The Iterative Design Process

STEAM CONNECTIONS

Science: Energy Transfer
Technology: Computational Thinking and Collaboration
Engineering: Developing Solutions
Visual Arts: Creating

DURATION

60 Minute Lesson

MATERIALS

- **Designer's Notebook** (1 per learner)
- **Iterative Design Process Poster**
- **Charged Tello batteries** (2 per group)
- **Fringe costume panels** with attachments from previous day
- **Team bags with:**
  - **Lanyards with inserted production team role cards**
  - **Tello drone** (1 per group)
  - **Tello protective cage** (1 per group)
  - **Wifi-enabled device** (1 per drone) with DroneBlocks app installed
- **Access to Internet and projector for viewing videos**
- ***Drone Designers* Daily Slides** (optional but highly recommended)

SCHEDULE

- Introduction to Prop Wash (15 min)
- Drone Costume Prototype Flight Test (35 min)
- Wrap-Up (10 min)

OBJECTIVE

Analyze the previous lesson's hand-testing experiences and program a mission in DroneBlocks to best highlight the costume's movements.

ALIGNED STANDARDS

Next Generation Science Standards (NGSS)

NGSS 4-PS3-4. Energy Transfer.

NGSS 3-5-ETS1-2. Engineering Design.

International Society for Technology in Education (ISTE) Standards

1d. Students understand the fundamental concepts of technology operations, demonstrate the ability to choose, use and troubleshoot current technologies and are able to transfer their knowledge to explore emerging technologies.

5d. Students understand how automation works and use algorithmic thinking to develop a sequence of steps to create and test automated solutions.

7c. Students contribute constructively to project teams, assuming various roles and responsibilities to work effectively toward a common goal.

Idaho Computer Science (CS) Standards

3-5.AP.06. Construct and test problem solutions using a block-based visual programming language, both independently and collaboratively (e.g. pair programming).

National Core Arts Standards

VA:Cr1.2.5a: Identify and demonstrate diverse methods of artistic investigation to choose an approach for beginning a work of art

VA:Cr2.1.5: Experiment and develop skills in multiple art-making techniques and approaches through practice.

21ST CENTURY SKILLS

- Critical-Thinking and Problem-Solving
- Communication and Collaboration

HABITS OF MIND

- Gathering Data through All Senses
- Thinking Flexibly
- Applying Past Knowledge to New Situations

KEY TERMS

Iterative Design Process: the process of designing a product by testing and evaluating it repeatedly at different stages with the goal of improving the design over time.

Propeller Wash or "Prop Wash": the by-product of the propellers or airflow created by the propellers. This is a mass of air created by the thrust of a propeller.

Prototype: an original model, form or an instance of something that serves as the basis from which all later forms are developed.

Version: a specific form or variation of something; something a little different from others of the same type. For example, hardback and paperback copies of the same book.

BACKGROUND INFORMATION

When Léa Pereyre embarked on her first drone costume design, there were a lot of questions to answer. How is the drone going to fly with a costume? Will the costume fall off during flight? Is it possible for the drone to power its LED lights? To answer these questions, Léa sat down with the engineers and programmers at Verity Studios to get the deeper scoop on the physics of flight and how they will play into each costume. One of the challenges she faced was prop wash.

Prop wash is the force generated behind a propeller, particularly on or before take-off. Because of how drones are designed, prop wash is the airflow that moves across the curved surface of a propeller blade and then is pushed through the bottom of the drone. This means that anything below the drone, like a fringe costume, for example, is going to be affected by the increase in airflow. This airflow, however, can be a blessing in disguise. It's going to be up to your groups to determine how they're going to mitigate or accentuate prop wash with their final costume designs. But, that's big picture stuff. Today is more about discovering what, and how, a costumed drone reacts while in flight.

Today, it's important to encourage learners to experiment and problem-solve, especially with the concept of propeller wash. The areas of high and low pressure around the propellers and the force of air downward below the propellers may cause the fringe costume to be sucked into the protective cage and become shredded by the propellers. Expect this as a normal part of experimentation and the iterative design process.

