for UAV scripting, handling data-heavy applications, and automating processes such as mapping and ML. Its simplicity and ease of use make it ideal for rapid prototyping and iterative development. Python's extensive libraries, such as NumPy for numerical processing, Pandas for data manipulation, and TensorFlow for ML, provide UAV developers with powerful tools to build systems that can perform complex tasks like real-time image recognition, terrain mapping, and object detection [14]. Python's integration with the ROS also makes it suitable for autonomous navigation, enabling UAVs to interact with multiple sensors and make decisions based on environmental inputs. For example, [17] highlight the use of Python in conjunction with ROS for building autonomous UAV systems on educational platforms. Python is used for scripting and real-time control, while ROS facilitates communication between various system components, enabling students to easily implement and test different algorithms. This combination of Python's accessibility and ROS's flexibility makes it an ideal framework for developing and managing autonomous UAV operations in educational settings.

**Applications:** Python's flexibility makes it an excellent choice for data-heavy applications such as geospatial mapping and ML algorithms. For example, UAVs equipped with cameras or LiDAR systems can use Python to process large datasets, allowing for detailed topographic maps or 3D models to be created. Python's libraries for deep learning can also be used for object tracking and autonomous navigation in real-time.

- **C++ for Real-Time Control:** C++ is indispensable in UAV development, particularly for low-level control tasks that require high performance and precise memory management. In contrast to Python, C++ is a compiled language, meaning it is optimized for speed, making it suitable for time-sensitive operations such as flight stabilization, sensor fusion, and real-time data feedback [14]. For instance, flight controllers such as ArduPilot and PX4 rely on C++ for efficient and reliable control of UAV motors, ensuring that the UAV remains stable during flight, even in dynamic environments. C++ excels in managing real-time operations, making it critical for tasks where low latency is necessary. For UAVs, this includes controlling motors, integrating sensor inputs like GPS or inertial measurement units (IMUs), and responding to changing environmental conditions. It is also highly relevant for battery management systems (BMS) and ensuring communication protocols such as MAVLink function seamlessly.

**Applications:** C++ is widely used for embedded systems in UAVs, such as flight controllers and onboard computing. It is essential for implementing real-time algorithms that manage UAV propulsion, ensure precise movements, and maintain flight stability during critical operations like obstacle avoidance, formation flying, or aerial data collection.

- **Practical Learning and UAV Programming:** Practical experience in UAV programming is crucial to building the competencies necessary for real-world UAV operations. Courses like

the Open-Source Drone Programming Course provide hands-on experience with programming languages such as Python and C++, in combination with robotic frameworks like ROS, which enables students to develop practical skills in autonomous navigation and object detection [14, 11]. These courses often simulate real-world UAV environments, allowing learners to program UAVs for complex tasks such as mapping, surveillance, and logistical operations. Project-based learning models, as highlighted in [6], emphasize the importance of allowing students to work on real-world UAV projects, fostering critical 21st-century skills such as collaboration, creativity, and critical thinking. In addition to ROS, practical learning also includes working with simulators such as Gazebo or AirSim, which allow UAV developers to test and debug their code in a safe, controlled virtual environment [18]. Such simulators replicate real-world conditions, including wind patterns, obstacles, and varied terrain, allowing for comprehensive testing before deploying UAVs in physical environments.

**Applications:** Practical experience helps UAV developers better understand system integration and how to troubleshoot issues that arise during real-time operations. Simulations enable the testing of autonomous flight scenarios, such as route planning, collision avoidance, and sensor fusion. These skills are particularly important in fields such as public sector governance, where UAVs are used for monitoring infrastructure or in logistics, where they ensure the timely delivery of packages in constrained environments.

Mastery of these programming languages enables developers to create complex UAV systems that can perform autonomous tasks, process vast amounts of data, and integrate with broader systems like IoT networks [14].

## 2.3 System Integration Skills

System integration is a core competency in UAV development, requiring the alignment of hardware, communication protocols, and software platforms into a coherent and reliable system. Key areas of integration include:

- **Hardware Integration:** Involves connecting and configuring essential components such as cameras, sensors, GPS modules, and communication devices with the UAV's onboard software. Proper hardware integration enables autonomous operation, accurate data capture, and reliable communication with ground control systems [3]. This skill set is especially important in applications like UAV-assisted building inspections, where multiple sensors must operate in synchrony to produce precise structural data [19].
- **Communication and Control Frameworks:** Requires proficiency in protocols such as MAVLink, which supports data exchange between UAVs and ground stations, as well as frameworks like the ROS, which enables modular, scalable, and complex robotic control systems [3]. Mastery of these frameworks ensures that UAVs can execute advanced autonomous behaviors and exchange information effectively within wider system architectures.
- **Cross-Platform System Coordination:** Focuses on integrating diverse hardware and software ecosystems to optimize UAV performance for different mission profiles. This includes ensuring compatibility between sensor suites, flight-control software, cloud

platforms, and mission-management tools for applications ranging from precision agriculture to autonomous surveillance [5].

