

DRONES IN STEM EDUCATION AND AVIATION TRAINING

Sanja Pavlović¹

Abstract: Drones, also known as Unmanned Aerial Systems (UAS), are rapidly emerging as transformative tools in both STEM (Science, Technology, Engineering, and Mathematics) and aviation education. In STEM education, drones provide a dynamic platform for teaching key concepts in physics, aerodynamics, robotics, electronics, coding, and data analysis. In the context of aviation education, drones serve as effective, cost-efficient tools for pilot training, offering students the ability to simulate flight conditions and practice maneuvers in a controlled, risk-free environment. Drones are particularly valuable in introducing students to aviation fundamentals, such as flight dynamics, navigation, and control systems, before they transition to more complex, manned aircraft training. Additionally, drones offer real-time performance analytics, which can be used to provide immediate, data-driven feedback to instructors and students, further enhancing the learning experience. This work explores how drones are being used in STEM education and aviation training, providing real-world examples of their impact and potential.

Key words: Drone, STEM education, aviation education, teaching examples, real-world applications, flight simulator.

1. INTRODUCTION

The integration of drones into various fields is reshaping the approach to education and training, particularly in STEM (Science, Technology, Engineering, and Mathematics) and aviation. Once relegated to military or industrial uses, drones have evolved into powerful educational tools that can engage students and professionals in hands-on learning [1].

2. REVIEW AND EXAMPLES

2.1. Drones in STEM and aviation Education

Drones offer a unique opportunity for interactive, experiential learning in STEM fields. These unmanned aerial vehicles (UAVs) can be used to teach concepts in physics, engineering, computer science, and even environmental science. By engaging students in drone-based projects, educators can bring abstract concepts to life, making learning more engaging and relevant to real-world applications [2], [3]. Drone based teaching examples in STEM education are listed in Table 1.

2.1.1. Physics and Engineering

Drones provide an excellent platform for teaching principles of physics, such as aerodynamics, motion, and forces as it was presented in previous work. Students can experiment with how changing wing angles, weight distribution, and propeller speed affect a drone's flight. Students also can investigate the relationship between drone payload, battery capacity and flight duration [4], [5], [6], [7].

2.1.2. Computer Science and Robotics

Drones are increasingly being used in computer science courses to teach programming, automation, and artificial intelligence. Students can write software to control drone movements, program autonomous flight paths, or implement machine learning algorithms to improve drone performance in tasks such as obstacle avoidance or image recognition [8], [9], [10].

¹ PhD Sanja Pavlović, *College of Applied Studies Aviation Academy, Belgrade*, Pavlovic.s@vakademia.edu.rs

2.1.3. Environmental Science and Geography

Drones are powerful tools in environmental science, enabling students to collect and analyze data on ecosystems, climate change, and natural resources. Drones equipped with sensors can monitor air quality, assess the health of forests, track wildlife, or survey coastal erosion [1], [5], [11], [13].

Table 1 - Drone based teaching examples in STEM education

Education institution	Purpose	Results
Aviation Academy in Belgrade	- Teaching principles of physics [4], [5], [6], [7] - Thermal imaging [6] - Analysis software made for thermal cameras [6] - Monitor the health of surrounding ecosystems [11], [12], [13].	- Students can experiment with how changing wing angles, weight distribution, and propeller speed affect a drone's flight. Students also can investigate the relationship between drone payload, battery capacity and flight duration - Students have learned to make in real life aeroplane surface inspection using drone equipped with thermal camera and to do basic analysis of thermal images taken by a drone using appropriate image analysis software made for thermal cameras. - Students learn to understand the complexities of environmental science and the importance of data collection in preserving natural resources
Embry-Riddle Aeronautical University	- Use of drone-based platforms for Educational process in STEM [14] - Introducing robotics and mechatronics concepts to students [14].	- Providing students with hands-on experience and enhancing learning outcomes - Can enhance cognitive, affective, and psychomotor learning
University of Maryland	"AeroVenture" program to learn about aerodynamics and control systems [15].	- Through hands-on projects, students design, build, and test drone prototypes, applying physics and engineering principles in real-world scenarios. - This type of project-based learning enhances understanding of complex STEM concepts and fosters critical thinking
Stanford University	A course in "Autonomous Aerial Robotics" [16].	- Students develop and program drones to navigate through indoor environments autonomously - introduces students to key concepts in robotics, computer vision, and AI, equipping them with the skills needed to work with advanced technologies in real-world applications