OVERVIEW

Day 4 is a continuation of the previous lesson, focused on helping learners understand the iterative design process so that they have a structure for creating their drone costume prototypes and accompanying choreography. Expect much of the same today and remind groups that this activity is to bring art and drones together in a fun way, all while learning the basics of programming. This lesson's challenge is very similar to yesterday's basic paper fringe costume testing, however, it does include coding flight maneuvers to now test the costume and protective cage with the drone. In doing so, students learn more about one of the forces at play that cause the drone costume to move distinctly in the air: prop wash.

Guiding Questions:

- How does prop wash alter costume intentions and designs?
- Is it possible to program a flight that either utilizes or decreases prop wash and its effect on a costume?

Use these questions throughout the lesson to check-in with your learners and make sure they're understanding and tackling the day's main objectives. Find time to pose the Guiding Questions to your group as a whole or sprinkle them in individually as your learners work through each activity.

DAILY PREP

Once you've completed the instructor prep on pages 8-9, previewed this lesson and charged all batteries, today's prep should take 15 minutes:

- **Prep all materials needed to complete today's activities.**
- **Set up a computer connected to a projector** to share supporting slides and videos with learners.
- **Check Tellos** for properly mounted propellers, any damage and updated firmware.
- **Make sure devices and Tello batteries are fully-charged.**
- **Keep a broom or vacuum on hand** for any tissue paper that may become shredded by drone propellers. This is normal.
- **Find a well-lit, open space,** such as a gym, where groups can spread out to test costume prototypes. While you can complete this lesson in a classroom, we do recommend a larger space without obstacles like chairs and tables. If you have a set place for the final drone performance(s), begin testing in this space today. Make sure that the area where you're flying is well-lit to maximize the Tello's accuracy.

External Link Guide

Introduction to Prop Wash

- Stunning 3-D Animation Reveals How a Drone Moves Air (0:00-1:26): https://www.wired.com/video/watch/tk-drone-aerodynamics
- "Léa Pereyre: Drone Costume Design" WORLD.MINDS video (04:28-5:17): https://youtu.be/0MBPn7x2oFU?t=268

Additional Educator Resources at the end of the lesson

- *Production Team Roles and the Need to Rotate*
- *Taking Advantage of Teachable Moments Related to Safety and Repairs*

STEP-BY-STEP DIRECTIONS FOR INSTRUCTORS

Whole Group Discussion

INTRODUCTION TO PROP WASH

Welcome back to *Drone Designers*! Today is all about taking costumed flight for the first time. Before we can get to that, it's up to you to remind learners to use their experience from the previous lesson to improve today's testing. They should have a few ideas about what worked and what did not with the hand-testing, which should be considered as they improve their drone costume design and write code with particular maneuvers or choreography.

To set learners up to start considering the effects of propeller wash on their drone costumes, gather your group and remind them of the wrap-up questions from the day before:

- Were your predictions about how the costume would move in the air correct or not. Why or why not?
- How would you change the paper fringe costume to improve its movement in the air?
- Which maneuvers created the most dramatic effects with the paper fringe costume? (Up and down, side-to-side, etc.) How would you like to create your coding in DroneBlocks to try out new maneuvers with the drone in costume?

Spend some time discussing those questions as a whole group, then introduce the concept of propeller wash.

> When applying your knowledge gathered from testing your costume prototype by hand, consider how the forces of the drone affected the costume's movement. You may have noticed, especially on our first flight day when the drone landed on your hand, you felt a rush of air as the drone drew near. The by-product of the airflow created by the propellers is called propeller wash or "prop wash." This is a mass of air created by the thrust of a propeller. Of course, how the Tello is programmed to fly will determine the amount of prop wash created. This is an important concept to consider as you take advantage of the prop wash of the Tello to blow the paper costume, causing the design to move in distinctive ways.

Video

To share a better idea of what prop wash looks like, present this video to learners.

- **Stunning 3-D Animation Reveals How a Drone Moves Air** (0:00-1:26): https://www.wired.com/video/watch/tk-drone-aerodynamics

The video contains more detailed technical information that is helpful for learners to hear, but it isn't crucial information. This lesson only focuses on the basic concept of propeller wash and how it will affect the placement and design of drone costumes.

After that, share a prop wash test from Léa Pereyre's lab at Verity:

- **"Léa Pereyre: Drone Costume Design" WORLD.MINDS video** (04:28-5:17): https://youtu.be/0MBPn7x2oFU?t=268

Whole Group Discussion

Then lead a quick discussion of what was seen:

> Notice how the propeller wash makes the plastic billow and blow below the drone. Based on what you learned about propeller wash, what goes wrong in Léa's flight test of the costume prototype?

