Da Vinci and His Flying Machines

Session Time: Session Time: Two, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

Appreciate the rich, global history of aviation/aerospace and the historical factors that necessitated rapid industry development and expansion. (EU1)

Understand the importance of professionalism, ethics, and dedication as they relate to all aviation/aerospace operations. (EU4)

Appreciate the global nature of the modern aviation/aerospace industry and embrace the discovery and inclusion of cultures outside the learner's typical experience. (EU7)

ESSENTIAL QUESTIONS

1. How does human flight compare with a bird's flight?
2. Who is Leonardo da Vinci and why is he still relevant to aviation?
3. How has da Vinci's work impacted the development of modern aviation?

LEARNING GOALS

Students Will Know

- Leonardo da Vinci's contributions to aviation, even though he never built and tested any of his designs

Students Will Be Able To

- *Describe* and *summarize* the earliest images of human flight based on the observations of animals in flight (DOK- L2)
- *Explain* how engineering practices can be applied to da Vinci's earliest flying inventions to develop new aircraft models. (DOK-L2)

ASSESSMENT EVIDENCE

Warm-up

Students write responses to two questions about da Vinci's inspiration for his designs and why one, in particular, never flew.

Formative Assessment
In teams, students will formulate and share their findings for a design challenge.

Summative Assessment

Write a summary on da Vinci's *Codex on the Flight of Birds* and take a stance on whether this may have impacted the development of modern aviation.

LESSON PREPARATION

MATERIALS/RESOURCES

- Da Vinci and His Flying Machines Presentation
- Da Vinci and His Flying Machines Student Activity 1
- Da Vinci and His Flying Machines Student Activity 2

Create Your Own Paper Helicopter (materials per student)

- Paper
- Paper clip
- Scissors

Da Vinci's Design Dilemma (materials per team)

- Scissors
- Clear tape
- Fishing line or string
- Washers or marbles
- Template for spacecraft
- Area to drop from (or ladder)
- Plastic grocery bags
- Rulers
- Digital scale or balance
- Stopwatch/other timing device (can use app on cellphone)
- Small resealable sandwich bag
- Cardstock or old file folders for spacecraft template
- Tissue paper or plastic tablecloths

LESSON SUMMARY

Lesson One Flight in Greek Mythology
Lesson Two Da Vinci and His Flying Machines

As a warm-up, ask driving questions about da Vinci and his inspiration for human flight. Leonardo da Vinci studied the flight of birds and bats, and he designed machines in hopes they would fly. Although many of his inventions attempted to mimic the flight of birds, one device that didn't was called the "air screw," which was his attempt at an early helicopter. Students will build simple helicopters, complete modifications, and conduct performance challenges.

A class discussion will provide students with a better understanding of da Vinci's impact on flight. This will be followed by an engineering design challenge that will extend into the second session of the lesson. At the conclusion of the activity, students will share their findings with the class.

Students will learn that da Vinci recorded a number of observations and beginning concepts that would find a place in the development of successful airplanes in the early twentieth century. As a summative assessment, students will write a summary about da Vinci's *Codex on the Flight of Birds* and how it may have impacted development of modern aviation.

BACKGROUND

During the 16th century, Leonardo da Vinci was more than a gifted painter. His notebooks, including writings and drawings, provided evidence of his curiosity and brilliant mind. Among many of his interests, flight particularly intrigued him. His work included more than 35,000 words and 500 sketches portraying things that fly and the nature of aerodynamics. Many of da Vinci's aeronautical designs were ornithopters, machines with flapping wings to generate thrust and lift. These designs were based on his study of how birds fly. In his notebooks, he shared his observations about bird flight and the relationship between a curved wing and lift. In fact, da Vinci discovered that the motion of birds flapping their wings actually generates the thrust needed to propel the bird forward to generate lift. This was the beginning of the study of aerodynamics.

Da Vinci was the first true systems engineer, documenting his findings and observations. This would later lead to the design and manufacturing of flight vehicles. He also was believed to be the first true aeronautical engineer, who understood how the forces of flight such as lift, drag, thrust, and weight act on a body in flight. Having documented the relationship between lift and drag and how surface area affects the total lift and drag generated, da Vinci receives credit for the first understandings of this essential concept.

MISCONCEPTIONS

Because the ornithopter is considered a "famous invention," students may think it actually flew, but it never got off the ground.

LEARNING PLAN

ENGAGE

Teacher Material: Da Vinci and His Flying Machines Presentation

Slides 1-3: Introduce the topic and learning objectives for this lesson.

