FUTURE U.

Drone Wing Design

Objectives

Students will be able to:

- **Experiment** with wing structure and **construct** a strong and flexible wing
- **Research** and **summarize** how various birds and insects have adapted for flight, and **consider** how these wing characteristics could apply to drone wing design
- **Design** an innovative drone wing that mimics nature's designs
- **Review** and assess the design prototypes of their peers in order to **recommend** one with which to move forward

Overview

As new members of Boeing's aerospace engineering team, students will be challenged to find inspiration from nature as they innovate drone wings. Students will first complete a wing-building activity to gain a better general understanding of wing structure. They will then be encouraged to design a new drone wing inspired by biomimicry. After reading about examples of biomimicry in the world around them, they will work in teams to research the wings and flight patterns of several living things. They will ultimately synthesize their learning as they create a drone wing prototype that emulates nature.

This lesson focuses on

Engineering Design Process

- Defining the Problem
- Designing Solutions
- Creating or Prototyping

21st Century Skills

- Communication
- Collaboration
- Critical thinking
- Creativity

Timing

Three 60-minute class periods

Materials

DAY 1

- Device with ability to project, one for the instructor
- Devices with Internet access, at least enough for half the class
- Handout 1: Create a Wing, enough for half the class
- For the wing-building activity:

- Several types of paper (about 100 pieces each of construction paper, index cards, copy paper, etc.) for the class to share
- Optional: Paper straws, about 100
- Tape (any kind), at least enough dispensers for one-quarter of the class
- Scissors, at least enough for one-quarter of the class
- Paper cups (any size), enough for one-quarter of the class
- Marbles or other weight (coins, etc.), enough to fill each of the paper cups
- String, about 10 feet

DAY 2

- Device with ability to project, one for the instructor
- Devices with Internet access, enough for at least half the class
- "What is Biomimicry" video
- "Biomimicry: 9 Ways Engineers Have Been 'Inspired' by Nature" article, one per student (or students may access it online)
- Handout 2: Wing Research, one per student

DAY 3

- Handout 3: Drone Wing Design, to project or one per student
- Modeling clay, one palm-sized ball for each group of three students
- Handout 4: Biomimicry Redesign*, enough for one-third of the class
- Design Assessment and Recommendation slip (cut out in advance), one per student
  Note: In the box labeled "#____", pre-write #1, #2, #3, and so on, so each handout has a different number.

Have you ever wondered. . .

What exactly is a drone?
A drone refers to an aircraft or a spacecraft that does not have a pilot. Another popular term for drone is "unmanned aerial vehicle" or UAV. While unmanned, today's drones have different levels of autonomy and cannot currently perform all of their functions without human intervention. The most autonomous drones still require a human to preprogram their flight paths, but they do operate using a wide range of technologies, including artificial intelligence and computer vision.

Drones date all the way back to World War I when the U.S. and France worked to develop unmanned and automatic airplanes. However, it was only a few years ago that drones began increasing in popularity. Because of the way in which they can be controlled from afar and are easily able to access remote areas, more and more drones are now being used for a range of commercial purposes—from monitoring traffic, surveying remote areas, fertilizing crops, and delivering medical supplies. As drones continue to progress and evolve, they should move toward full autonomy in all aspects of flight.[1]

What is biomimicry?
According to the Smithsonian Science Education Center, biomimicry is "the imitation of designs and processes found in nature. It asks how we humans can benefit from mimicking the intricate and graceful systems

displayed by life forms all over the world." It is based on the premise that because organisms have been evolving for billions of years, many have already developed optimal solutions to living on Earth. It therefore makes sense that scientists, engineers, and inventors would look to the natural world as they try to design sustainable solutions! From examining processes such as birds' flight, underwater signals sent by dolphins, or how fish swim, humans are able to learn from evolution and imitate nature as they create better, stronger, and more sustainable systems and designs.[2]

Make Connections

How does this connect to students?

Drones are currently changing industries in both commercial and nonprofit sectors. They are credited with being able to "increase work efficiency and productivity, decrease workload and production costs, improve accuracy, refine service and customer relations and resolve security issues."[3] While they've become critical to many businesses and organizations, others are just starting to recognize their potential.