2.2. Drones in Aviation Training

In aviation, drones are becoming indispensable for training purposes. They offer a safe, cost-effective, and versatile platform for pilots to practice and develop skills before moving on to manned aircraft. Additionally, drones provide an opportunity to simulate complex flight scenarios that might be difficult or expensive to recreate in traditional training settings. Drones are also being used in aviation training for emergency response and search-and-rescue missions. UAVs equipped with thermal cameras, GPS, and real-time data transmission can be deployed in disaster zones to locate victims or assess damage.

Drone based teaching examples in aviation are listed in Table 2.

2.2.1. Flight Simulation and Pilot Training

Drones are increasingly being used in flight training programs to simulate flight scenarios. They can be used to train pilots in various conditions, including adverse weather or emergency situations, without the risk associated with traditional flight training [17].

2.2.2. UAV Pilot Training and Certification

With the growing demand for commercial drone operators, specialized UAV (Unmanned Aerial Vehicle) training programs are becoming essential. These programs are designed to teach individuals how to safely and effectively operate drones for a variety of purposes, from aerial photography to agriculture and surveying [18].

2.2.3. Emergency Response and Search-and-Rescue Training

Drones are also being used in aviation training for emergency response and search-and-rescue missions. UAVs equipped with thermal cameras, GPS, and real-time data transmission can be deployed in disaster zones to locate victims or assess damage [19].

Table 2 - Drone based teaching examples in aviation

Education institution	Purpose	Results
Aviation Academy in Belgrade	- Drones with multispectral cameras were used and test flights were conducted for the development of algorithms and environmental data to identify correlations between measures and the effects of climate change [5], [6], [11] - Collision avoidance system testing [11].	applying theoretical knowledge in practical work, research, analysis, data collection, and interpretation

Embry-Riddle Aeronautical University	• In the aerospace engineering program use drones to study stability and control systems [14] • Simulate real-world challenges in aviation, such as turbulence or engine failure [14].	• enhances student's understanding of flight principles but also prepares them for working with larger, more complex aircraft systems
MIT University	• Courses on flight dynamics and control systems [20].	• students learn to program and analyze drone behavior in various aerodynamic conditions
Ohio State University's	• Program uses drones as part of its flight simulation training [21].	• teach students about flight controls, weather systems, and navigation in a safe, controlled environment • allows aspiring pilots to gain valuable flight experience and confidence before moving on to full-sized aircraft

3. PROPOSED MODEL EXAMPLE

Most of cabinet flight simulators works based on a software programed in their control unit, this software simulates the environment of a flying aircraft by converting it to a mechanical effect which can be felt by the trainee using the simulator. However, in most ground-based simulators, the artificial environment produced by mechanical effects does not exactly match the environment of a real flying aircraft.

Drones could be also used for designing a ground-based flight training simulator. This simulator depends on a drone to transfer the flying environment in real-time to the trainee. Drone Controlled Real Live Flight Simulator (DCRLFS) are simulators considers the idea of using drone's movement and vision by a pilot sitting in a training cabinet on the ground. Special mechanism transfers the drone's movement to the cabinet to provide the needed environmental effects to the pilot. The conceptual model of the simulator is shown in the below diagram, started by connecting the control system of the drone with the control panel of the training cabinet so the trainee can have full control to fly the drone, and a camera which is connected to the drone in order to provide the needed visibility for the trainee [22].