Ask learners to consider how different movements might cause more or less movement from the prop wash. This will aid them in planning their flight test.

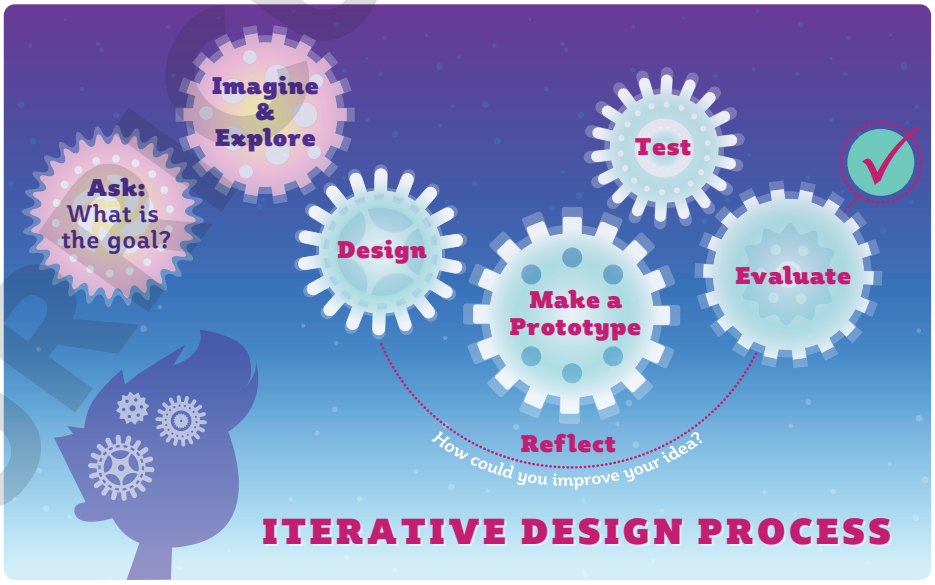
Whole Group Discussion

DRONE COSTUME PROTOTYPE FLIGHT TEST

After the video discussion has wrapped up, introduce today's main activity:

> Today's objective is to practice working together as a production team to follow the iterative design process to create code in DroneBlocks that highlights the movement of the simple drone costume in the air. Take time today to consider how the costume may be affected by propeller wash.

Before letting groups free, refer to the Iterative Design Process poster to remind learners of each stage.



Then, lead a safety procedure and production team roles review.

PRE-FLIGHT CHECK

- Always wear safety glasses, whether you're piloting or observing.
- The Safety Officer should always perform a pre-flight check before powering on the drone:
  - Make sure you have enough space for the drone to execute the mission.
  - Check propellers for nicks or bends: if any are damaged, ask the Pilot-in-Command to replace them with a new one.
  - Check the battery: if it's cracked or puffy, have the Pilot-in-Command swap it for an undamaged one.
- Have a plan to control a runaway drone.
- Don't keep flying when the drone signals that the battery is low. Land right away and replace the battery with one that's fully charged.
- Before picking up a drone that's landed, the Safety Officer makes sure the motors are completely off and the propellers have stopped spinning.
- Know the plan in case there's a fire or if someone needs first aid.

PRODUCTION TEAM ROLES

Creative Director: serves as the team leader to help the other members of the team work together to achieve their goal; also serves as the lead choreographer for the team.

Lead Designer: manages all materials related to the drone's costume and takes the lead in generating ideas and creating the drone costume; also observes the drone during flight for any changes to costume.

Programmer: creates the missions for the drone in the DroneBlocks app. Observes the drone during flight to ensure coded maneuvers are being executed.