As students progress through school, it is likely that the impact of drones on their lives (and their future careers) will continue to grow. Drones are already used for everything from delivering packages and prescriptions to monitoring and spraying crops to capturing high definition imagery for real estate agents. . . and their use is only expected to expand.

Therefore, it is important for students to be aware of drones' potential so they are ready to join the workforce and the world with an understanding of the role that they play.

How does this connect to careers?

Aerospace Engineer: Aerospace engineers design aircraft, spacecraft, drones, and satellites. These engineers have many standards and goals that their designs must meet, depending on the industry that their design will service.

Software Engineer: Software engineers develop software and systems for everything from games and business applications to drone operating systems. They work with others to determine their software needs, and then they design, develop, and test their system according to the user's specifications.[4]

Biomimicry Specialist: Biomimicry specialists usually receive a graduate certificate in biomimicry so they are equipped to help companies or organizations incorporate sustainable design and biomimicry principals into their problem solving. They may work as product designers, packaging designers, building designers, inventors, or sustainability-focused engineers.[5]

How does this connect to our world?

The uses of drones in today's world is ever-expanding. While their commercial potential is huge, it is also important to note the way in which drones can make a difference.

Drones, for example, are becoming more and more useful in delivering medical supplies to remote populations. For instance, a company called Zipline uses drones to deliver medical supplies and products to remote areas around the world, flying over 25,000 miles each day from various global distribution centers.[6]

Similarly, drones have helped with the COVID-19 pandemic. Morocco, for instance, has used drones for public service announcements, sanitation, and aerial surveillance during lockdowns. Australia is experimenting with how drones can be used to preemptively spot signs of sickness (such as coughing and high body temperatures), and several Asian countries have used drones to spray disinfectant.[7]

These are just a few examples of how drones can be used for global good. As they become more and more autonomous, their uses will only continue to evolve and grow.

Sources

[1] "Drone technology uses and applications for commercial, industrial and military drones in 2020 and the future." Business Insider. businessinsider.com/drone-technology-uses-applications

[2] "Five Things to Know About Biomimicry." Smithsonian Science Education Center. ssec.si.edu/stemvisions-blog/five-things-know-about-biomimicry

[3] "Drone technology uses and applications for commercial, industrial and military drones in 2020 and the future." Business Insider. businessinsider.com/drone-technology-uses-applications

[4] "Learn About Being a Software Engineer." Indeed Careers. indeed.com/career-advice/careers/what-does-a-software-engineer-do

[5] "Who employs biomimicry specialists and professionals?" Medical Technology Schools. https://www.medicaltechnologyschools.com/biological-sciences/what-is-biomimicry

[6] Zipline. flyzipline.com/

[7] "Is the future of drones now?" Forbes. forbes.com/sites/stevebanker/2020/06/11/is-the-future-of-drones-now/#463270e03284

Blueprint for Discovery

DAY 1

1. Begin the class session by writing "DRONE" on the board. Explain that "drone" refers to an aircraft or spacecraft that does not have a pilot. There are many different kinds of autonomous vehicles—including those that travel underseas as well as on the ground—but drones refer specifically to those that can fly.

2. Then challenge students to brainstorm all the uses for drones that they can think of. If needed, kick off with an example like aerial photography or shipping and delivery.

   Once students have shared their thoughts, identify any of the following ideas that have not been mentioned: aerial photography, express shipping/delivery, disaster assistance, search and rescue operations, geographic mapping, building safety inspections, crop monitoring, cargo transport, law enforcement, storm tracking and forecasting, military uses such as target decoys, and more.[2] Also mention that other types of autonomous vehicles are being explored for transport of cargo and even humans!

3. Go on to explain that drone use is still in its initial phases. They cannot yet function entirely by themselves; they need some kind of support from people on the ground. However, companies are finding that drones can help increase productivity and decrease workloads because they do not require people aboard! They also help companies access remote areas easily and quickly. As more and more companies around the world are beginning to recognize the potential of drones, their adoption is growing and their technology is continuing to progress.