System integration skills are therefore essential for ensuring that UAVs function reliably, safely, and efficiently in diverse operational environments. These competencies are especially critical for autonomous UAV systems, where multiple subsystems must interact seamlessly to support complex missions [3, 5, 19].

## 2.4 Data Analysis and Interpretation

UAV operations generate substantial volumes of telemetry, imagery, and sensor data, requiring strong competencies in data analysis and interpretation to extract meaningful and actionable insights. Key areas of data-related skills include:

- **Handling Large Data Sets:** UAVs equipped with advanced sensors produce extensive and heterogeneous data streams. Proficiency in analytical tools such as Python's Pandas library and machine-learning frameworks is essential for processing, cleaning, and interpreting these data sets to support informed, data-driven decision-making [15].
- **Navigation and Performance Optimization:** Telemetry data, environmental inputs, and flight-performance metrics can be analyzed to optimize UAV operations. This includes real-time processing for adaptive flight-path adjustments, obstacle avoidance, and system-performance enhancement. Effective analysis of these data sources is crucial for ensuring safe and efficient autonomous flight [15].
- **Application in Domain-Specific Contexts (e.g., Agriculture):** In application areas such as precision agriculture, data interpretation is central to functions like crop monitoring, disease detection, and yield estimation. UAVs equipped with multispectral sensors and imaging systems generate detailed datasets that support decisions on irrigation, fertilization, and pesticide usage [5]. Analytical models derived from UAV data enable operators to improve resource allocation and enhance overall agricultural productivity [8].

Proficiency in data analysis thus enables UAV developers and operators to extract valuable insights from sensor outputs, supporting more capable, reliable, and efficient UAV systems across industries including logistics, agriculture, and environmental monitoring [15, 5].

## 2.5 Problem-Solving and Debugging

UAV coding operates within real-time, safety-critical environments in which software errors or system faults can disrupt mission execution. As a result, strong problem-solving and debugging competencies are essential for ensuring safe, reliable, and efficient UAV performance. Key areas of these skills include.

- **Real-Time System Debugging:** Maintaining system performance requires the ability to diagnose and resolve issues that occur during flight. Developers must be proficient in using debugging tools, simulators, and real-time monitoring platforms to identify software malfunctions, sensor inconsistencies, and communication errors that emerge under operational conditions [2].

- **Troubleshooting Autonomous Systems:** Because UAVs frequently operate with a high degree of autonomy, developers must be capable of addressing challenges related to autonomous navigation, obstacle detection, sensor fusion, and unexpected system behavior. These skills are crucial for mitigating risks and preventing failures during mission-critical operations [2].
- **Practical Skill Development Through Challenges and Competitions:** Hands-on learning environments such as drone competitions and problem-solving challenges described in [2], provide valuable opportunities for students and developers to refine their debugging techniques and improve their ability to address real-world UAV issues. Such experiences enhance both technical competence and situational judgment in complex UAV scenarios [20].

Problem-solving and debugging skills are therefore indispensable for UAV development and operation, particularly in dynamic, real-time environments where system errors may directly compromise mission success [2].

## 2.6 Concluding Remarks

The integration of coding into UAV applications requires a broad and sophisticated set of competencies that extend well beyond basic programming. These include digital literacy, programming proficiency, system integration expertise, data analysis capability, and strong problem-solving skills. Each of these competencies is essential for the effective development, deployment, and operation of UAV systems, supporting their use across sectors such as agriculture, logistics, tourism, and public-sector governance. By mastering these skills, developers and operators can fully leverage UAV technologies to enhance data collection, strengthen decision-making processes, and optimize operational workflows across diverse fields. As the demand for UAV systems continues to grow, the development of these skill sets becomes increasingly critical to ensuring that UAV applications are carried out safely, efficiently, and reliably in complex real-world environments.

## 3 Integration of Coding into UAV Training

The integration of coding into UAV training presents a series of challenges and opportunities in educational contexts. UAV coding involves not only programming but also an understanding of interdisciplinary knowledge that spans across fields like electronics, aerodynamics, and real-time data processing. However, a number of barriers have been identified, particularly in vocational and technical education.

### 3.1 Challenges in Training

Training individuals in UAV programming presents several challenges that can affect the learning process and the development of basic skills. These challenges stem from the

complexity of the coding required for UAV operations, the need for interdisciplinary knowledge, and the difficulty in bridging the gap between theoretical teaching and practical applications. A thorough understanding of these challenges is essential for educators, students, and training program developers who aim to create more effective and engaging learning experiences in the field of UAV technology.

