GENERATION
BEYOND

EDUCATOR GUIDE

TOPIC

Nature-Inspired Aviation Solutions

KEY LEARNING OBJECTIVES

Students will be able to:

- Describe forces that contribute to flight
- Describe forces that contribute to buoyancy
- Design a flying drone that can land on water

LESSON OVERVIEW

In this lesson, students will be challenged to design a flying drone that can land on water using designs found in nature as inspiration. This lesson begins with students questioning how things fly in the air and float in water. Through a series of investigations, they will explore the science behind the forces that contribute to the flight and flotation of objects. Students will discover that engineers can study nature to inspire their designs. Then, they will apply what they learn to analyze how a vehicle could be used in both air and water.

The accompanying presentation was created with PowerPoint so that it can be used in a variety of classrooms. If you are using a laptop with an LCD projector, simply progress through the PowerPoint by clicking to advance. All of the interactive aspects of the presentation are set to occur on click. If you are using an interactive whiteboard, tap on each slide with your finger or stylus to activate the interactive aspects of the presentation. It does not matter where you tap, but you can make it appear as if you are making certain things happen by tapping them. In the notes for each slide there will be information on how to proceed.

CONTENT AREA

Biomimicry, Physical Sciences

ACTIVITY DURATION

3 class sessions (45 minutes each)

GRADE LEVEL

Grades 9–12

ESSENTIAL QUESTIONS

1. What forces contribute to the movement of flying and floating objects?
2. How can scientists use structures found in nature to create flying drones that land on water?

MATERIALS

- Paper
- Scissors
- Stopwatch
- Pencil
- Large basin
- Smaller basin that floats within the large basin
- Ruler
- Ten 250-g masses
- Aluminum (e.g., paper clips), plastic (e.g., plastic pipes), and wood (e.g., balsa wood) materials
- Sheets of soft and hard plastic (e.g., plastic bags, transparency film)
- Small battery-operated fans (e.g., MB50100V2)
- Batteries
- Water-resistant tape and glue
- “Build an Airplane” Student Activity Sheet
- “Floating Masses” Student Activity Sheet

BACKGROUND INFO

Although engineers have been using machines to fly since 1903, when the Wright brothers successfully piloted their Flyer in Kitty Hawk, North Carolina, nature has been designing flying objects for millions of years. Through evolution, nature has tested many strategies for flying, and only the most successful strategies have survived. Now, scientists and engineers designing new flying machines can be inspired by these natural strategies to improve the designs of their own flying machines. Using this logic, students will be inspired by organisms that fly to design their own flying machines.

This guide was created to give educators ideas and strategies for presenting the content in the digital lesson. It provides slide-by-slide details to prepare educators to engage with students as they explain, discuss, and investigate the content in the presentation. The presentation is designed to cover three 45-minute class sessions, but it is flexible, depending on students’ needs and time available.

During the lesson, students will learn about the forces that act on flying objects. Engineers consider two main forces when designing things that stay in the air: weight and lift. Weight is the gravitational force that pulls objects toward the ground. It is the reason that flying objects tend to return to the earth. Lift is the force that opposes gravity. In order for objects to stay aloft, sufficient lift needs to be provided to counteract weight.

Flying objects tend to use wings to provide lift. Birds and insects flap their wings to push air molecules toward the ground. By Newton's third law of motion, applying a force that pushes air molecules to the ground will result in an equal and opposite force that pushes the animal into the air. Planes use a different strategy to provide lift because their wings do not move. The wings of planes are shaped so that the top is rounded and the bottom is flat. In order for air to move around the wings, molecules have to travel a greater distance above the wings than below the wings. By Bernoulli's principle, the faster-moving molecules create an area of low pressure, pulling the wings upward and providing lift.

During the lesson, students will also learn about forces that allow objects to float in water. Flotation depends on Archimedes principle, which states that the mass of the floating object is equal to the mass of water displaced by the floating object. Objects with low density float because they have a large volume compared to their mass. The large volume of the object can displace a large volume of water. If the mass of water displaced by the object equals the mass of the object, the object floats.

After understanding the forces involved in flying and floating, students will think about how to design an object that can both fly and float. Students must consider the constraints of both functions and balance design elements that promote flying with those that promote floating. Students will then build and test a prototype that they can use to evaluate their design.

