FUTURE U.

Sustainable Flight Solutions

Objectives

Students will:

- **Compare** and **contrast** bird and airplane flight.
- **Consider** the advantages of birds' flight adaptations.
- **Investigate** how memory metals could lead to reduced carbon emissions.
- **Create** an airplane wing designed to make flights more sustainable.

Overview

In this lesson, students will be welcomed to a special Boeing task force focused on making flights more sustainable. After learning that the task force's primary goal is to help airplanes fly more efficiently, students will investigate how to help airplanes consume less fuel and emit less carbon dioxide. Students will begin their sustainable flight exploration by comparing and contrasting airplanes with birds through the use of videos, diagrams, and short readings. After developing an understanding of birds' flight adaptations, students will consider how airplanes could be modified in order to fly more similarly to birds. Next, students will be introduced to the concept of memory metals. Through a group jigsaw reading, they will learn about the chemistry behind memory metals and how Boeing is currently exploring their potential. Students will then apply what they have learned as they use modeling clay to create an "ideal" airplane wing, complete with an explanation of how such a wing could help make flights more sustainable.

This lesson focuses on

Engineering Design Process

- Defining the Problem
- Designing Solutions
- Creating or Prototyping
- Refine or Improve

21st Century Skills

- Communication
- Collaboration
- Critical thinking
- Creativity

Timing

Three 50- to 60-minute class periods

Materials

DAY 1

- Devices with Internet access, at least enough for half the class
- Elements of Flight handout, one per student
- Flight Analysis handout, one per student

DAY 2

- Devices with Internet access, at least enough for half the class
- Student work from Day 1
- Highlighters (at least two different colors), two colors per student
- Shape Memory Metals Jigsaw handout, one per student

DAY 3

- Student work from Days 1 and 2
- Modeling clay (roughly a palm-sized ball), for half the class
- Sustainable Flight Solutions handout, for half the class
- Wing Labels, one table for half the class
- Scissors, enough for half the class
- Tape, enough for half the class
- Toothpicks, about 300

Have you ever wondered

What is biomimicry?

According to the Smithsonian Science Education Center, biomimicry is "the imitation of designs and processes found in nature. It asks how humans can benefit from mimicking the intricate and graceful systems displayed by life forms all over the world." Biomimicry 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. Therefore, it 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 we create better and more sustainable systems and designs.[1]

What are memory metals?

Memory metals—also called shape memory alloys—are mixtures of two or more metals that are able to shift form and then return to their original shape. Shape memory alloys have two different states: austenite and martensite. When shape memory alloys are in lower temperatures, they take the form of martensite, which means the metal becomes softer, easier to shape, and more like plastic. When its temperature increases, the metal changes into austenite—or a harder material that is difficult to mold or deform. These alloys are called memory metals because they remember their original form and return to this form when temperatures raise.[2]

Make Connections

How does this connect to students?

Students will be entering college and the work force at a critical moment. Today, greenhouse gas emissions are at their highest level on record, and human systems must be transformed to ensure that the Earth's temperature doesn't rise past an additional 2°C. To limit global warming to 1.5°C, the United Nations warns that global carbon emissions need to fall by 45 percent by 2030 from 2010 levels.[3] In order to achieve this, the world's transportation, energy, food, agriculture, forestry, and industry systems must all do everything they can to lower their emissions.

By helping students become aware of the impact of our current systems, we can guide them in understanding the importance of learning from nature. This will not only help students begin to protect the environment in small ways today but will help them approach their future field with an understanding of the importance of controlling our carbon footprint and living sustainably.

How does this connect to careers?

Aerospace engineer: Aerospace engineers design aircraft, spacecraft, and satellites. These engineers have many standards and goals that their designs must meet, and sustainability is one of them.

Environmental, health, and safety engineer: These engineers monitor the impact that humans have on the environment and protect the health and safety of humans. To do this, they evaluate exisiting systems and develop new processes to ensure that the environment and humans coexist as optimally as possible.

Environmental scientist: Environmental scientists study natural science, including the effects of human activity on ecosystems. They can advise companies, industries, and policy makers in making informed environmental decisions.

How does this connect to our world?

Climate change is affecting every country and every continent. As the United Nations states, "It is disrupting national economies and affecting lives, costing people, communities and countries dearly today and even more tomorrow."[3]

In 2015, countries around the world collaborated to develop the UN's 17 Sustainable Development Goals (SDGs) that aim to reduce extreme poverty, reduce resource inequalities, and combat the threat of climate change by 2030.

While many of the goals relate to climate change, SDG 13 combats it directly. Its overarching goal is to: "Take urgent action to combat climate change and its impacts."

If governments and individuals around the world don't collaborate to take action and our Earth's temperature increase is beyond 2°C, every ecosystem will be affected. Citizens around the world therefore need to unite in making changes—both big and small—to reduce consumption, increase our energy efficiency, and swap our fossil fuel use with cleaner energy alternatives.