Some of the key challenges encountered when integrating coding into UAV training programs are:

- **Steep Learning Curve:** Integrating coding into UAV training programs presents a significant learning challenge for both students and educators. UAV programming requires proficiency in languages such as Python and C++, as well as a solid understanding of how UAV systems operate in real-world environments. The complexity of tasks such as autonomous navigation, obstacle avoidance, and real-time data analysis further complicates the training process [3]. In addition, students are often expected to manage both hardware and software components simultaneously, demanding competencies not only in coding but also in mechanical and electronic systems [15]. According to [16], this complexity is even more pronounced in Science, Technology, Engineering, Arts, and Mathematics (STEAM) drone education, where the interdisciplinary requirements of drone assembly, flight control, and programming introduce additional layers of difficulty for learners.
- **Interdisciplinary Knowledge Requirements:** UAV development is inherently interdisciplinary, requiring students to possess knowledge in robotics, aerodynamics, and control systems in addition to coding [14]. For instance, they must understand how to integrate sensors such as GPS, cameras, and LiDAR, which are essential for precise UAV operations. The gap between the theoretical knowledge delivered in classroom settings and the practical, hands-on skills needed to develop and troubleshoot UAV systems further complicates efforts to integrate coding into training programs.
- **Theoretical vs. Practical Gap:** A significant gap exists between theoretical coding instruction and real-world UAV applications. Many educational programs emphasize theoretical knowledge of coding without providing students with practical opportunities to apply these skills to UAVs [21]. The disconnect between classroom-based instruction and real-world UAV missions often leaves students inadequately prepared for industry demands, where UAV systems must operate autonomously and respond to environmental conditions in real time.

## 3.2 Successful Models of Skill Transfer

Integrating coding skills into UAV training requires effective educational models that ensure students can transition theoretical knowledge into practical skills. Successful models of skill transfer are crucial for preparing students to meet the demands of the UAV industry, which requires both technical proficiency and hands-on experience. These models focus on approaches that engage learners in practical, real-world applications, making the learning process more immersive and relevant.

Some proven strategies have demonstrated strong effectiveness in facilitating the transfer of

the skills required for UAV programming and development:

- **Project-Based Learning:** Project-based learning represents an effective educational model for integrating coding into UAV training. By engaging students in real-world UAV projects, PBL helps bridge the gap between theoretical instruction and practical application [6]. Through hands-on tasks that reflect industry scenarios, learners gain a deeper understanding of UAV operations, coding complexity, and system behavior. Moreover, PBL fosters essential 21st-century competencies such as problem-solving, collaboration, and critical thinking, all of which are central to UAV development [22].
- **Design Thinking Approach:** Design Thinking has emerged as a successful educational strategy for integrating coding into UAV training. This approach emphasizes a student-centered learning process, where learners are encouraged to experiment, prototype, and iteratively refine their solutions. According to [23], this methodology enhances motivation and engagement by enabling students to participate in hands-on problem-solving within authentic practical contexts. In UAV training, Design Thinking can be used to frame coding challenges as real-world projects, such as programming UAVs for specific missions or designing autonomous flight systems. This approach helps learners grasp the interdisciplinary nature of UAV programming, including hardware integration and real-time data analysis, while fostering creativity and problem-solving skills. The iterative structure of Design Thinking also complements other experiential strategies such as PBL, providing an effective means of bridging the gap between theoretical instruction and practical application in UAV coding [23].
- **Online Coding Platforms:** Drone-oriented online platforms have significantly expanded access to UAV programming education. Open-source drone programming courses provide scalable, high-quality learning opportunities independent of geographical limitations [14]. Many of these platforms incorporate simulators, enabling learners to practice coding and flight-logic development without requiring costly UAV hardware. This reduces entry barriers and supports broader participation in UAV education.
- **Industry-Education Partnerships:** Collaborations between educational institutions and technology companies have proven highly effective in enhancing UAV coding competencies. Such partnerships often include internships, joint research initiatives, and access to advanced UAV hardware and software. For example, vocational programs partnering with drone manufacturers have provided students with opportunities to work directly on real-world UAV projects, thereby building practical skills and industry readiness [6].

### 3.3 Concluding Remarks

Integrating coding into UAV training poses significant challenges due to the technical complexity and interdisciplinary nature of UAV systems, which demand a combination of programming proficiency, mechanical aspects of UAV operation, and familiarity with UAV-specific technologies such as sensor integration and autonomous navigation. Despite these difficulties, several instructional approaches such as project-based learning, online coding platforms, and industry–education partnerships have demonstrated strong effectiveness in supporting skill development. Project-based learning provides hands-on experience that



bridges theoretical knowledge and practical application; online platforms expand access to high-quality training and simulated environments; and industry collaborations offer exposure to advanced technologies and real-world UAV operations. Collectively, these strategies help prepare learners for the rapidly advancing UAV sector by equipping them with the technical and analytical competencies required for success.