Figure 1 –Training Cabinet Connecting with Drone [22]

A DCRLFS consists of two major parts, the training cabinet and the simulation drone (Figure 1). The trainee can use the controlling dashboard in the cabinet to control the drone, in return, the drone returns back the flight effects in a form of data that moves the mechanical motors of the cabinet's base. Any aircrafts can fly in three-dimensions or angles pitch (i.e., nose up or down about an axis running from wing to wing), yaw (i.e., nose left or right about an axis running up and down) and roll (rotation about an axis running from nose to tail) (Figure 2). The axes are alternatively designated as vertical, lateral, and longitudinal. These axes move and rotate relative to the Earth along with the aircraft.

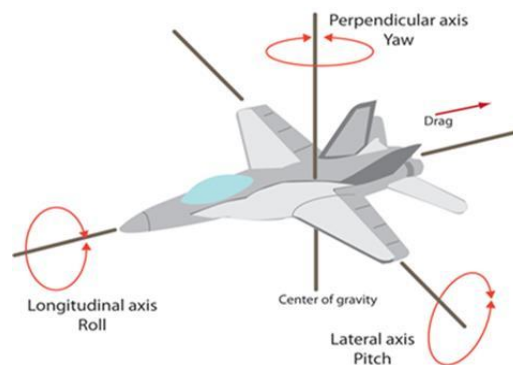


Figure 2 –Aircrafts Movement

The gyroscope gives the attitude (pitch, roll and yaw) of aircraft in the sky on the attitude indicator.

The aircraft flies in the desired route by means of navigation. The navigation method used depends on on-board navigation equipment, which keeps the aircraft in the desired route. The route has many parameters such as aircraft position (attitude), distance, directions to the airports, speed etc. The devices that offer most of these parameters are gyroscope and radio compass also called Automatic Direction Finder (ADF).

A gyroscope is a component used to measure the three axes of angular velocity. It is applied to define the direction of the object depending on the concept of the angular momentum. Gyroscopes are being used in many applications in smartphones, flight controlling, gaming and missile guidance.

Different types of gyroscopes are available like MEMS (Micro Electro-Mechanical Systems) gyroscopes, mechanical gyroscopes, optical fiber gyroscopes and ring laser gyroscopes. The drone also can be equipped with piezoelectric gyroscope. The Piezoelectric Gyroscope is a gyroscope that uses a vibrating structure of piezoelectric material to determine the rate of rotation. Fig. illustrates the piezoelectric gyroscope. To simulate the operation of the gyroscope and indicate the changes in the position of the aircraft, the different micro electro boards are used and connected with the laptop.

4. CONCLUSION

Drones have become transformative tools in STEM and aviation education, bridging theoretical learning and real-world application. They enhance student engagement, deepen understanding, and provide cost-effective platforms for practical skills and pilot training. In present work it has been given some good examples of drone application in STEM education and aviation training.

Innovations like the Drone-Controlled Real Live Flight Simulator (DCRLFS) demonstrate the evolving potential of drones in immersive, real-time training. As their applications expand, drones are shaping the future of education and preparing students for emerging challenges in STEM and aviation.

