Aircraft Structural Materials

Session Time: Two, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

The intended purpose and use of an aircraft drives aircraft design considerations and construction techniques, materials, and components. (EU1)

Innovations in aviation are driven by the desire to make aircraft safer, more capable, and more efficient. (EU3)

A deep understanding of how an aircraft operates enables a pilot to fly the aircraft to its maximum capabilities in both normal and abnormal situations. (EU5)

ESSENTIAL QUESTIONS

1. What are the best aircraft made of?
2.

Which aircraft construction material is superior over all others?

LEARNING GOALS

Students Will Know

- Types of materials used in the construction of historic and modern aircraft
- Strengths and weaknesses of various material types

Students Will Be Able To

- *Identify* the types of materials that have been used in aircraft construction. (DOK-1)
- *Formulate* an aircraft design based on the strengths and weaknesses of various material types. (DOK-3)

ASSESSMENT EVIDENCE

Warm-up
Students are asked to list materials that have been used in the construction of aircraft throughout history. They will discuss if any one of these materials is superior for all applications and to justify their response.

Formative Assessment
Students complete a SWOT analysis of fabric, metal, and composite construction materials for aircraft.

Summative Assessment
Students present designs for an aircraft for their personal use with details about the materials selected for the design, justification of those selections, and the implications for use of those materials.

LESSON PREPARATION

MATERIALS/RESOURCES

- Aircraft Structural Materials Presentation
- Aircraft Structural Materials Student Activity 1
- Aircraft Structural Materials Student Activity 2
- Aircraft Structural Materials Teaching Notes

Build-A-Plane Activity

- Rolled paper or poster board
- Markers

LESSON SUMMARY

Lesson 1: Aircraft Structural Materials

Lesson 2: Aircraft Safety Features

Lesson 3: Unmanned Aircraft Materials

The first session of this lesson begins with students being asked to create a list of all of the materials that have been used to construct aircraft throughout history. They are then asked to discuss with a partner whether any one of these materials is superior to all the others. They will also be asked to justify their responses. Once this is completed, students will receive a brief historical account of the materials that have been used in the construction of aircraft. Reflect on knowledge gained from historical applications of aircraft as discussed in the ninth grade curriculum.

Students will then engage in a SWOT activity in which they complete research to determine the advantages and disadvantages of various materials that have been used in the construction of aircraft.

During the second session of the lesson, students will work in groups to design an aircraft for their personal use. As part of this activity, they will identify the materials they would need to construct the aircraft and why they chose those materials. They will also consider relevant implications of their design (e.g. cost, safety, complexity, capacity, speed, etc.). At the end of the second session, each group will present a very brief overview of their design and decision making processes.

BACKGROUND

This lesson focuses on the structural materials used in building aircraft. From the Montgolfier's balloon to the Wright Flyer, wood and fabric formed the backbone of aircraft development through the years leading up to World War II, when metal construction began to takeover. Composite construction first debuted in the 1950s, but its popularity in aircraft construction is really a product of the 1980s. Despite the availability of the technology, composites did not become common in general aviation until companies like Diamond Aircraft and Cirrus Aircraft began producing all-composite general aviation aircraft. Commercial airlines use composite structures now due to weight savings and strength increases.

Students will consider strengths and weaknesses in various structural materials while also learning about the internal structure of the aircraft and how the structural covering of the aircraft is supported by its internal form. Safety implications will be addressed in the next lesson, but these issues can certainly be introduced here. An excellent resource for teachers who may be less familiar with some of the concepts covered in this lesson can be found in the *Pilot's Handbook of Aeronautical Knowledge* which is published by the FAA.

Fabric construction (in conjunction with wood for structural support)

- Cheaper and easier to produce and maintain

- Lighter overall aircraft weight
- Relatively fragile and unable to sustain fast speeds

Wood construction (in conjunction with fabric for skin covering)

- Widely available and relatively inexpensive
- Lightweight, but extremely perishable

Metal construction

- Easy to shape, construct, and repair
- Stronger than fabric
- Heavier than fabric but also enables faster speeds

Composite construction (students may not recall this technique this early in the lesson)

- Easiest to form into high efficiency (aerodynamic) shapes
- Lightweight nature of fabric but even stronger than metal

MISCONCEPTIONS

Students may think that aircraft constructed of fabric are a thing of the past, but fabric-covered aircraft are still in production today.

Students may assume that composites are a superior material from which to construct aircraft due to their weight and strength; however, composite aircraft are more difficult and more expensive to maintain. Just because a technology is new does not mean that it is always the best option. Students should be encouraged to think "big picture" in aviation. It is usually a bad practice to overly focus on any one specific factor. Aircraft materials is a good application of this lesson.