## 4 Research Analysis

This section examines the essential coding competencies required for UAV development and evaluates how these skills support UAV adoption across sectors such as logistics, agriculture, tourism, and public-sector governance. The analysis identifies key skill gaps, assesses current competency levels, and reviews the broader technological and organizational factors influencing UAV integration.

The analysis is structured around the following focal areas:

- Skills Gap Analysis
- Competency Framework Development
- Technology Adoption Analysis
- Stakeholder Analysis
- Impact Assessment

### 4.1 Skills Gap Analysis

This analysis evaluates the existing coding competencies of developers and students in relation to the increasing technological demands of UAV applications across various industries. The focus is placed on general programming proficiency, UAV-specific coding frameworks, and the ability to apply skills in practical operational contexts.

#### 1.1.6 Current Competencies

Developers and students typically possess foundational knowledge of Python and C++, the two primary languages used in UAV development. Python is widely applied in data-intensive tasks such as mapping and machine-learning workflows, while C++ remains essential for low-level operations including flight stabilization and sensor management. However, proficiency in UAV-specific framework, such as MAVLink for ground-to-air communication and ROS for hardware–software integration, remains limited.

Beyond general programming proficiency, competencies related to real-time control algorithms and data processing are notably underdeveloped, despite their importance for applications such as autonomous navigation and sensor integration. As a result, many learners are insufficiently prepared to manage complex operational scenarios, including automated crop monitoring, delivery-route optimization, and UAV-supported urban-planning tasks.

#### 1.1.7 Future Demands

There is a growing need for advanced coding competencies that enable UAVs to perform increasingly complex autonomous tasks. Developers will be required to manage sensor fusion, a process in which data from multiple sources such as GPS, cameras, and environmental sensors are combined to create real time situational awareness. These capabilities are especially important in sectors such as agriculture, where UAVs support crop health monitoring and resource optimization, and in logistics, where autonomous drones are used to

enhance the efficiency of delivery systems.

In addition, developers must integrate ML algorithms that allow UAVs to analyze sensor data and make predictive decisions during flight. Applications of ML, including object detection and flight path optimization, are becoming essential in tourism for improved aerial imaging and visitor experiences, as well as in public governance for monitoring environmental changes and supporting planning processes.

### **1.1.8 Skill Gaps**

A substantial gap persists in the practical application of programming skills, particularly in the areas of real time system integration, autonomous decision making, and flight control. Although many educational programs provide foundational theoretical instruction, they frequently lack comprehensive hands on UAV training that would allow learners to apply concepts in realistic operational contexts. This includes experience in navigating UAVs under dynamic weather conditions, detecting and addressing errors in real time, and managing sensor driven autonomous behavior.

Furthermore, developers often have limited exposure to integrated UAV platforms where hardware components such as cameras, GPS receivers, and environmental sensors must function in coordination with software protocols like MAVLink. Without this exposure, learners are less prepared to develop, test, and refine UAV systems that can operate reliably across diverse industrial environments. The absence of such experience contributes to a broader skills gap, particularly in sectors that require high levels of automation and precise coordination between hardware and software subsystems. Strengthening practical training environments, simulation based exercises, and industry linked projects is therefore essential for ensuring that future UAV developers acquire the competencies needed for seamless operational performance.

## **4.2 Competency Framework Development**

To meet the demands of UAV programming, a comprehensive competency framework outlines the technical and operational skills required at different levels of proficiency (beginner, intermediate, advanced). Aligning these competencies with industry standards is crucial to ensure that students and professionals can meet the specific needs of sectors like logistics, agriculture, and public governance.

According to [24], integrating industry requirements into vocational and technical training results in educational programs that are closely aligned with market expectations and technological trends. This alignment strengthens the relevance and effectiveness of skill development, enabling learners to acquire capabilities that directly support real world applications. In the context of UAV technology, where operational requirements evolve rapidly, a dynamic and industry responsive competency framework is essential for preparing a workforce capable of adapting to emerging challenges and contributing to the continued advancement of UAV systems.

### **Core Competencies**

Developing UAV programming expertise requires a set of core competencies that span

programming proficiency, system integration, and data processing. These competencies form the foundation for effective UAV development and ensure that learners can contribute to modern UAV applications across sectors such as agriculture, logistics, tourism, and public governance.