NATIONAL STANDARDS

Next Generation Science Standards

High School

PS2.A: Forces and Motion

Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)

Developing Possible Solutions

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)

PROCEDURE

Day 1

Engage (Slides 1–5)

Overview: Students will be introduced to their challenge to design a drone that can both fly through air and land on water. They will brainstorm animals that fly and things that float. Based on these natural designs, they will speculate what elements of these designs are important for flight and flotation.

Slide 1

- Introduce students to this challenge by telling them to get ready to let their creativity soar as they identify key ideas to unpack the mission!
    - Show Nature Inspired Aviation video. Pause the video every few minutes for students to jot down their thoughts related to the following categories:
        - A = Adjective: List a word or two that describes something you saw or learned.
        - E = Emotion: Describe how a particular part of the segment made you feel.
        - I = Interesting: Write something you found interesting about the content/topic.
        - O= Oh!: Describe something that surprised you.
        - U = Um?: Write a question about something you learned or want to learn more about.
    - Pause at the predetermined points to allow students 60 seconds to add information to their list.
    - When the video concludes, have students complete a Pair & Share of their A-E-I-O-U statements.
- Present students with the challenge activity. Tell students that some machines travel in air and some machines travel in water, but very few do both. Their challenge today is to design a drone that can both fly in the air and float on water!
- In order to do this, students will use designs inspired by nature. By observing the natural world, engineers can learn from other organisms that have evolved to fly in the air or float on water.
- Engineers can use similar designs to develop machines that accomplish the same tasks.
- Distribute one Design Journal to each student. Explain that the Design Journal involves a series of steps that lead to the development of a new product or system. These steps simulate the process that many manufacturers and engineers take as they design and build new products. In this design challenge, students are to complete each step and document their work as they design their drone.
- Explain to students that the first step in the engineering design process is to identify a problem that needs to be solved. Guide students to complete Step 1 of their Design Journal using their challenge activity and information from the video. Circulate around the room to answer questions and clarify directions.

Slide 4

- Divide the class into small groups. Ask students in each group to brainstorm a list of animals that fly. Write down their ideas on a sheet of paper.
- Once they have gathered their ideas, ask them to think about what these animals have in common. Encourage them to think about the structure of each animal. Have each group share their best ideas with the class.
- Then present slide 2. Explain that many animals that fly have wings. Ask students to think about why animals use wings to fly.

Slide 5

- In their groups, have students complete a similar brainstorming activity for things in nature that float. (These may include animals and plants as well as natural objects such as wood, leaves, and cork.) Have them write down their ideas on a sheet of paper.
- After considering their list, ask students what characteristics are shared by all things that float. In particular, have them focus on the physical properties of floating objects. Then have each group share their best ideas with the class.
- Present slide 3 and tell students that things that float are less dense than water. This does not mean that a floating thing is lighter than water. However, per unit volume, it has less mass than the same volume of water has.

Day 1

Explore (Slides 6–7)

Overview: In this section, students will learn what forces are involved in flying and floating. Students will investigate the impact of wing shape on the ability of objects to stay in the air. They will also investigate how changing the mass of a floating object alters its buoyancy.

Slide 6

- Begin this section by giving each group of students the "Build an Airplane" Student Activity Sheet. Challenge each group to fold each piece of paper into an airplane. They can use scissors to trim the wings of each plane into different shapes. Encourage them to test long, narrow wings and wide, broad wings. Using a stopwatch, have students time how long each plane can stay in the air. Then have them say what aspects of wing design most impacted the ability of the plane to fly.
- After students have formulated a hypothesis about what enables a plane to stay aloft, present slide 4. This slide shows the forces that are involved in flight. The two forces involved are weight and lift. Weight pulls objects toward the ground and lift pushes objects into the air.
- Ask students to refer to the list of flying things they produced earlier. Can they think about what produces lift in each object?

