DRONE FLIGHT

GUIDE TO TEACHING FLIGHT INSTRUCTION

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LEARNING TO BE AN INSTRUCTOR

Student learning is significantly impacted by the quality and effectiveness of the instructor. Instructors directly affect how students learn, what they learn, and the way they interact with challenges and new scenarios. Considering the degree of the instructor's influence, it is important to review how to be an effective instructor.

KEY QUALITIES FOR AN INSTRUCTOR

The skills needed for effective teaching involve more than just expertise in the field. An effective instructor must be able to connect with the students, demonstrate their knowledge, communicate complex issues in appropriate language and work at the speed of the students.

BE ENGAGING

A lecture is an efficient way to deliver information to large numbers of people, but it is an inefficient way to provide students with lasting knowledge and skills. Keep students listening by talking with energy, making eye contact, telling jokes (even bad ones) and showing genuine interest in the material. Students will remember how they felt during a lesson more than the lesson or the instructor. A boring or unpleasant lesson will be counterproductive. Talk with confidence. Use the full range of your voice – vary your inflection, volume and cadence – to be expressive. The instructors voice is a powerful instructional tool in the educational process.

BE PREPARED AND ORGANIZED

Your expertise in the field provides the foundation of instruction but remember that students come from a variety of backgrounds and experiences, which may or may not be similar to yours. Not only should you know the material in the method that you learned it but be prepared to address a multitude of different learning approaches and experiences. Have a plan for what you want to teach, prioritizing the key points and essential context.

PRIORITIZE THE INTENT OF INSTRUCTION

Effective instructors can explain complex ideas in a variety of ways – simple explanations, analogies, as well as detailed discussions and demonstrations. But your lesson should match the needs and expectations of the students. For newcomers, avoid jargon and complex nuances. If a question arises about a complex situation, provide some background information, but avoid diving too deep into a topic that the student may not have the requisite foundation to follow the conversation. An example inquiry response might sound like "Great question. That is a complex situation that involves several issues. For now, we will keep things simple, but we'll be sure to talk about some of these issues throughout the day."

BE PATIENT

Give students time to process information and comprehend. Remember that it is fine for students to make mistakes if they can learn from them. Don't be quick to remove their control – intervene only when safety is compromised.

INSTRUCTION METHODOLOGY

The Demonstration-Performance Method for instruction is a well-established method for teaching kinesthetic skills, such as flight controls. The Demonstration-Performance Method is broken down into four phases:

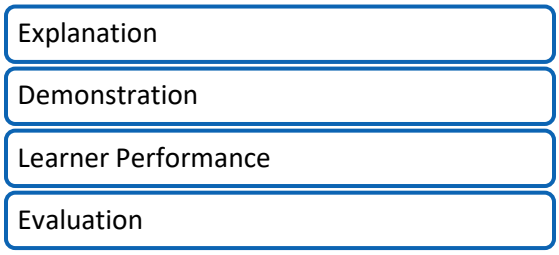


Figure 1: Demonstration-Performance Method

EXPLANATION PHASE

In the explanation phase, the instructor will explain the skills and techniques for the lesson. They should go over, with words and diagrams, the necessary actions and situational assessments to make to complete the maneuver. During the explanation phase, ensure to review all the appropriate safety procedures and the purposes behind each step.

DEMONSTRATE PHASE

In the next phase, the instructor will demonstrate and walkthrough the motions of the lesson. Be sure to repeat a handful of times to ensure the students have an opportunity to see all the actions within the maneuver.

LEARNER PERFORMANCE PHASE

Once the student has the controls, they must be given sufficient time to explore and practice the maneuver at hand. Through doing, the students are given the opportunity to build the mental and physical connections. During this time, the instructor monitors the students performance, providing constructive feedback and guidance.