DIFFERENTIATION

To support student motivation in the **EVALUATE** section of the lesson plan, allow students the option to create a poster instead of giving an oral presentation of their aircraft designs.

If students struggle with how to conduct a SWOT analysis, an alternative might be to do a SWOT analysis with a more familiar concept, such as trying out for the basketball team.

LEARNING PLAN

ENGAGE

Teacher Material: Aircraft Structural Materials Presentation

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

Slide 4: Conduct the **Warm-Up.**

Warm-Up

Ask students to create a list of all the materials they can think of that have been used in the construction of aircraft throughout history. Then, they will engage in a discussion with a partner in which they consider the following questions. Review some sample answers with the entire class.

- Is any one of these materials superior for all applications?
- Why or why not?

Possible Responses:

Aircraft have been built of many different materials. The most recent aircraft are built of composites, such as fiberglass and carbon fiber, which allow smooth surfaces and complex curves. Modern airliners, such as the Boeing 787 are built of carbon fiber strings which are woven in place. Before composites, most aircraft were made of aluminum alloys, which are strong and light. Other materials which have been used include cloth, wood, paper, rubber, plastic, titanium and even steel.

Regarding the superiority of one material over another, if all aircraft had the same role and purpose, one material might be sufficient. No one material is superior in all applications. Aircraft designers select the lightest material strong enough for the job. Airplanes that fly fast or carry heavy loads require stronger materials that would be too heavy or hard to work with in small aircraft. In order to enable multiple aircraft uses, like fast speed, large carry weights, etc., multiple construction styles were and still are necessary.

Teaching Tips

Given the misconceptions listed in the **MISCONCEPTIONS** section of the lesson plan, expect students to indicate that composite materials are superior to all others, and use this opportunity to point out some of the potential drawbacks of such materials as a primer to the SWOT activity they will complete in the **EXPLAIN** section of the lesson.

EXPLORE

Teacher Material: Aircraft Structural Materials Presentation

Student Material: Aircraft Structural Materials Student Activity 1

Slide 5: Show students photos of the Wright flyer made of spruce wood, a French World War I fighter airplane made of wood, steel, and aluminum, and the Boeing 787 made entirely of composite materials.

Slide 6: Show students a video that describes how Cirrus Aircraft are produced in Duluth, MN. Ask students the following questions. Stop the video at the appointed times to allow the students to answer the questions as a class. If time is short, the video can be stopped after 7 minutes. Provide students with copies of **Aircraft Structural Materials Student Activity 1** so they can anticipate the questions that will be asked.

- "How Cirrus Builds Airplanes" (Length: 13:36)

  http://video.link/w/zhPd

Questions

What makes aircraft more difficult to build than cars? (0:42 sec)

They are built in small numbers and require a lot more work by hand.

Why is the factory so focused on efficiency? (2-4 min)

Being efficient means building airplanes in less time for less money, allowing the company to charge their customer less and also make more money for themselves.

Why do they reorganize their factory? (4 min)

For flow and efficiency.

What are Cirrus airplanes made of? (4-6 min)

Composites

Why use robots to build the airplanes? (7 min)

Reduce the cost of tooling and provide more flexibility.

Slides 7-11: During the next few slides, students will learn properties, advantages and disadvantages of fabric, metal and composite construction materials.

Slide 9: The fabrics used to cover airframes were of natural fibers such as cotton and linen. They were strong for their weight and readily available, but did have issues, such as flammability and a short life when exposed to the elements.

Modern fabrics used to cover gliders, home-built, and light sport aircraft today are synthetic blends such as nylon and polyester, which are much stronger and more durable.

Slide 10: Metals replaced wood and fabrics for building military and commercial aircraft between the world wars due to their greater strength and durability. Metal construction materials such as aluminum and steel offer more stability and protection from the elements. Metals used in modern aircraft construction include:

Aluminum Strong, lightweight, does not corrode easily

Steel Strong, stiff, heavy, heat-resistant. Ideal for landing gear assemblies

Titanium Strong as steel, but lighter, resistant to corrosion, costly

Slide 11: Students were introduced to composite construction in several lessons during the ninth grade curriculum. Composite construction first debuted in the 1950s, but its popularity in aircraft construction is really a product of the 1980s. Despite the availability of the technology, composites did not become common in general aviation until companies like Diamond Aircraft and Cirrus Aircraft began producing all composite general aviation aircraft. Commercial airlines use composite structures now due to weight savings and strength increases.