The main competency areas that support UAV development include the following:

- **Programming Proficiency:** A strong command of programming languages is essential for developing UAV systems that can operate autonomously, process data in real time and interact effectively with onboard sensors and control algorithms. In UAV development, Python and C++ represent the two primary languages, each supporting different but complementary aspects of UAV functionality.
  - **Python:** Python is a high-level programming language known for its ease of use and extensive library support, making it suitable for tasks like real-time data processing, image analysis, and integrating ML models. Python's capabilities are particularly valuable in applications like aerial mapping for agriculture, where UAVs capture large datasets that require efficient processing. For instance, Python libraries such as OpenCV can process visual data, enabling the detection of features like crop health or areas that need attention. Meanwhile, TensorFlow and PyTorch facilitate the integration of ML models that can classify vegetation types, predict crop yields, and identify stress patterns in plants through aerial imagery. These applications enable more targeted interventions, such as applying precise amounts of water or fertilizers to specific areas, thereby optimizing resource use and improving overall crop yields. This comprehensive ecosystem makes Python indispensable for both research and practical deployment in UAV-based agricultural solutions.
  - **C++:** For UAVs, C++ is essential due to its speed and efficiency, especially in low-level, real-time tasks. This includes precise control over flight paths, management of sensor data, and the implementation of stabilization algorithms necessary for maintaining flight integrity. Unlike Python, C++ is a compiled language, making it ideal for high-speed data processing and operations where real-time decision-making is critical. In sectors such as logistics, C++ enables drones to autonomously navigate through complex urban environments, ensuring timely package delivery while avoiding obstacles. Additionally, in public governance, C++ facilitates the development of systems that allow drones to monitor infrastructure like bridges and roads, providing real-time feedback for maintenance.
  - **System Integration:** Integrating UAV hardware with software is a core skill for developers, as UAV systems rely on a seamless interaction between sensors, GPS units, cameras, and control algorithms. A key component of this integration is the ROS, which serves as a middleware for coordinating complex UAV operations. ROS allows UAVs to process inputs from multiple sensors and execute commands, ensuring that the drones can autonomously navigate and adjust to their environment. For example, in public sector projects like urban infrastructure monitoring, ROS enables UAVs to analyze real-time data from

various sensors and communicate findings to ground stations, facilitating prompt decision-making. Similarly, in agriculture, integrating ROS with environmental sensors allows UAVs to autonomously monitor large areas, optimizing irrigation schedules and pesticide application based on real-time data.

- **Data Processing and Analysis:** The UAVs generate substantial amounts of data, which is critical for applications in precision farming, logistics, and environmental monitoring. Developers need to be adept at using Python libraries such as Pandas and NumPy to clean, process, and analyze this data. In precision agriculture, for example, UAVs equipped with multispectral cameras can collect data on crop conditions, and Python's data manipulation tools help interpret this information to identify areas suffering from nutrient deficiencies or water stress. Additionally, ML algorithms can be applied to predict crop yield, enabling farmers to optimize their management practices. In logistics, data analysis helps optimize delivery routes by analyzing traffic patterns and environmental conditions, thus improving the efficiency of UAV operations. The ML models can also be trained to forecast demand, allowing UAV delivery services to adjust their operations in real-time.

This competency framework not only outlines the essential skills for UAV programming but also emphasizes the practical application of these skills in industry-specific contexts. By focusing on programming languages like Python and C++, system integration through ROS, and data analysis capabilities, the framework ensures that developers are well-equipped to meet the technological demands of modern UAV applications. As highlighted in the study [24], the integration of industry needs with vocational training models is key to producing skilled professionals who can seamlessly transition into the workforce. Such alignment is particularly important in the UAV sector, where the ability to adapt training programs to industry standards can greatly enhance the relevance and impact of educational outcomes.

## 4.3 Technology Adoption Analysis

This analysis examines the extent to which UAV technologies are being adopted across key industrial sectors and evaluates how coding competencies influence operational efficiency, innovation and sustainability. Understanding adoption patterns is essential for identifying skill shortages and assessing the alignment between industry needs and existing educational programs.

Adoption rates across key sectors indicate substantial variation in how UAV technologies are being integrated into operational practices, as illustrated in the following examples:

- **Logistics and Supply Chain Management:** UAVs are increasingly applied in logistics to automate deliveries and optimize supply chain operations. Adoption, however, remains constrained by the shortage of developers capable of coding UAVs for real time navigation, obstacle avoidance and route optimization. Although UAVs offer significant potential for improving the efficiency of last mile delivery operations, many logistics companies encounter challenges due to limited availability of skilled UAV programmers.
- **Agriculture:** In precision agriculture, UAVs support tasks such as crop health monitoring, irrigation management and pesticide application. Despite their potential, adoption is

uneven, particularly among smaller or rural agricultural operations. Many agricultural professionals lack the coding expertise required to fully utilize UAV systems, and the absence of trained developers limits the integration of autonomous flight, sensor based decision making and data driven agricultural management.