4. Tell the class that Boeing is one of the many companies that recognizes the potential of drones, and they would like to increase the number of employees focused on this important area! Therefore, you would like to welcome the students to Boeing's aerospace engineering team. As new members of the team, they will be asked to help develop innovative drone wings.

5. To better understand the overall mechanics of wings, explain that the class will begin by experimenting with their own wing design. Their challenge will be to create a basic wing that is flexible, strong, and lightweight! It should be as light as possible so it requires less fuel, but it also must remain strong and able to fly without breaking.

6. Write the word "deflection" on the board and explain that deflection occurs when a structure bends. Wings must be built to deflect a little bit. However, if a wing deflects too much, it can break and/or may not be able to fly.
7. To demonstrate this point, ask a student volunteer to come to the front of the class and help with the following:
    - Ask the student to hold one arm out straight, parallel to the ground.
    - Give them a book to place on their shoulder and ask them to describe how heavy the book feels.
    - Then ask the student to move the book from their shoulder to the top of their extended hand.
    - Ask: Does it feel harder, easier, or the same amount of difficulty to hold the book this way?
    - Ask: If I were to continue adding books to the top of your hand, what do you think would happen?
    - Encourage the student to demonstrate that, after a certain amount of weight is added, they would no longer be able to hold their arm parallel to the ground. **This is deflection!**
8. Then divide students into groups of three and distribute one *Handout 1: Create a Wing* to each student. Tell students that—rather than you telling them *how* to create a wing that is strong, flexible, and able to deflect a little bit—they will try it for themselves!

    Read the directions provided and show the class where they can find the materials for this activity. Then explain that they will have the next 25–30 minutes to brainstorm, build their wing design, and optimize it (if time allows).
9. When there are about 15 minutes left in the class period, give students a five-minute warning.
10. When there are about 10 minutes left in the session, ask students to place their wings on display around the classroom. Once the wings are in place, instruct the class to quietly rotate around the room and observe their peers' designs. Encourage them to look for similarities and differences among the designs.
11. Conclude the session with a full-class discussion around the following questions:
    - What features do many of the wings share? Why may this be the case?
    - Did you see any unique design features that caught your eye?
    - What design aspects could increase wing strength? What design aspects may increase wing flexibility?
    - As we look to build the strongest, lightest, most flexible wings possible, what could we look to (outside of this classroom) for inspiration?
12. Wrap up by previewing that in the next session, students will look toward nature as they investigate what they can learn about wing design from living things that take flight!

DAY 2

1. Welcome students back to the second day of their new aerospace engineering position. Explain that today they will continue to investigate drone wing structure—this time through the lens of biomimicry.
2. Play the "What is Biomimicry?" video and ask students to listen for what biomimicry is.
3. When the video is complete, ask students to summarize their understanding of biomimicry. Guide them in understanding that *bio* means life and *mimicry* means to copy. Therefore, biomimicry is when humans use (or copy) ideas from nature to solve their own problems.

4. To better grasp how humans use biomimicry to solve design problems, pass out a copy of the "Biomimicry: 9 Ways Engineers Have Been Inspired' by Nature" article to each student or direct them to bit.ly/3kTU2OX. Encourage them to read the article independently and annotate (or jot notes on) the article for:
    - 3 interesting facts
    - 2 points that surprised them
    - 1 thing they wonder
5. Once students have finished reading, ask: Do you think biomimicry could help us develop innovative drone wings? Why or why not?

    After listening to students' ideas, explain that in order to learn from nature, they are about to investigate the wings and flight patterns of several living things!
6. Divide the class into new groups of three and distribute one *Handout 2: Wing Research* to each student. Prepare the class for the research activity by completing the following:
    - Review the directions provided and read through the chart's three categories. Be sure students understand that they will find information for the second column in the article and/or video—and then they will apply what they learned as they fill in the third column.
    - Instruct groups to split up the animals/insects to be researched. If they finish their portion of the research before time is called, they should move on to the final row and research a winged animal/insect of their choice.
    - Explain that students will have about 20–25 minutes to complete their research before sharing it with their group members.
7. When there are about 15 minutes left in the class session, instruct groups to reconvene and share their research with each other. They should take notes in their chart as their classmates share. Encourage students to focus especially on the last column and share what can be learned from each winged creature. This will help them as they prepare to create their own drone wing!
8. Wrap up the class session by inviting groups to share some of their most important takeaways. Encourage students to take notes on ideas that they may not have come up with in their own groups! Then either collect the students' work or instruct them to keep it in a safe place until the following class session.