Slide 4: Conduct the **Warm-Up.** Display questions about the inspiration for one of da Vinci's early designs and why if never flew. Working individually, have students write down their answers and then share them with the class. Allow no more than five minutes for students to complete their answers before collecting them for grading. [DOK 4; connect; synthesize]

Warm-Up

Using slide four, should students a photo of one of da Vinci's early flying machines and ask students to predict where he received the inspiration for the design. Also ask students why they think this design was unsuccessful. Students should write their answers individually and then share them with the class as time allows.

Questions

Where do you think da Vinci received the inspiration for this design?

He studied the anatomies of certain wild creatures, especially birds and bats. He also tinkered around with mechanisms like gears and pulleys that he incorporated into some flying machine designs that were way ahead of his time.

Why was this particular effort unsuccessful?

Building wings is very complicated. The wings were too heavy for flight and couldn't create enough lift to hold the weight of a human.

Slide 5: Introduce students to some unfamiliar terms and concepts. Point out to students that da Vinci's ornithopter was supposed to fly with flapping wings. This will set the context for the humorous video that follows in the next slide.

Slide 6: Have students watch a video that airline Virgin Atlantic released as an April Fool's Day joke. Then moderate a discussion with students about how "flapenergy" is a creative (and funny) example of nature influencing design. Take special note that the airplane is not real. The video was created by Virgin Airlines as an April Fool's joke and published on its various social media sites.

- "Is it a bird, is it a plane?"(Length 1:35)

  http://video.link/w/wkVd

Slide 7: Da Vinci's ornithopter seems to show a resemblance to bat wings. The ornithopter never flew because a person could not generate enough energy to cause it to lift off the ground.

EXPLORE

Teacher Material: Da Vinci and His Flying Machines Presentation
Student Material: Da Vinci and His Flying Machines Student Activity 1

Slide 8: For a long time, innovators attempted to fly like birds. Leonardo da Vinci studied the flight of birds and bats, and he designed machines in hopes that they would fly. Although many of his inventions attempted to mimic the flight of birds, one device that didn't was called the "air screw." It looked somewhat like a helicopter and was designed to be powered by several men.

The image that resembles a helicopter was found in da Vinci's notebook. This is only one of many aeronautical designs that da Vinci drew. The contraption was designed to be powered by four men running around in the center holding a shaft causing rotation. The machine rotated opposite of the rotor and never worked.

Slide 9: Students will cut out and fold a simple version of a helicopter using **Da Vinci and His Flying Machines Student Activity 1.** Directions for the task and challenges are reproduced below.

Directions for Students

1. Cut only along the solid lines of the template.
2. Fold along the dotted lines. Fold the propeller blades in opposite directions.

3. Attach a small paper clip to the bottom of the paper helicopter so it will keep its form while falling to the ground.

4. Drop it from above your head or while standing on a chair or ladder (carefully), and it should spiral to the ground.

5. Challenge yourself by making slight variations to see how they affect the helicopter's flight.

Slide 10: Once students have built and tested the basic paper helicopters, ask them to answer the following questions about ways to modify the design in order to optimize flight.

1. How could each paper helicopter be optimized to stay aloft for a longer period of time?

2. What needs to be physically done to the paper helicopter in order for it to stay in the air longer?

3. What are some of the design constraints which are encountered in this design change?

4. Write a brief engineering proposal on how you will change the design. Provide proof of how this will be an improvement of the standard paper helicopter below. Sketch what the new design will look like, how you will collect and analyze the data, and the reasoning behind the new design.

EXPLAIN

Teacher Material: Da Vinci and His Flying Machines Presentation

Slide 11: Provide students a better understanding of da Vinci's interest in STEM beyond his exceptional artistic ability. Students should realize that although da Vinci was best known as an artist, his thinking was advanced far beyond his time in science and engineering. He excelled in both the arts and sciences. He was very precise in his notetaking and used sketches and descriptions to draw conclusions.

Slides 12-13: Leonardo spent a good deal of time thinking about how people could get around faster—on the earth, in the water, and even in the air. Da Vinci produced countless sketches of bats, birds, and machines and technology used in the military, but it is not known if they were ever built. His work led to the idea of aerial reconnaissance.

EXTEND

Teacher Material: Da Vinci and His Flying Machines Presentation
Student Material: Da Vinci and His Flying Machines Student Activity 2

Slide 14: Use **Da Vinci and His Flying Machines Student Activity 2** to help students understand da Vinci's problem-solving process. Begin by reading through the dilemma with students and then show the NASA video.