- **Tourism:** Tourism applications involve aerial monitoring, site visualization and the creation of immersive virtual tour experiences. UAVs can significantly enhance visitor engagement, particularly in locations that are difficult to access. However, broader adoption is limited by insufficient expertise in programming UAVs for autonomous tour paths, real time image processing and integration with digital tourism platforms. Expanding coding skills in this domain is crucial for unlocking the full potential of UAV technologies in tourism.
- **Public Governance:** In public sector contexts, UAVs are used for infrastructure inspection, urban planning and environmental monitoring. Government agencies increasingly rely on UAVs to inspect roads, bridges and public utilities, generating real time data that supports maintenance and safety assessments. For urban planning, UAVs assist in producing accurate 3D models and spatial analyses that inform zoning and development decisions. These applications require advanced coding capabilities, including automated waypoint navigation, dynamic route adaptation and processing of large geospatial datasets.

Barriers to adoption also emerge across sectors, and the most significant challenges can be summarized as follows:

- **High Cost of UAV Technology:** Many small scale agricultural operations and public sector organizations face substantial financial barriers related not only to the purchase of UAV hardware but also to ongoing expenses such as maintenance, sensor upgrades and software licensing. These costs can be prohibitive for smaller entities that operate with limited budgets or lack access to dedicated technological funding.

Even in cases where UAV platforms are acquired, organizations often struggle to maintain full operational capacity because they cannot invest in essential components like high resolution cameras, multispectral sensors or robust communication modules. The absence of developers capable of coding advanced automation and sensor integration further limits effective deployment, resulting in UAVs being underutilized or used only for basic manual tasks rather than fulfilling their full potential in autonomous operations.

- **Insufficient Access to Specialized UAV Training:** Educational institutions frequently lack dedicated programs focused on UAV specific coding, system integration and real time data processing. As a result, many graduates enter the workforce without the technical competencies needed to develop, manage or troubleshoot autonomous UAV systems. The gap is particularly pronounced in vocational and technical education settings, where curricula often emphasize general programming skills but do not include instruction on UAV communication protocols, mission planning algorithms or sensor fusion.

This shortage of specialized training constrains adoption in sectors such as logistics and tourism, where the demand for UAV programming expertise continues to grow due to increasing reliance on autonomous navigation, aerial imaging and data driven decision support. Without expanded access to focused training, industries face a persistent shortage of professionals capable of implementing and maintaining advanced UAV solutions.

## 4.4 Stakeholder Analysis

Key stakeholders play a critical role in shaping UAV coding training programs and in supporting the broader adoption of UAV technologies across different sectors. Their contributions influence curriculum development, resource allocation and the alignment of educational outcomes with industry needs.

Stakeholders involved in UAV development and deployment contribute in different ways to the design, implementation and continuous improvement of UAV coding training programs, as illustrated in the following groups:

- **Educational Institutions:** Educational institutions provide the foundational coding knowledge required for entry into UAV development, yet there is an increasing need for more specialized courses that address UAV specific programming, system integration and real time data processing. Existing programs, such as the Open Source Drone Programming Course, incorporate hands on learning but must continue evolving to include advanced UAV frameworks and communication protocols. Strengthening collaboration between educational institutions and industry partners is essential to ensure that training programs reflect real world technological requirements and prepare learners for industry relevant challenges.
- **Public Sector Organizations:** Government agencies represent significant users of UAV technologies in areas such as urban infrastructure monitoring, environmental assessment and public safety. These organizations require developers capable of programming UAVs for automated data collection, waypoint navigation and real time decision making. Skilled UAV programmers contribute directly to more efficient urban planning, early detection of infrastructure issues and improved resource management, making the public sector an important driver of demand for specialized UAV coding competencies.
- **Technology Providers:** Companies that design and manufacture UAV hardware and software supply the platforms on which developers build operational UAV systems. These providers play an important role in advancing UAV capabilities through firmware updates, sensor innovations and new software toolchains. By collaborating with educational institutions, technology providers help ensure that academic programs remain aligned with emerging industry standards and that learners receive training on tools commonly used in logistics, tourism, agriculture and other UAV intensive sectors.
- **Industry Professionals:** Developers, engineers and technical specialists working in industries such as logistics, agriculture and public governance offer practical insights that are essential for shaping effective UAV training programs. Their feedback highlights the specific coding challenges encountered in real operational contexts, including fleet level drone coordination, autonomous delivery routing, precision agriculture analytics and infrastructure monitoring. For instance, in the logistics sector, UAV engineers are often expected to develop software for managing coordinated drone fleets used in automated delivery systems, yet such specialized skills are rarely addressed in current curricula. Incorporating these industry informed needs into training programs is crucial for narrowing the skills gap and supporting successful UAV integration across sectors.

## 4.5 Impact Assessment

UAV technology plays a transformative role in enhancing operational efficiency, driving innovation and supporting sustainability across a wide range of industries. When appropriately programmed, UAV systems enable high quality data collection, automation of complex tasks and real time decision making.