EVALUATION PHASE

To complete the instruction, the student must demonstrate that they have learned the lessons at hand. This can be accomplished as part of the student's practicing or as a separate step. The instructor should evaluate the student's performance, records the student's performance and verbally advises the student of the progress made toward the objectives, even if there still remains performance deficiencies. Always offer concrete suggestions on improving performance and recommendations of further activities to try.

UAS FLIGHT INSTRUCTION CONCEPTS

FLIGHT INSTRUCTION LEARNING OBJECTIVES

Flight instruction can be split into two sets of learning objectives. One set of learning objectives for kinesthetic skills – moving the physical sticks in the correct direction and force, and the second set of learning objectives for problem solving skills – responding correctly to abnormal situations. Each set of learning objects have different methods for evaluation and analysis.

KINESTHETIC SKILLS

Kinesthetic skills refer to skills that require mental and physical coordination, such as moving the flight control sticks in the correct direction and force. Experienced pilots have an instinctual response to maneuvering the UAS but new pilots often need to think about which stick controls which motion and how much to move the stick to achieve the desired velocity. Evaluating these kinesthetic skills can be tricky. Use the following metrics to be a judge of whether the student is mastering kinesthetic skills:

Evaluation Metrics

- Response time
- Accuracy of using the correct stick commands
- Incorrect or inadvertent button pressing

PROBLEM SOLVING SKILLS

Problem solving skills refer to the mental skills necessary for recognizing and understanding a situation, identifying or deciding a correct course of action and responding. For new pilots, this often is a challenge. When working with students to improve their problem-solving skills, break down each problem into parts: Perceive the issue, Process what needs to be done, and then finally, Perform the solution (3P Model). This is especially important when working with flight maneuvers with varying orientations, especially nose-in orientation.

Evaluation Metrics

- Verbal confirmation of situation, and assessment
- Response time

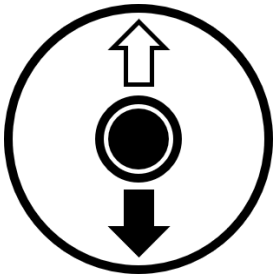
UAS FLIGHT INSTRUCTION LANGUAGE

The language used for flight instruction plays a role in student understanding and comprehension of flight maneuvers.

BEGINNER FLIGHT INSTRUCTION LANGUAGE

In the beginning stages of flight instruction, the use of flight instruction language can be used to build the kinesthetic skills for hand-eye coordination. Start with consistent and informative language to build the relationships of commands and actions.

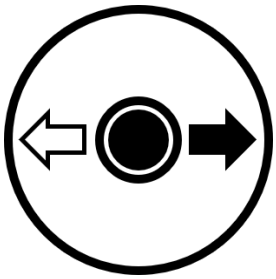
Altitude



Push Up

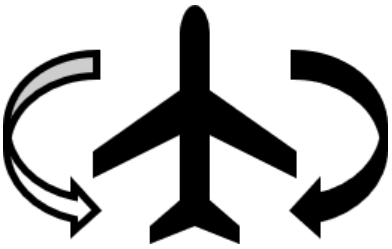
Pull Down

Heading

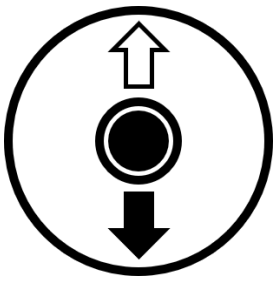


Turn Left

Turn Right

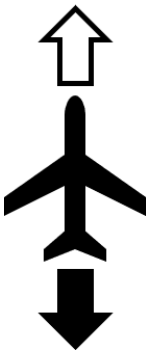


Forward Motion

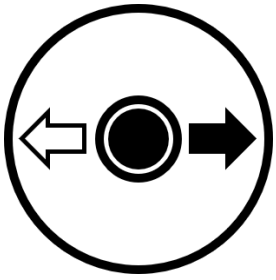


Push Forward

Pull Backwards



Side Motion



Roll Left

Roll Right

Example Commands

- **Push Forward** about 10 ft
- **Pull Back** to bring the drone to us
- **Push Up** to reach 20 ft altitude
- **Pull Down** to lower to 15 ft altitude
- **Turn Right/Left** to face North
- **Roll Right/Left** to align with the line

INTERMEDIATE FLIGHT INSTRUCTION LANGUAGE

Once the student is comfortable with the actions of the sticks, challenge students by varying language to build comprehension and problem-solving skills.