DAY 3

1. Begin the class session by displaying or distributing *Handout 3: Drone Wing Designs* and explain that these four designs are currently the most popular drone wing designs.

    Give students a moment to look over the designs and share their observations.

    Then ask students to consider: Based on these different wing designs…
    - Which drones may be able to hover best?
        - Answer: Single rotor and multi rotor
    - Which drones may be best suited for longer flights?
        - Answer: Fixed Wing, Single Rotor, and Fixed-Wing Hybrid
    - Which drone(s) may need a longer distance for take-off and landing?
        - Fixed Wing

2. Go on to explain that each current drone design has its own pros and cons. No design is perfect…. and for that reason, Boeing would like to continue innovating!

   Explain that now that their training is complete, the students are ready to complete their first assignment: Develop innovative drone wings, based on what works well in nature!

3. Ask students to take out their completed *Handout 2: Wing Research*. Then ask students to get back into their research groups and pass out one *Handout 4: Biomimicry Redesign* to each group. Prepare students for the activity by reviewing the following:
   - Read the handout's directions aloud.
   - Explain that students will work with their research groups to create their new drone wing design.
   - Emphasize that they *must* base their design decisions on biomimicry and what they learned from building their own wings. They must include labels on their sketch that explain their decision decisions.
   - Show groups where they can find the modeling clay when they are ready to create their 3D models.
   - Answer any student questions.
   - Deduct about 15–20 minutes from the end of the class period. Explain that students will have this much time to complete their designs, and then encourage them to begin!

4. Give students a five-minute warning when there are 15–20 minutes left in class.

5. When time is up, instruct groups to place their 2D sketches and 3D prototypes on display around the classroom, similar to how they previously shared their wing designs.

6. Distribute one *Design Assessment* and *Recommendation* slip to each student and read the slip aloud. Explain that students will now rotate around the classroom, review each group's sketch and prototype, complete their recommendation, and then hand their slip to you.

7. Wrap up by sharing the prototype that received the highest number of votes and take a moment to note some of the ways it incorporated biomimicry in order to be lightweight, strong, and flexible.

   Then thank the students for their hard work and each of their innovative and nature-inspired designs. Encourage students to keep an eye on drones in the future to see how they continue to evolve and progress!

Extension

Students can perform additional research on the different uses of drones. They will then consider for which use(s) their drone design may be best suited and they can optimize their wing design for this specific use.

National Standards

Next Generation Science Standards

Engineering Design

- MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Biological Evolution: Unity and Diversity

- Disciplinary Core Idea:
    - LS4.C: Adaptation
        - Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

Common Core State Standards for English Language Arts

- CCSS.ELA-LITERACY.RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.

Create a Wing

Your Challenge: Build a lightweight wing structure that is at least 12 inches long. It must be able to hold a heavy load without deflecting too much or breaking. Be creative!

Directions: Gather the materials listed below and then follow Steps 1-4 to build your own wing.

You Will Need:

- Different types of paper
- Scissors
- Tape
- Straws
- One paper cup
- String
- Marbles or other weight

Step 1: Brainstorm and Design
Consider how the available materials could be used to build a strong and flexible wing. You may find it helpful to sketch your design ideas on a separate piece of paper.
Tip: Consider layering materials or arranging them in triangular patterns.

Step 2: Construct
Bring your ideas to life! Build a strong, flexible, and lightweight wing that is at least 12 inches long (and as wide as you would like it to be).