Slide 7

- Give students a copy of the "Floating Masses" Student Activity Sheet. Fill a large basin with water. Place a smaller basin in the water (make sure the smaller basin floats!). As a class, place 250-g masses, one at a time, into the smaller basin. After each addition, ask students to measure the water level. Each time more mass is added, students should realize that the small basin sinks a little and the water level rises an equivalent amount.
- Present slide 5, and tell students that when the small basin sinks, it displaces more water. The weight of water displaced each time is equal to the weight being added on top of the flotation device.
- Some students may be confused by the relationship between mass and weight in this activity. Explain that mass and weight are related because weight is the force of gravity experienced by a mass. Since all objects on Earth experience the same acceleration due to gravity, mass and weight are directly proportional. However, mass is a measure of the amount of matter in an object, while weight is a measure of force experienced by the object.
- Some students may have learned in the past that objects float when their density is less than that of water. They may be surprised to learn that this activity actually shows that an object floats when its density is equal to that of water! Explain to them that density is equal to mass per unit volume. In this case, the volume in question is the volume of the small basin under the water. Each time a weight is added, the small basin sinks a little more. That is to say: as mass is increased, the volume of the basin under the water increases as well. In fact, the mass of the small basin divided by the volume of the basin under the water line will exactly equal the density of water. If you are able to substitute a shallow graduated cylinder for the small basin (cutting off a 2-L cylinder at the 200-mL mark will work), students can use this activity to calculate the density of water by dividing the mass inside the cylinder by the volume of the cylinder that is submerged. If you choose to calculate the density of water in this way, be sure to tare the graduated cylinder to improve the accuracy of the density calculation.
- Before proceeding to slide 6, have students look back at their list of things that float. How does each thing on their list displace water?

Day 2

Explain (Slide 8)

Overview: In this section, students will use what they know about flight to explain what enables a drone to fly. They will discuss weaknesses of a common drone design to explain why the drone cannot land on water.

Slide 8

- Begin this section by presenting students with slide 6. This slide presents students with a common drone design that can fly in the air for long periods of time but that is not designed for landing on water.
- Using what they know about the forces involved in flight, have students draw a model of the drone on a large sheet of poster paper. Each group should label components of the drone that contributes to flight. In addition to the obvious moving parts that provide lift, encourage students to think about how the shape of the drone provides aerodynamics and the material of the drone reduces weight.
- Then have students create a T chart that lists the aspects of the drone design that are compatible with flotation and the aspects of the design that are not compatible with flotation. (Students may consider whether the material of the drone is compatible with water, whether the volume of the drone will displace sufficient water, and whether the drone is too heavy to be buoyant.) Using this chart, students should explain why a new design is needed for their challenge activity.
- Finally, students should outline their drone's criteria and constraints in Step 2 of their Design Journal. Guide students to individually begin to design a solution using Step 3 of their Design Journal. In this step, students should consider which materials they want to use and start to sketch out and annotate their ideas.

Day 2

Elaborate (Slide 9)

Overview: In this section, students will analyze the design of a hawk and explain how its anatomical design enables flight. Students will then explain how engineers can use the hawk's design to improve the flight of drones.

Slide 9

- Present slide 7 to students.
- Tell students that hawks are efficient fliers that can stay in the air for long periods of time. On another sheet of poster paper, have students draw a model of the hawk. On the model, have students point out designs that are particularly useful for flying. On a separate sheet of paper, have students use a two-column chart to indicate how each design element they identified can be incorporated into the design of a drone.
- Have each group of students revisit their drawings in Step 3 of their Design Journal and incorporate one of the elements they identified in the hawk. Make sure students explain how the drone is improved by the new design element.

Day 3

Evaluate (Slide 8)

Overview: In this section, students will design a drone that can fly in the air and land in the water in the Challenge Activity. Students will begin by sketching a design of a drone. Using their design, they will build a prototype and test its ability to fly and to land in a basin of water.