Sources

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

[2] "Shape Memory Metals. Explain that Stuff!" explainthatstuff.com/how-shape-memory-works.html.

[3] "Climate Action: Why it Matters." United Nations Sustainable Development Goals. un.org/sustainabledevelopment/wp-content/uploads/2017/07/13.pdf.

Blueprint for Discovery

Instructor Prep: If needed, you may use this resource to further familiarize yourself with the forces of flight before beginning this lesson. It may also be helpful to have a digital or paper copy available during the sessions to help with student questions as they arise.

DAY 1

1. Begin by challenging students to see what they know about carbon emissions and climate change.
    - First ask: What are carbon emissions?
        - After calling on several students to answer, be sure the class understands that the process of using fossil fuels such as oil, natural gas, and coal, releases carbon dioxide into the atmosphere. Carbon dioxide is a greenhouse gas that traps heat around the Earth and contributes to global warming.
    - Then ask students: What activities and industries contribute to carbon emissions?
        - Accept answers such as electricity, heating, manufacturing industries, transportation, etc.
    - Finally, encourage all students to hold up fingers or hands to guess: If you think about all of the carbon emissions produced around the world, what percentage would you guess is created by the aviation industry?
        - Wrap up by explaining that the aviation industry contributes to about 2 percent of carbon dioxide emissions. Explain that the majority of these emissions come from flights that are over 900 miles in length—so there often aren't other practical modes of transportation!
2. Tell the class that, to combat this percentage, Boeing is starting a special task force focused on making flights more sustainable. Today, each student will join this group. Explain that this task force's primary focus will be to investigate how to help airplanes fly more easily. When planes fly more easily, they consume less fuel, which in turn emits less carbon dioxide. To kick off this investigation, the task force will first study something that has already been flying sustainably for millions of years: birds!
3. Pass out one Elements of Flight handout and one Flight Analysis handout to each student. Bring students' attention to the Elements of Flight handout first. Explain that students are about to explore how birds and airplanes are able to fly. Read through the flight element categories and ensure students understand the information they will be looking for.
4. Then bring students' attention to the Flight Analysis handout and explain that this page outlines the sources students will use to complete their research. Explain that students do not have to access the articles, videos, and diagrams in the order they appear on the sheet. While students *must* view all sources, they may find it helpful to jump between them. For instance, it could be helpful to have the airplane diagram open in one tab while they read about how airplanes work in another tab, so they can toggle back and forth.

5. Finally, instruct students to find a partner and grab a device. They should then spend the rest of the class session completing their research!
6. Rotate around the classroom as students work, and answer questions as needed. As the class period winds down, give a 10-minute and a 5-minute warning. At the end of the session, either collect the students' handouts or instruct them to store their work in a safe place until the following class session.

DAY 2

1. Begin by welcoming students to the second day of the sustainable flight task force. Then either pass back the students' Flight Analysis handouts or instruct the class to take them out from safekeeping. Distribute two different color highlighters to each student.
2. Instruct students to find their taskforce partner from the previous session, review their Flight Analysis handout notes, and compare and contrast how birds and airplanes fly. Students should highlight key differences in one color and similarities in another color. Allow pairs about five minutes to review and highlight their flight analysis notes.
3. Then bring the class back together and recap with the following questions:
    - What key elements help an airplane fly?
    - What adaptations do birds have that enable them to fly?
    - Explain: Biomimicry is when humans learn from (or mimic) nature in order to solve design problems. Then ask: How could airplanes be changed so they fly more similarly to birds?
    - Could these changes help flights use less fuel and emit less carbon dioxide? Why or why not?
4. Explain that students are going to explore one possible way to help airplanes fly more like birds: memory metals. Distribute one Memory Metals Jigsaw handout to each student.
5. Explain that student pairs will be assigned one of the three articles included on the handout, and they will read the article together to answer the handout's question. Assign one-third of the pairs Reading #1, one-third of the pairs Reading #2, and one-third of the pairs Reading #3. Explain that pairs will have about 15 minutes to access the article using their device and answer the question provided. Be sure students understand that both partners must record notes on their own handouts.
6. Once the reading is complete, reassemble the class and form new groups of three or four students. Be sure that each group has at least one person who read each article. Then bring students' attention to Box #4. Read the directions aloud, and encourage the new groups to share what they have learned from their articles with each other and then discuss the final question.
7. When about 10 minutes have passed or the discussions are complete, encourage groups to share their answer to: How could memory metals help airplanes fly more easily?
8. Explain that during the next class session students will be applying what they have learned as they provide a recommendation for a new airplane wing! Then, either collect the students' work or instruct them to store it in a safe place until the following session.

DAY 3

1. Begin class by instructing students to find their task force partner, and either pass back the students' work or ask them to take it out from safekeeping.
2. Then explain that each pair will now apply what they have learned over the last two sessions to

develop a recommendation on how Boeing could design their airplane wings in order to help it fly more efficiently and reduce carbon emissions.