Example Commands

- Go to the …
- Head …
- Move forward …
- Slide …
- Face …

DEVELOPMENT OF HABITS

Effective and safe flight operation relies on building the pilot's safety habits. For new pilots, it is easier to start with good habits than trying to correct bad habits later. The early establishment of the habits of effective safety preflight checks, spatial awareness and procedures is highly useful for the learner. The instructor must model the behavior the students should learn.

Demonstrate Good Habits:

- Never skip pre-flight checks
- Never skip weather/airspace checks
- Always practice safe flying, no show-boating
- No advanced maneuvers until they understand why it is advanced

FLIGHT INSTRUCTION PROCESS

Flight instruction is an iterative process – one cannot learn how to pilot an aircraft all in one lesson. Lessons build upon each other, but it is also important to recognize how the lessons are structured and the lesson's objectives. From there, we can explore how to organize the flight instruction lessons. Once the lessons begin, it is time to ensure the flight instruction is effective during all phases of a flight: Positive Exchange of Flight Controls, UAS Motion, and Launching and Landing.

FLIGHT INSTRUCTION STRUCTURE

When organizing a flight training session, it is important to have a structure to the material. Know what lessons need to be taught – this means not only what maneuvers to teach, but also being prepared to adapt to the competency of the student pilots.

STRUCTURE THE FLIGHT INSTRUCTION

Work one lesson objective at a time. Avoid trying to cover more than one maneuver or objective at a time. Give the students time to practice and explore before moving on.

SET THE STUDENTS UP TO SUCCEED

Build the student's confidence by setting the student up to succeed. For example, when practicing the kinesthetic flight skills, arrange the lesson in a manner that seems almost too easy. Remember, the learning objective for the basic skills is to develop the mental and physical coordination.

KNOW WHEN TO PROVIDE CHALLENGE

Once the kinesthetic skills are in place, then up the challenge by varying the language or introducing new maneuvers to strengthen comprehension and problem-solving skills. Keep the students with an appropriate challenge to prevent them from being disengaged from the flight training session. Recognize that within any student group, some students will advance quickly while others may require additional time. Mentally keep track of the students progress and recognize that some lessons will require modification to provide an appropriate challenge for each student.

VISUAL LINE OF SIGHT

When first learning how to operate a UAS, the students should focus on looking directly at the UAS rather than watching the screen. Students should learn how the control sticks directly influence the motion of the UAS. During these first lessons, the UAS should stay within a very short distance of the student pilot – within 20 to 30 feet - such that the orientation, altitude and position of the UAS is clearly visible. Use these early lessons to reinforce the importance of visual line of sight and understanding the motion of the UAS, particularly how the UAS responds to momentum and control inputs.

FIRST PERSON VIEW OPERATION

Once the students are familiar with the motion of the UAS, operation through the screen or First Person View (FPV) can be introduced. However, any instruction of FPV operation must include a comparison of the motion of the UAS as compared to the view through FPV. Modern UAS have both mechanical and digital stabilization for FPV

that provide incredibly stable footage for photos and videos, but completely obscure the motion and velocity of the UAS.

Of note, speed perception through a camera system is directly influenced by camera field of view (FOV) and motion-sensitive peripheral vision. In camera systems with a narrow FOV, students are likely to underestimate flight speed – for example, an FPV pilot of a DJI Mavic 2 Pro will perceive that the UAS flies at a slower speed than a DJI Mavic 2 Zoom (with the same flight characteristics) and may underestimate necessary stopping distances or maneuverability as a result. The same follows when operating in a region with minimal moving elements on the outer edges of the camera screen, such as when operating at a high altitude in an empty region.