The practical impact of UAV coding can be observed across several key sectors:

- **Logistics:** UAVs have significant potential to streamline last mile deliveries, reduce operational costs and improve delivery times. Achieving these benefits requires developers to design UAV systems capable of real time flight optimization, obstacle detection and navigation across diverse environmental conditions. The limited availability of skilled UAV programmers remains a major constraint on broader adoption within the logistics sector.
- **Agriculture:** In precision agriculture, UAVs support real time monitoring of crop conditions, efficient allocation of resources and data driven decision making. Developers must build UAV systems that can process large volumes of sensor data and apply machine learning algorithms to assess crop health, predict yields and optimize resource utilization. The adoption of UAVs in agriculture can substantially improve sustainability by reducing the use of water and pesticides, but this depends on the availability of developers with advanced coding expertise.
- **Tourism:** Tourism applications leverage UAVs to generate immersive visual experiences, including aerial imagery, virtual tours and monitoring of hard to reach locations. Programming UAVs for autonomous tour paths, high resolution imaging and seamless integration with digital tourism platforms requires advanced coding skills that are currently underrepresented in tourism related training programs.
- **Public Governance:** In public governance, UAVs assist with urban planning, infrastructure monitoring and environmental management by automating data collection and spatial analysis tasks. Properly programmed UAVs can perform systematic aerial surveys, monitor extensive urban areas and deliver real time insights that support informed decision making in public infrastructure and environmental projects.

## 4.6 Concluding Remarks

This research analysis highlights the critical need to address existing gaps in UAV coding competencies in order to fully realize the potential of UAV technologies across multiple industrial sectors. Strengthening these competencies requires the development of a robust and industry aligned framework that encompasses UAV specific programming languages, real time data processing and advanced system integration. Enhancing training provision and fostering stronger collaboration between educational institutions and industry professionals will be essential for ensuring that learners acquire the skills demanded by modern UAV applications.

Through such targeted capacity building, the AVICO project is well positioned to support the

wider adoption of UAV technologies in logistics, agriculture, tourism and related sectors. The capability to program UAVs for automation, sensor integration and data driven decision making will be increasingly important for industries aiming to advance efficiency, sustainability and innovation.

## 5 Conclusion

The rapid advancement and growing integration of UAV technologies across sectors such as agriculture, logistics, tourism and public governance highlight the need for a workforce equipped with specialized competencies in UAV programming, data processing and autonomous system operations. This literature review has examined the intersection of coding education and UAV development within vocational training contexts, identifying the essential technical skills required for UAV programming, the challenges associated with training delivery and the pedagogical methodologies most effective for supporting skill acquisition.

The AVICO project, with its emphasis on bridging the gap between coding education and UAV technology, plays a central role in preparing learners for the demands of an increasingly digital and automation driven job market. By prioritizing project-based learning and incorporating both block based and text based programming into the curriculum, the project aligns with broader European policy objectives related to digital skill development. Findings from the review indicate that successful integration of coding into UAV training depends on the development of a broad competency set, including programming proficiency, system integration capabilities, data analysis skills and the ability to solve complex, real time operational problems. These competencies are essential for designing UAV systems capable of autonomous decision making and sector specific deployment.

The review also underscores the critical importance of collaboration between industry and educational institutions in ensuring that vocational training remains aligned with evolving technological requirements. Such partnerships support curriculum relevance, facilitate access to up-to-date tools and platforms and help learners transition smoothly into the workforce. Effective models of skill transfer, including project-based learning, design thinking approaches and online coding platforms, provide learners with meaningful opportunities to apply theoretical knowledge in authentic operational contexts, thereby narrowing the gap between classroom learning and industry expectations.

In conclusion, integrating coding into UAV training is essential for fostering innovation, improving operational efficiency and supporting the wider adoption of UAV technologies across European industries. By developing a comprehensive competency framework, providing specialized training and strengthening cooperation among educational institutions, technology providers and industry stakeholders, the AVICO project can significantly contribute to the advancement of UAV capabilities. As UAV technologies continue to evolve, the sustained development of a highly skilled workforce will remain a key factor in ensuring productive, sustainable and economically beneficial deployment of UAV systems.