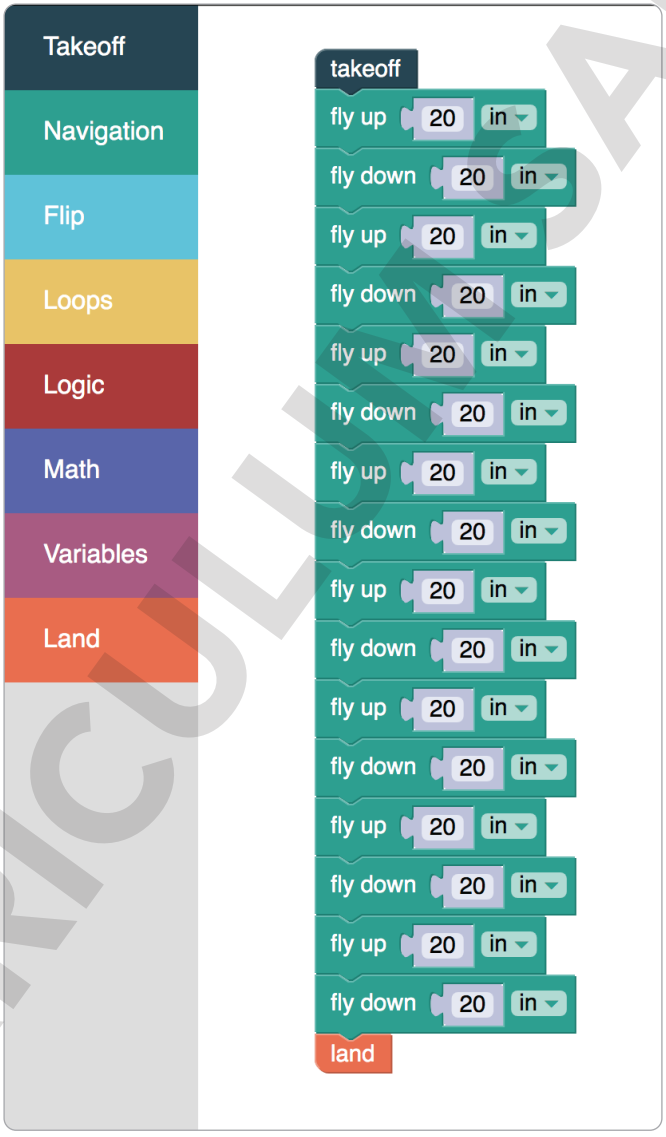
Pilot-in-Command: ensures the drone is properly connected to the device, launches the code and manages the controller during flight; manages all drone equipment and makes any repairs, such as carrying the drone to the flight area, swapping batteries, adjusting propellers or prop guards and making sure all materials are returned in good working condition at the end of the day.

Safety Officer: supports the Pilot-in-Command during flight operations and steps in as needed for hand launches and landings to protect the drone and its costume; makes sure the team is following all safety protocols, such as performing a thorough pre-flight check, watching for the drone's low battery warning, wearing safety glasses (this alone can be a full-time job) or notifying the instructor if someone needs first aid or fire control.

After the review, direct groups to choose their first production team role of the day with the appropriate badge and lanyard.

Tip: Remind Lead Designers and Safety Officers to be especially vigilant today as the paper fringe may get caught in the drone's propellers due to prop wash and costume placement. Lead Designers and Safety Officers will want to actively lead group problem-solving to ensure a successful costume design with coded movement. Safety Officers will want to ensure that ALL team members are wearing their safety glasses. Also, have a jacket or sweatshirt available for the Safety Officer to carefully cover the drone in case the costume causes the drone to improperly execute code and the "abort mission" function in DroneBlocks is delayed.

With badges chosen, show students how to code a series of up and down movements in DroneBlocks, taking time to ask learners what they remember about the takeoff and landing blocks. Example code is printed in the Designer's Notebooks for learner reference.



Before breaking into production teams, review the process of connecting the Tello to the device serving as its controller and address any troubleshooting issues groups encountered before.

Tip: Make sure that students program the up/down movement to occur several times in a row before landing so that they really understand this coding task as a study in movement. As the students' code will be very long, this will set them up well to want to learn about loops (repeated programmed actions) that will streamline their code in the next lesson.

Flight Test

Break for production teams to build their code, run their programs and practice up and down movements.

- After each flight, teams should rotate roles, with Creative Directors becoming Lead Designers, Lead Designers → Programmers, Programmers → Pilots-in-Command, Pilots-in-Command → Safety Officers and Safety Officers → Creative Directors, so everyone has a chance to try out different parts of flight operations.
- Ask Safety Officers to perform a hand launch to prevent the possibility of the papers becoming caught in the propellers or motors. A hand launch gives Lead Designers and Safety Officers a chance to see how the paper fringe and future costume features will move and react. They'll also observe potential safety issues for placing the costume in areas that could get caught in the propellers.
- Groups should not navigate too closely to one another to prevent a collision. As the facilitator, block out specific spaces for production teams to stay within. If time and space allows, use masking tape or painter's tape to block quadrants for students to operate their drones within.