EXPLAIN

Teacher Materials: Aircraft Structural Materials Presentation, Aircraft Structural Materials Teacher Notes

Student Material: Aircraft Structural Materials Student Activity 2

Slide 12: Conduct the **Formative Assessment**.

Provide students with copies of **Aircraft Structural Materials Student Activity 2.**

Before assigning the formative assessment, discuss the purpose of a SWOT analysis and discuss the questions that students should ask about each material. A SWOT analysis stands for Strength, Weakness, Opportunity, and Threat. The purpose of a SWOT analysis is to provide the opportunity to develop a strategy by making sure all of the strengths, weaknesses, opportunities, and threats have been considered for a given topic.

Direct students to ask the following questions while they are conducting their SWOT analysis:

- Strengths - What does this material do well? What advantages does it have over competing materials?
- Weaknesses - What does this material lack? What disadvantages does this material have?
- Opportunities - In what situations should this material be used over others? Has there been any recent advancements in this material or in the aviation field that make this material more desirable over other materials?
- Threat - What are the competing materials? What situations might threaten the use of this material? Has there been a significant change in prices or availability of this material? Has a new material been introduced that makes this material obsolete?

See the slide for an example SWOT analysis on a paper airplane. Review with students to help model the SWOT process before they begin the student activity. If time allows, have them generate another example for each box to ensure they understand the SWOT process.

Formative Assessment

For the remainder of the first session, students will complete the SWOT analysis as described in **Aircraft Structural Materials Student Activity 2.** Encourage students to complete the assignment in small groups. They will need to conduct research in order to complete this assignment. This may be assigned as homework. Answers to the activity are provided in **Aircraft Structural Materials Teacher Notes.** [DOK-3; draw conclusions; investigate]

EXTEND

Teacher Material: Aircraft Structural Materials Presentation

Slide 14: Introduce the aircraft design activity the students will be working on during the second session of the lesson. Point out to the students that they will be making brief presentations about their designs to the rest of the class when they are finished.

Students will design an airplane for their personal use. Split the students into groups of three to five for this activity. They should consider the following as they design their airplanes.

- Number of passengers, speed and endurance
- Materials used to construct the fuselage, wings, control surfaces, and landing gear
- Produce:
    - a sketch of the aircraft
    - a list of materials used to create the parts
    - justification for the use of each material including benefits and limitations of the material
        - NOTE: If students choose to make the aircraft out of only one material, they should explain why

- a paragraph discussing the implications of the materials chosen for their design, including:
  - cost
  - ease of construction
  - performance and durability

Teaching Tips

Students could sketch their aircraft design on a regular piece of drawing paper to be submitted for grading or you might consider having them create it on poster paper to be displayed around the room. The poster would also be a better visual aid for the presentations.

Students may need access to the Internet to conduct research about existing personal aircraft in order to make their design choices.

EVALUATE

Teacher Material: Aircraft Structural Materials Presentation

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

Summative Assessment

After the students have created their designs, they will give a brief 2- to 3-minute presentation of their designs and discuss each of the activity requirements. This activity is worth 10 points and can be graded with the 10 point rubric that follows. [DOK 3; cite evidence; develop a logical argument].

Summative Assessment Scoring Rubric

Follows assignment instructions

Answers show evidence of one or more of the following:

- Justification of materials chosen or not chosen
- Potential limitations of materials

Answers show an in-depth understanding of the concepts covered in the lesson

Presentation is clear and well organized

Presenters provide appropriate answers to questions that are posed to them

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

GOING FURTHER

If time permits, allow students to explore the advanced materials that will be used on the spaceships of tomorrow. https://www.nasa.gov/vision/space/gettingtospace/16sep_rightstuff.html

Show a brief video describing the evolution of the materials used in the construction of the airplane fuselage from wood to composites. This should serve as an excellent point to discuss how similar changes occurred in the materials used in the construction of other airplane components.

- "Aircraft Construction" (Length: 2:58)

  https://www.youtube.com/watch?v=aYB2h_tUfYM

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-dimensional Learning

- **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
    - Asking Questions and Defining Problems
  - Disciplinary Core Ideas
    - ETS1.A: Defining and Delimiting Engineering Problems
    - ETS1.B: Developing Possible Solutions
  - 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
    - Asking Questions and Defining Problems
  - Disciplinary Core Ideas
    - ETS1.A: Defining and Delimiting Engineering Problems
    - ETS1.B: Developing Possible Solutions
  - Crosscutting Concepts
    - None

COMMON CORE STATE STANDARDS

- **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** - Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.
- **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.9-10.8** - 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

https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/pilot_handbook.pdf
http://cubcrafters.com/carboncub/ss