## Bibliography

- [1] Norman, H. et al, "A Framework of Drone-based Learning (Dronagogy) for Higher Education in the Fourth Industrial Revolution," *International Journal of Engineering & Technology*, vol. 7, no. 3.14, pp. 1-6, 2018.
- [2] Bermúdez, A. et al, "Drone Challenge: A Platform for Promoting Programming and Robotics Skills in K-12 Education," *International Journal of Advanced Robotic Systems*, vol. 16, no. 1, pp. 1-19, 2019.
- [3] Gacovski, Z. (Ed.), *Unmanned Aerial Vehicles (UAV) and Drones*, Arcler Press, 2020.
- [4] V. Farr and G. Light, "Integrated STEM Helps Drone Education Fly," in *2019 IEEE Integrated STEM Education Conference (ISEC)*, Princeton, NJ, USA, 2019.
- [5] Psirofonía, P. et al, "Use of unmanned aerial vehicles for agricultural applications with emphasis on crop protection: Three novel case-studies," *International Journal of Agricultural Science and Technology*, vol. 5, no. 1, pp. 30-39, 2017.
- [6] S. Samsudi, E. Suprptoño, S. Sunyoto and S. Rohman, "The Implementation of Project-Based Learning in Productive Skill Programs for the Development of 21st Century Vocational School Students," *KnE Social Sciences*, p. 470–479, 2019.
- [7] A. Rejeb, K. Rejeb, S. J. Simske and H. Treiblmaier, "Drones for supply chain management and logistics: A review and research agenda," *International Journal of Logistics Research and Applications*, vol. 26, no. 6, p. 708–731, 2021.
- [8] T. F. Slater, "Identifying Implementation Strategies for Integrating Drones into STEM and Career Technology Education (CTE) Programs," *Education Sciences*, vol. 14, no. 1, pp. 1-11, 2024.
- [9] C. Sevilla-Sevilla, A. Mendieta-Aragón and L. Ruiz-Gómez, "Drones in Hospitality and Tourism: A literature review and research agenda," *Tourism Review*, vol. 79, no. 2, pp. 378-391, 2024.
- [10] Stöcker, C. et al, "Scaling up UAVs for land administration: Towards the plateau of productivity," *Land Use Policy*, vol. 114, pp. 1-12, 2022.
- [11] Voštinár, P. et al, "The Programmable Drone for STEM Education," in *17th International Conference on Entertainment Computing – ICEC 2018*, Poznan, Poland, 2018.
- [12] M. R. Dileep, A. V. Navaneeth, S. Ullagaddi and A. Danti, "A Study and Analysis on Various Types of Agricultural Drones and its Applications," in *2020 Fifth International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN)*, 2020.
- [13] P.-N. Chou, "Smart Technology for Sustainable Curriculum: Using Drone to Support Young Students' Learning. Sustainability," *Sustainability*, vol. 10, no. 10, pp. 1-17, 2018.
- [14] Cañas, J. M. et al, "Open-Source Drone Programming Course for Distance Engineering Education," *Electronics*, vol. 9, no. 12, 2020.

- [15] Yepes, I. et al, "Use of Drones as Pedagogical Technology in STEM Disciplines," *Informatics in Education*, vol. 21, no. 1, p. 201–233, 2022.
- [16] Chen, C.J. et al, "Exploring the Learning Effectiveness of “The STEAM Education of Flying and Assembly of Drone”,“ in 2018 Seventh International Conference of Educational Innovation through Technology (EITT), Auckland, New Zealand, 2018.
- [17] Eller L. et al, "Advanced Autonomy on a Low-Cost Educational Drone Platform," in 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2019.
- [18] Al-Mousa, A. et al, "UTSim: A framework and simulator for UAV air traffic integration, control, and communication," *International Journal of Advanced Robotic Systems*, vol. 16, no. 5, pp. 1-19, 2019.
- [19] H. Freimuth, J. Müller and M. König, "Simulating and Executing UAV-Assisted Inspections on Construction Sites," in 34th International Symposium on Automation and Robotics in Construction (ISARC 2017), Taipei, Taiwan, 2017.
- [20] M. J. Khan and C. A. Aji, "Impact of Programming Robots and Drones on STEM Attitudes," in 2018 ASEE Annual Conference & Exposition, Salt Lake City, Utah, USA, 2018.
- [21] Hidayatullah, R. S. et al, "Collaborative Problem-Based Learning: An Analysis of Problem Solving Skills in Vocational Schools," *IJORER: International Journal of Recent Educational Education*, vol. 1, no. 3, pp. 209-217, 2020.
- [22] A. Nuryanto and K. Y. Eryandi, "The 21st Century Ideal Skills for Vocational High Schools," in *Proceedings of the International Conference on Educational Research and Innovation (ICERI 2019)*, 2020.
- [23] B. Díaz-Lauzurica and D. Moreno-Salinas, "Applying Design Thinking to Enhance Programming Education in Vocational and Compulsory Secondary Schools," *Applied Sciences*, vol. 13, no. 23, pp. 1-26, 2023.
- [24] S. Pei, "Research on Industry-Education Integration Model of Vocational Education Applying Automatic Coding," *Applied Mathematics and Nonlinear Sciences*, vol. 9, no. 1, pp. 1-17, 2024.