Step 3: Test and Optimize

1. When your wing is complete, place two holes on opposite sides of the top of the paper cup, and loop string through the holes. Then tie the two ends of the string together so it can be placed over the wing. It should look like the picture included here.
2. Select a group member to hold one end of your wing for testing. Then place the string over the other end of the wing (about two inches from the end) so the cup hangs below.
3. Test the strength and flexibility of your wing by loading marbles (or another weight) into the cup. Observe what happens as you add more and more weight and consider how you could alter the wing design to make it even stronger or more flexible. Feel free to stop mid-test and make changes. Your goal is to have your wing hold as much weight as possible without breaking!
4. Continue to optimize, or improve, your wing design until time is called.

Wing Research

Directions: See what you can learn about wing design from nature by researching the living creatures below.

As you read and view the suggested sources in each category, record notes about each living thing's wing design, flight patterns, and/or how they fly. Then consider what information might be helpful as you begin to design new drone wings, and record this in the third column.

Insect / Animal	Key facts about their wing design, flight pattern, and/or *how* their bodies have adapted to successfully fly	How may this help us as we design new drone wings?
Butterflies	Research: • youtu.be/zfpXW3xJXmI • sciencefocus.com/nature/why-dont-butterflies-fly-in-straight-lines	
Bats	Research: • youtu.be/tYzOwACodwY • livescience.com/1245-bats-efficient-flyers-birds.html	
Bees	Research: • askabiologist.asu.edu/how-do-bees-fly • youtu.be/yRE2rMIXvyU	

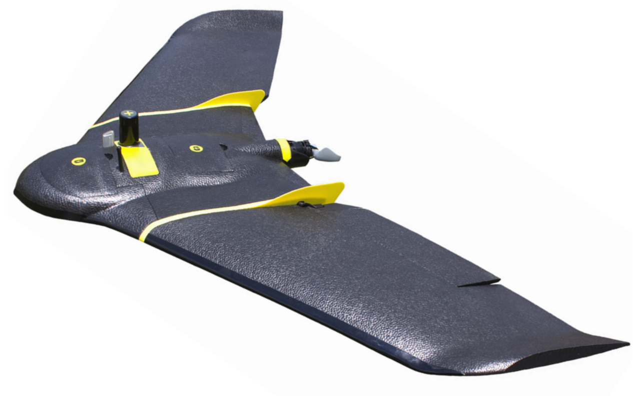
Wing Research

Insect / Animal	Key facts about their wing design, flight pattern, and/or *how* their bodies have adapted to successfully fly	How may this help us as we design new drone wings?
Flying Snakes	Research: • popularmechanics.com/science/animals/a33289391/flying-snake-physics/ *Tip:* Undulate means to move smoothly up and down	
Flies	Research: • wired.com/2015/01/flies-fly/	
Additional Flying Insect / Animal of your choice	Sources used:	

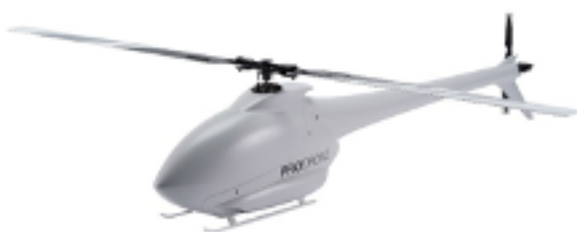
Primary Drone Designs

Multi-Rotor Drone

Fixed Wing Drone



Single Rotor Drone



Hybrid Drone

Biomimicry Redesign

Directions: Apply what you have learned to create an innovative drone wing design that is strong, lightweight, and flexible. You must:

- Decide whether you will optimize an existing drone wing design *or* begin a completely new design.
- Incorporate wing characteristics from at least **two** different living things.
- Draw a 2D sketch of your design in the box below. Your sketch must include labels that describe your key design decisions, including *why* you made each decision and the animal/insect it is mimicking.
- Create a 3D prototype of your 2D sketch using modeling clay.

#_____

Biomimicry Redesign

DESIGN ASSESSMENT AND RECOMMENDATION:
If Boeing were to select one wing design for their newest drone, which one (other than your own) would you recommend?

Be sure to consider how well it incorporates biomimicry in order to be strong, lightweight, and flexible.

Once you have made your selection, record the design number here _______ and then explain your recommendation below:

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