Table 1: Example UAS Models and Camera FOV

UAS Model	Camera FOV
DJI Mavic 2 Zoom (no Zoom)	83°
DJI Mavic 2 Zoom (full Zoom)	48°
DJI Mavic 2 Pro	77°
DJI Mavic 2 Mini	83°
DJI Mavic 2 Air	84°
DJI Phantom 4 (various)	84°

POSITIVE EXCHANGE OF FLIGHT CONTROLS

The first step for all new pilots is not learning how to maneuver the aircraft or how to land or launch. Instead, for most new pilots, their first experience controlling a UAS occurs when the instructor hands the controller to them. Ensure this first control exposure is handled correctly and safely.

- The instructor shall move the UAS to a safe location and ensure that it is stable and stationary.
    - The handover location should be well within visual line of sight, with the UAS orientation clearly visible and comprehensible.
- The instructor shall explain the aircraft's orientation to the student and include describing the visual cues utilized to determine the aircraft orientation.
    - For example, on many DJI UAS, the motor arms have red or green lights. Red lights are on the front arms and green lights are on the back arms. We can use these lights to tell whether the drone is facing towards or away from the pilot using the mnemonic - Red is Dead, Green is Good.

- Once the student has confirmed their understanding of the orientation of the UAS, the instructor can hand the controller to the student.
    - The student should hold out their hands to be ready to receive the controller.
    - Holding the controller from the top, the instructor should place the controller into the students hands in the correct orientation.
    - Avoid handing controllers from the side or upside down to minimize inadvertent stick actions from mishandling.
- Before the student begins manipulating the flight controls, the student shall verbally confirm that they have a firm grasp of the controller and that the controller is in the correct orientation.
- The instructor shall acknowledge and confirm, and the student may proceed with the flight exercise.

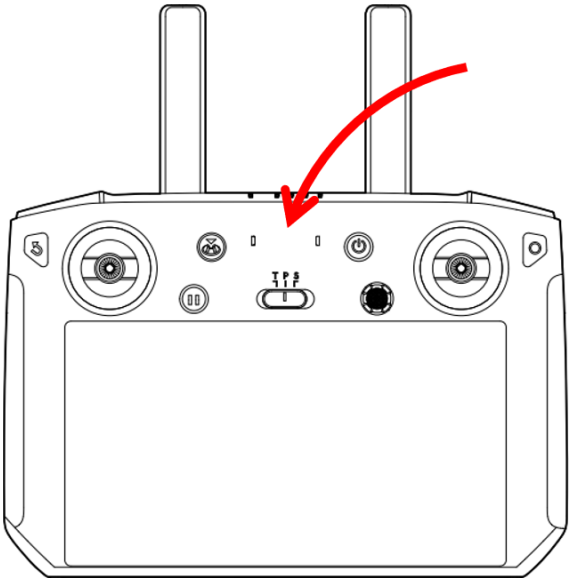


Figure 2: The Instructor should hold the controller from the top to ease the handoff.

When the time comes for the student to return the controller back to the instructor, the student should follow the same procedure.

UAS FLIGHT MANEUVERS

Teaching flight maneuvers is straight forward using the Demonstration-Performance Method. Explain the maneuver, demonstrate the maneuver, then pass the controller to the student for the student to practice and be evaluated. Here is some guidance for teaching some of the maneuvers.

HOVER IN PLACE

Start with the most important maneuver: Do Nothing.

The first instruction for new pilots is what the UAS does when there are no stick inputs – the UAS should hover in place. This lesson should be taught and revisited with every lesson. It is instinctual to push the flight control sticks in the event of an emergency, but in nearly every case, the correct maneuver is to release the sticks to assess the situation. This habit should be engrained into every new pilot.