5. REFERENCES

- [1] Mohsan, S.A.H., Othman, N.Q.H., Li, Y. et al.: *Unmanned aerial vehicles (UAVs): practical aspects, applications, open challenges, security issues, and future trends*, Intel Service Robotics **16**: 109–137, 2023. <https://doi.org/10.1007/s11370-022-00452-4>.
- [2] Bolick M.M., Mikhailova E.A. and Post. C. J.: *Teaching Innovation in STEM Education Using an Unmanned Aerial Vehicle (UAV)*, Education Sciences **12**: 224, 2022, <https://doi.org/10.3390/educsci12030224>.
- [4] Ng, W. S., & Cheng, G. : *Integrating drone technology in STEM education: A case study to assess teachers' readiness and training needs*, Issues in Informing Science and Information Technology, Vol.16: 61-70, 2019, <https://doi.org/10.28945/4288>
- [5] Mart in Monteiro, Cecilia Stari, Cecilia Cabeza, Arturo C. Mart, *Simple physics behind the flight of a drone*, Physics Education, 57 (2): 025029, 2022, <http://dx.doi.org/10.1088/1361-6552/ac484a>
- [6] Pavlović S., Crnoglavac D. Starčević A., Examining the role of drones as educational tools: an practical teaching example in enhancing learning experiences in STEM education, in *Proceedings Book, International scientific and professional conference Politehnika 2023*, Belgrade, Serbia, 2023, p.p. 501- 507.
- [7] Pavlović S., Examples of good practice with drone based teaching methods in problem - solving and active-learning study approaches in aviation college education, in *Proceedings Book, International Multidisciplinary Conference "Challenges of Contemporary Higher Education"*(CCHE 2024), Belgrade, Serbia, 2024, p.p. 383 -389.
- [8] Staples G.: *Propeller Static & Dynamic Thrust Calculation - Part 2 of 2*, 2014, [Electric Aircraft Guy](#)
- [9] Janke, C., Luthi, K., Kleinke, S., & Lin, Y. : Using Small UAS for STEM Education: Introducing Robotics and Mechatronics with Drones. *Florida Conference for Recent Advances in Robotics 2022*, <https://commons.erau.edu/publication/1852>
- [10] Quan Quan, *Introduction to Multicopter Design and Control*, Springer Nature Singapore Pte Ltd., ISBN 978-981-10-3381-0, Singapore, 2017.

- [11] Qun Quan, Xunhua Dai, Shuai Wang, *Multicopter Design and Control Practice, A SerieExperiments based on MATLAB and Pixhawk*, Publishing House of Electronics Industry, ISBN 978-981-15-3137-8, Singapore (2020).
- [12] Safe Drones Over Safe Environment, Foundation Tempus and Erasmus + project the European Union. Available on: <https://www.ecosafedrones.eu/site/belgrade/>
- [13] Safe Drones Over Safe Environment- Handbook, Foundation Tempus and Erasmus + project of the European Union, <https://www.ecosafedrones.eu/site/media/io/serbia/SRP%202020-1-RS01-KA202-065370.pdf>
- [14] Matese, A. and Di Gennaro, S.F., Practical Applications of a Multisensor UAV Platform Based on Multispectral, Thermal and RGB High Resolution Images in Precision Viticulture, *Agriculture*, 8, 16, 2018, <https://doi.org/10.3390/agriculture8070116>
- [15] Embry-Riddle Aeronautical University,(2020), “Drones in Aerospace Education: Enhancing Practical Learning.”, erau.edu.
- [16] https://aero.umd.edu/research/uoc?utm_source=chatgpt.com
- [17] https://online.stanford.edu/programs/robotics-and-autonomous-systems-graduate-certificate?utm_source=chatgpt.com
- [18] T. Longbridge, J. Burki-Cohen, and T. Go, “Flight simulator fidelity considerations for total air line pilot training and evaluation,” 2013, <https://doi.org/10.2514/6.2001-4425>
- [19] Shengjun Qia, Feng Wang and Li Jing, *Unmanned Aircraft System Pilot/Operator Qualification Requirements and Training Study*, MATEC Web of Conferences 179, 03006 (2018)
- [20] <https://doi.org/10.1051/mateconf/201817903006> 2MAE 2018
- [21] Mingyang Lyu at al., *Unmanned Aerial Vehicles for Search and Rescue: A Survey*, *Remote Sens.* 2023, 15(13), 3266, <https://doi.org/10.3390/rs15133266>
- [22] <https://news.mit.edu/topic/drones?page=2>
- [23] <https://aviation.osu.edu/drones>
- [24] Mays S. Obaid and Salman O. Mebayet , *Drone controlled real live flight simulator*, Journal of Physics: Conf. Ser. 1818 012104, 2021, DOI: [10.1088/1742-6596/1818/1/012104](https://doi.org/10.1088/1742-6596/1818/1/012104)