3. Distribute one Sustainable Flight Solutions handout, one piece of modeling clay, and one Wing Label table to each pair. Read through the handout's instructions together, and show students where they can find the toothpicks, scissors, and tape. Once you answer any questions, deduct about 10 minutes from the end of the class session and tell students that they will have this amount of time to complete each step on this handout.
4. Provide students with timing alerts throughout the session. When there are 15 minutes left in class, ask students to begin cleaning up and prepare to put their airplane wing on display.
5. When there are 10 minutes left in the class session, instruct the pairs to display their wings and explanations on desks around the classroom.
6. Ask students to quietly walk around the room and observe the wing designs that their peers created. As they do, encourage them to look for similarities and differences across the designs.
7. Then bring the class back together as you wrap up the session. Encourage them to think about the varied wing designs that they just viewed, and conclude with a final discussion question: How could incorporating biomimicry and memory metals into aviation wing design help us make airplane flights more environmentally-friendly?
8. Finally, thank students for their research, analysis, and innovation. Remind students of the importance of collaborating to build a sustainable future, and explain that many kinds of engineers, technicians, scientists, and technologists work together at Boeing to find innovative solutions around the world that improve environmental performance. Encourage students to explore careers in sustainability and the environment as they begin to consider their own futures and the future of our planet.

Extend

Students can continue exploring biomimicry through the lens of other modes of transportation. As they investigate the design of boats, trains, cars, etc., they can consider what they can learn from nature and then redesign these modes of transportation to be more sustainable.

National Standards

Next Generation Science Standards

Earth and Human Activity:

- MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

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.

Common Core English Language Arts Standards

Reading:

- CCRA.R.1: Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

Writing:

- CCRA.W.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Speaking and Listening:

- CCRA.SL.1: Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.
- CCRA.SL.2: Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

Elements of Flight handout

Elements of Flight	Birds	Airplanes
Lift: the force that causes a flying object to rise into the air and stay there. The lift must overcome the weight of the flying object and the downward force of gravity!	How do birds get the lift needed to fly?	How do planes get the lift needed to fly?
Thrust: the force that moves a flying object through the air. Thrust must overcome drag (air resistance) in order for the object to fly.	How do birds create thrust?	How do planes create thrust?
Glide: A flying object can glide when its wings push air downwards—without flapping them or having **thrust** from another source. While **lift** can help hold the flying object in the air as it glides for a period of time, drag and gravity will eventually pull it down.	Can birds glide?	Can airplanes glide?
What else helps birds and/or airplanes fly?		

Flight Analysis

Directions: Fill in your Elements of Flight handout as you explore the websites below.

Read

Read through the following website sections and learn more about how planes and birds fly.

- Airplanes: tinyurl.com/y9tdgd8b
    - Focus on the following sections:
        - How Wings Lift the Plane
        - Forces of Flight
        - Controlling the Flight of a Plane
        - How does a Pilot Control the Plane?
- Birds: tinyurl.com/s8ztu49
    - Focus on the first Q & A

Observe

Watch the following videos as you look closely at how birds and airplanes fly.

- Airplanes: tinyurl.com/j6x9t3h
- Birds: tinyurl.com/v32wa3d

View

Study the airplane diagram and the bird skeleton as you consider how each one's structure may help them fly.

- Airplane Diagram: tinyurl.com/rltbtkl
- Bird Skeleton: tinyurl.com/sk223y6

Memory Metals Jigsaw

Reading #1: Shape Memory Materials

Website: tinyurl.com/uazomjr

Read the following sections:

- Intro paragraph
- What is Shape Memory?

Jot notes to answer: What is a shape memory alloy (otherwise called a memory metal)?

Reading #3: Memory Metals are Shaping the Evolution of Aviation

Website: tinyurl.com/uv5h4hm

Read: Entire article

Jot notes to answer: Why is Boeing investigating memory metals?

Reading #2: Shape Memory Materials

Website: tinyurl.com/uazomjr

Read the following sections:

- First paragraph
- How does shape memory work?

Jot notes to answer: How do shape memory metals work?

Part 2: Discuss

1. Share what you learned from your article, and jot notes as you listen to your peers.
2. Then discuss: How could memory metals help airplanes fly more efficiently?

Sustainable Flight Solutions

Step 1: Review what you have learned about birds and memory metals. Then discuss with your partner: If you were to create an ideal airplane wing that helps make flights more sustainable, what would it look like?

Step 2: Create a model of this wing with your modeling clay.

Step 3: Use the wing labels to write the name or a brief description of your wing's most important parts. Then cut out these labels, tape each one to a toothpick, and stick them into the clay to label your wing.

Step 4: Describe your design decisions in the space below. Be sure to include:

- The labeled parts of your wing and why you designed each part this way
- Which parts of your wing will use shape memory metal and why
- How your wing design will help make flights more sustainable

Wing Labels

Instructor directions: Cut out each table in advance, so you are ready to distribute one to each pair.

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