Slide 8

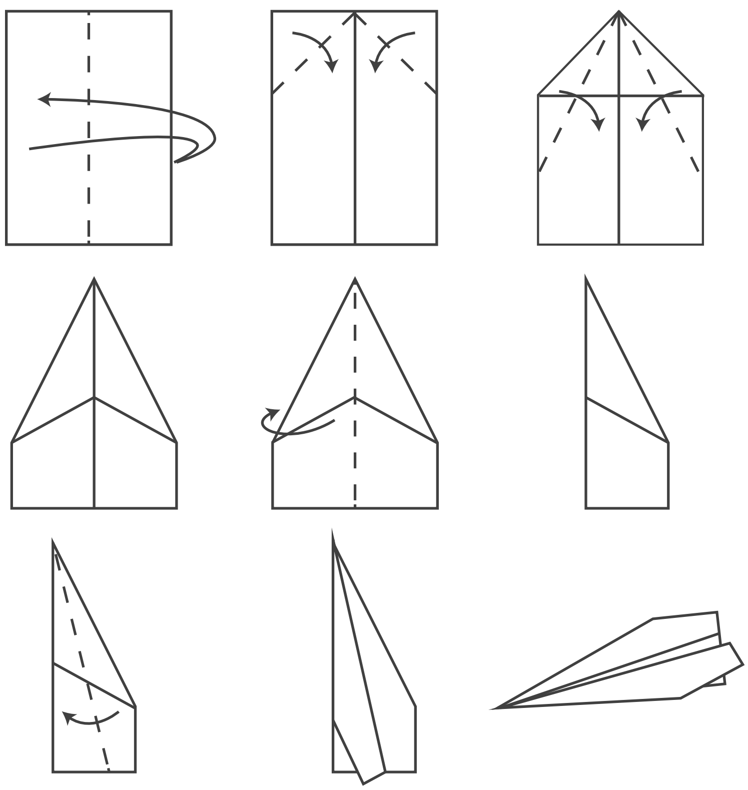
- Tell students that their challenge today is to design a drone that can fly in the air AND land on water. They will use inspirations from nature for their design.
- Before they begin their design, ask each group of students to brainstorm examples of animals that both fly in the air and float in water. What design elements are found in these animals that permit them to do both activities?
- Guide students to complete Step 4 of their Design Journal. In this step, group members will evaluate each other's designs to determine which one to build. Step 4 includes a chart for groups of students to evaluate each design by giving it a score. Students will use this score to guide which idea they would like to build. They might combine multiple ideas. Using paper and pencil, each group should sketch out a design of a drone based on an animal. Remind students that different animals use different strategies to accomplish the same goals. To improve their designs, they can combine elements from different organisms to produce their ultimate flying machine!
- When they have finished designing their drone, each group should name their drone after the animal or animals that inspired their design. Once they have their final labeled sketch in Step 5 of their Design Journal, they will need teacher initials to start construction.
- Using their design, students should build a prototype of their drone. To facilitate several students working on one design, students should use Step 6 of their Design Journal and complete the division of labor chart with their group. This will help the team work more efficiently to construct their drone design. Lightweight materials such as aluminum, plastic, and wood can be provided. These materials can be joined together using water-resistant tape and glue. To provide lift, students will need to attach small, battery-operated fans to their prototype.
- After building their prototype, each group should place its drone in a basin of water. If it floats, students should then turn on the fans. (If it doesn't float, students should remove the drone from the basin, set it on the ground, and turn on the fans to test whether it flies.) Are any drones able to both float in water and lift off from water? Remind students to be careful to protect the batteries and exposed leads to prevent short circuits.
- Guide students to leave a copy of the Gallery Walk Feedback Form with their project. As students rotate around to the different projects in their group, they will provide commendations and considerations. Guide students to break away from their groups and individually complete Step 7 of their Design Journal to reflect on their project and propose a redesign using the Gallery Walk Feedback Form. Each group should identify one thing they learned from the test flight. On a sheet of paper, they should describe what they learned and identify one design element of their drone that can be improved.

Materials

- Five sheets of paper
- Scissor
- Stopwatch

Procedure

1. In your groups, fold the sheets of paper into different plane shapes. Test planes with different wing styles. Use the scissors to help trim the wings into the sizes you want to test. One way to fold a paper airplane is shown. Use your creativity to try new shapes of plane!



2. Fly each of your planes. Using the stopwatch, time how long each plane stays in the air. Record your data below.

	Time in the Air
Plane 1	
Plane 2	
Plane 3	
Plane 4	
Plane 5	

BUILD AN AIRPLANE | Printout for Slide 10

In this activity, you will build paper airplanes to see which can stay in the air the longest.

Conclusions

1. Which plane flew the longest?

2. Why do you think that plane stayed in the air the longest?

3. What lesson(s) from this activity could you apply to design a flying machine?

FLOATING MASSES | Printout for Slide 5

In this activity, you will test how the mass of objects affects how they float.

Materials

- Large basin
- Smaller basin that floats within the large basin
- Ruler
- Ten 250-g masses

Procedure

1. As a class, fill the large basin with water up to 2 inches from the top.
2. Place the smaller basin in the large basin. Use the ruler to measure the height of the water in the basin. Record your data in the table.
3. Add a mass to the basin. Measure the height of the water again.
4. Continue adding masses until the small basin sinks to the bottom.

Mass	Height of water
250g	
500g	
750g	
1000g	
1250g	
1500g	
1750g	
2000g	
2250g	
2500g	