HORIZONTAL AND VERTICAL MOTION

Once the students have mastered doing nothing, the students can work on mastering horizontal and vertical motion control. It is important to stress safe maneuvering early – remind students to start with slow motions, moving the sticks only small amounts at a time until they gain further experience. The focus of the early lessons should be on maintaining complete authority over the motion of the aircraft. If the aircraft speeds too quickly, they are at risk for not responding fast enough to stop or maneuver the aircraft safely.

HEADING CONTROL AND MOTION

Heading control by itself is a relatively easy concept for new pilots – rotate the aircraft to point the camera. However, flying the UAS in any orientation other than nose pointing away from the pilot, is one of the most challenging aspects for new pilots. One tip to help students improve on flight operations in different orientations is to work on their spatial awareness is by adding two pre-action steps:

1. Identify the *aircraft* orientation
2. Identify in what direction (forward/backward/right/left) the *aircraft* needs to go

The key is to ask the student to describe orientation and the direction in terms of the aircraft. Ask the student:

> "What direction is the aircraft pointing in?"
>
> "Now, in what direction does the aircraft need to move?"

Guide the students towards the correct answers. Then, relate the answers to the stick commands – "roll to the right or roll to the left?"

This stage of flight training is the most variable across new students. Some students will have an excellent grasp of orientation and motion, but others may take significantly longer. The only way to master this is with repeated practice.

LAUNCHING/LANDING

Launching and Landing are the last of the basic maneuvers for flight instruction. Launching and landing should only be taught once a student is proficient with moving the aircraft around.

Modern UAS are now equipped with automated take-off and landing routines. These are perfect for the new student pilot and should be the default method for learning.

Manual launch and landings utilize Control Stick Commands (CSCs) for starting and stopping motors. It is possible for CSCs to accidently trigger roll or yaw motion if they are done incorrectly by a new pilot – if the stick commands are mistimed (one stick is moved into position before the other), or if the stick commands are not fully executed (sticks only halfway to the command location). It is safer, for new pilots, to exclusively utilize automated take-off and landing routines.

Once students are suitably proficient with the control of a UAS, then they can advance to manual take-off and landings.

The launch and land location should be designated with a landing pad and set between 5 and 10 ft away from the student group. The landing pad establishes a visual target for landing as well as providing protection for the camera system from loose dirt and gravel. The distance is far enough to not pose an immediate risk but close enough for the other students to remain engaged with the lesson. If the remainder of the student group is too far away, they are likely to lose interest and may miss out on learning opportunities from seeing another student in action.

While the instructor should utilize automated landing routines for landing, avoid using Return to Launch (RTL) or Return to Home (RTH) as a replacement for landings for new pilots. These maneuvers have

significant value, but for new pilots, these routines are often not suitable. RTL and RTH often have conditional logic within their behavior, automatically adjusting altitude and speed depending on distance and battery level, that may cause confusion to a new pilot who might expect the drone to come directly back for a landing. RTL and RTH maneuvers should be introduced when the student is familiar with the basics of flight maneuvering and is ready to extend their flight operation range to a suitable distance for RTL and RTH.

COMMON INCORRECT BEHAVIORS

Student pilots will make a lot of mistakes when learning to fly for the first time. Here are some common issues to look out for.

- Full stick in any direction
    - Remind the student to utilize small motions on the stick commands to practice positive control.
- Flicking the stick to nudge
    - Flicking the sticks should be replaced with steady, small motion for accurate motion.
- Moving faster than they can stop
    - Often a symptom of using full stick commands. Remind the student to utilize only small motion to maintain complete control over the UAS at all times.
- Accidently pressing buttons on the controller
    - UAS controllers are covered with buttons that may be inadvertently triggered when gripping the controller, or during a handoff. It is recommended to turn off custom-mapped buttons whenever possible and disable any advanced functionality.