- "Parachuting onto Mars: NASA STEM Challenge" (Length: 1:54) http://video.link/w/ZIJd

Split your class into small groups and ask how they might slow or decelerate the spacecraft. Possible answers could include parachutes, or other drag devices.

Teaching Tips

Teachers may need to provide more information to calculate the surface area of an object (sum of the areas of its faces), especially if it is an irregular shape. If the student's drag devices are irregularly shaped, students may need to use area formulas for shapes they know.

NASA is actually conducting research and development on this topic in its Low Density Supersonic Decelerator Program. If time allows, share more information about this project with students using the website https://www.nasa.gov/mission_pages/tdm/ldsd/index.html

Slide 15: Conduct the **Formative Assessment.**

At the conclusion of the activity, ask students to share their findings with the class about what designs worked well and how they modified their designs for improvement. (DOK 2; make observations, explain)

Formative Assessment

Each team will communicate the results of their design activity using the questions below. Have them write responses to these questions and also present their findings to the class.

1. What did you observe in your tests about the relationship between surface area and how long it took to hit the ground?
2. How did your parachute perform and what did you do to try to slow it down more?
3. What engineering practices did you use in this activity and how did you use them?

Slides 16-17: Da Vinci wrote many codices, notebooks filled with drawings and observations of his ideas, but this one was totally focused on flight during the years 1505-1506.

In 1994, Bill Gates bought da Vinci's *Codex Leicester.* At an auction, he paid $30.8 million for it, making it the most expensive book ever sold. It is 72 pages long.

Have students watch this video about da Vinci's *Codex on the Flight of Birds.*

- "Codex on the Flight of Birds" (Length 2:11)

  http://video.link/w/NkVd

Slide 18: In the *Codex*, da Vinci recorded a number of observations and beginning concepts that would find a place in the development of successful airplanes in the early twentieth century. He discussed crucial aerodynamic concepts, including the relationship between the center of gravity and the center of lifting pressure on a bird's wing. He even foreshadowed the modern concept of a stall. He demonstrated a basic understanding of lift on a wing and the concept of air as a fluid.

EVALUATE

[Teacher Material: Da Vinci and His Flying Machines Presentation]

Slide 19: Conduct the **Summative Assessment.**

Students will write a summary on da Vinci's *Codex on the Flight of Birds* and take a stance on whether it may have impacted the development of modern aviation. [DOK 2; infer, interpret]

Summative Assessment Scoring Rubric

Follows assignment instructions
Writing shows evidence of one or more of the following:

- An understanding of da Vinci's *Codex on the Flight of Birds*
- Ability to make inferences about *Codex on the Flight of Birds* and its impact on modern aviation

Writing shows an understanding of the concepts covered in the lesson.
Writing shows in-depth thinking including analysis or synthesis of lesson objectives.

Points	Performance Levels
9-10	Consistently demonstrates criteria
7-8	Usually demonstrates criteria
5-6	Sometimes demonstrates criteria
0-4	Rarely to never demonstrates criteria

Summative Assessment

Ten minutes before the end of class, have students write a one to two paragraph summary on da Vinci's *Codex on the Flight of Birds* and how it may have impacted the development of modern aviation.

GOING FURTHER

Show the students examples of maple seed "helicopters" or similar seeds, and discuss how plants spread their seeds by wind using their own kind of rotary blades.

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-dimensional Learning

- **HS-ETS1-1** - Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
    - Science and Engineering Practices
        - Asking Questions and Defining Problems

        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.A: Defining and Delimiting Engineering Problems
    - Crosscutting Concepts
        - Systems and System Models
        - Influence of Science, Engineering, and Technology on Society and the Natural World
- **HS-ETS1-2** - Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
    - Science and Engineering Practices
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.C: Optimizing the Design Solution
    - Crosscutting Concepts
        - none
- **HS-ETS1-3** - Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
    - Science and Engineering Practices
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.B: Developing Possible Solutions
    - Crosscutting Concepts
        - Influence of Science, Engineering, and Technology on Society and the Natural World

COMMON CORE STATE STANDARDS

- **RST.9-10.1** - Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
- **RST.9-10.2** - Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
- **RST.9-10.4** - Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- **RST.9-10.5** - Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
- **RST.9-10.7** - Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- **RST.9-10.8** - Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

- **WHST.9-10.1** - Write arguments focused on discipline-specific content.
- **WHST.9-10.2** - Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
- **WHST.9-10.4** - Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- **WHST.9-10.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.
- **WHST.9-10.7** - Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- **WHST.9-10.8** - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
- **WHST.9-10.9** - Draw evidence from informational texts to support analysis, reflection, and research.

REFERENCES

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