Once learners have tested how the costume responds to up and down movement, challenge groups to program a mission to focus on a new combination of movements — left/right, forward/backward, yaw (rotate), etc.

Whole Group

WRAP UP

Once the final missions have been flown, make sure that everyone powers down and removes the battery. Set out a bin for batteries that need to be charged and return fully charged batteries to the LiPo safe storage bag. Remember that the last learners to serve as Pilots-in-Command will return these items to the designated bin or team bag in good working order.

Now, gather as a group and reflect on today's design testing process:

- Based on your observations today, how would you alter or add to the paper fringe costume to improve its movement in the air?

- What did you discover about programming different movements in DroneBlocks?
  - Hover
  - Fly up/fly down
  - Fly left/fly right
  - Fly forward/fly backward
  - Yaw
  - Set speed to
  - Repeat

CHECK FOR UNDERSTANDING

- What is prop wash? How is it created? *(Prop wash is the force generated behind a propeller, particularly on or before take-off. Because of how drones are designed, prop wash is the airflow pushed through the bottom of the drone.)*
- What different kinds of motion can be programmed in DroneBlocks? *(Left/right, up/down, hover, forward/backward, yaw, etc.)*
- What are some of the challenges of testing your costume design movements repetitively in DroneBlocks?

EXTENSIONS

Exploring the X-Y-Z Coordinate System

If you have extra time, spend a day exploring the x-y-z coordinate system and experimenting with the "fly to x __ y __ z __" to code diagonal movements. We include a suggested mini lesson to introduce learners to coding diagonal lines on Day 9. See Day 9's instructions if you would like to introduce the concept today as an extension.

Intro to Choreography

Ask learners to begin assigning movements to characteristics of their drone. Groups can explore these questions:

- If your drone is excited, how might it move?
- If your drone is curious about something, how might it move?
- If your drone is tired, how might it move?

Now, have groups develop a short story, with a beginning, middle and end (i.e., The drone wakes up. It sees something intriguing, like a mirror, which excites, and baffles it. It soon realizes that the reflection is itself, so it carries on with its day).

- Direct learners to program a few movements within their coding vocabulary to assign movements to code.
- Have groups perform their drone choreography.

ADDITIONAL EDUCATOR RESOURCES

Production Team Roles and the Need to Rotate

Today is key for solidifying group roles and routines. Ensure that everyone starts the day with a new team role and is wearing the appropriate badge. Give reminders to the class to rotate roles during flight test time every 5 minutes. Set an online timer, if possible.

Taking Advantage of Teachable Moments Related to Safety and Repairs

If a propeller flies off when a piece of fringe becomes caught, use this as a teachable moment to demonstrate to the group how to reattach or safely replace the propeller. Have the propeller wrench and extra propellers on hand to show Pilots how to make these repairs. Remind Safety Officers and Pilots to watch for common issues like a chipped propeller tip or the correct placement of propellers for successful flight.

Overall, make corrections and/or interventions with groups as necessary to reinforce safety and flight team roles. Make sure to emphasize the need to reflect on the costume's design to fly properly and execute coded movements. Encourage groups NOT to blame the drone during flight for any "confetti" created by costumes caught in the propellers, or the drone's inability to properly follow coded maneuvers if it is out of balance, overburdened by costume weight or has insufficient battery life remaining. Instead, encourage learners to make adjustments to the costume placement or design and equipment based on observations. Use the following questions to guide student reflection:

- What variables are affecting the drone's performance?
- Do you need to move the fringe to a different part of the protective cage to avoid further shredding of the costume?
- Do you need to shorten the fringe or remove an added element to the costume?
- How is the drone's battery life?
- Is the battery percentage low and affecting the drone's ability to execute coded movements?
- How is the drone's center of gravity?
- Can the drone remain balanced to fly properly if it has more weight from a costume on one side than the other?

Groups should work to answer these questions for themselves. The Safety Officer and Lead Designer roles are especially important for making these kinds of observations and adjustments. Whether it's prop wash or costume design, it's up to teams to create something that will not hinder, but accentuate their drone performance!