TOOLKIT FOR INFORMAL EDUCATORS

Sample Education Materials

Table of Contents

2 **Table of Contents**

3 **60 Second Science Activity for Museum Docents**

3 Forces of Flight: Propeller & Parachute Toys (1 minute)

4 **Cart Activity for Museum Docents**

4 Materials Science: Build an Airplane (5-10 minutes)

6 **Demonstration Activity for Museum Docents**

6 One-Breath Bernoulli Bag (5 minutes)

8 **Workshop #1 for Museum Educators**

8 Carbon Fiber: A New Kind of Weave (90 minutes)

9 Activity #1: Everyday Composites (15 minutes)

10 Activity #2: Textile Tests (10 minutes)

10 Activity #3: Make & Take—Lap Loom (20 minutes)

11 Activity #4: Composite Factory (20 minutes)

11 Activity #5: Composite Testing Laboratory (25 minutes)

13 **Workshop #2 for Museum Educators**

13 Lighting Design Studio (45 minutes)

13 Activity #1: Color Psychology (10 minutes)

14 Activity #2: Cabin Design Challenge (20 minutes)

15 Activity #3: Color Lab (10 minutes)

60 SECOND SCIENCE ACTIVITY FOR MUSEUM DOCENTS

Forces of Flight: Propeller & Parachute Toys

(1 minute)

Four forces are required for flight: gravity, lift, drag, and thrust. With two simple toys and sixty seconds, you can quickly demonstrate the forces of flight. Lift, thrust, and gravity can be demonstrated with a propeller toy. Drag and gravity can be demonstrated with a parachute toy.

Key Information:

Ages: Appropriate for ages five and older.

Key Concept: Four forces of flight: gravity, lift, thrust, and drag.

Objectives: Museum visitors will be able to understand that gravity, lift, thrust, and drag are the four forces that are needed for flight.

Education Standards:

National Science Education Standards for Grades K-4

Position and Motion of Objects: Students develop abilities to describe the position and motion of objects.

National Science Education Standards for Grades 5-8

Motions and Forces: Students develop abilities to describe the position, direction, motion, and speed of objects.

National Science Education Standards for Grades 9-12

Motions and Forces: Students develop abilities to describe and measure the position, direction, motion, and speed of objects.

Summary of Supplies:

Item	Description	Quantity
Aero-Prop™ toy propeller	Plastic toy propellers with a propeller blade that is 3" (7.62 x 1.91 cm). The propellers can be imprinted with a custom message. Available from Aero-Motion (www.aero-motion.com) or other online toy stores. Cost: about $.80 each.	5
Paratrooper parachute toy	3" (7.62 cm) tall plastic figure with a plastic parachute attached with string. Available from toy stores or party stores. Cost: about $.20 each.	5

Safety Guidelines:

The Aero-Prop toys can fly up to 35' (10.67 m) in the air. Carefully choose a location for this program so that other museum visitors will not be at risk of getting struck by a flying Aero-Prop toy.

Procedure:

1. Welcome the museum visitor. Ask the visitor if he/she would like to investigate the four forces of flight with some fun flying toys.
2. Explain that there are four forces that together allow for flight to occur. These are gravity, lift, drag, and thrust.

ACTIVITY 1: LIFT AND THRUST

3. Aviation engineers have many challenges when they design an airplane. The first challenge is to design an airplane that has enough upward lift to counteract the downward pull of gravity.
4. Hand the visitor an Aero-Prop toy and show them how to launch the propeller into the air.
   - Hold the stick of the toy between the inside of your left palm and the fingertips of your right hand.
   - Tilt the propeller forward, away from your body.
   - Launch the toy by squeezing the stick between your two hands and rolling your right hand forward in a quick and firm motion.
5. Ask:
   - *What force do you think is pulling down on the toy? (Gravity).*
   - *What force do you think is allowing the toy to counteract gravity and fly up into the air? (Lift is lifting the toy up against the pull of gravity).*
   - *What provides lift? (The airfoil shape of the propeller).*
   - *What provides thrust? (The spinning motion of the propeller).*
6. Have the visitor launch their Aero-Prop again and together, watch the path that the toy makes. Ask the visitor:
   - *Would you want to ride on an airplane that only moved upward? (No, you want to go somewhere).*
   - *What helps the airplane move forward? (The spinning motion of the propeller; this is thrust)*

ACTIVITY 2: DRAG

7. Introduce the concept of drag by asking the visitor:
   - *What would happen if we put a 20-foot tall windshield on the front of a plane? Would it fly well? Would it speed up or slow down?*
8. Hand the visitor a parachute toy and show them how to hold the toy with the parachute closed, and then throw the toy into the air so that the parachute opens and the toy slowly floats back down to you.
9. Ask:
   - *We have talked about gravity pulling down, lift lifting upwards, and thrust pushing forward. What force do you think is slowing the toy so that it doesn't just plummet down to the ground? (Drag is caused by the shape of the parachute).*

Notes to Presenter:

This 60 Second Science Activity is appropriate for all ages. Given the short presentation time, the activity focuses on only one main concept, making it appropriate for younger children. Here are some ways to adapt the activity for different age groups:

5-8 year olds: Keep your language simple. Focus on having children describe the motion of the toys, using words such as: fly, lift, spin, float, fast, slow, up, and down. Young children may need help launching the Aero-Prop toys.

8-14+ year olds: Engage older children and adults in the activity by focusing on the four forces of flight. Encourage visitors to develop an understanding of the terms: gravity, lift, drag, thrust, and force. Ask visitors if they can think of other examples of objects that demonstrate the four forces of flight (such as birds, bats, insects, helicopters, airplanes, etc.).

Career Link:

- Airplane pilot
- Physicist
- Toy inventor

CART ACTIVITY FOR MUSEUM DOCENTS

Materials Science: Build an Airplane

(5-10 minutes)

Throughout history, aviation engineers and material scientists have designed airplane from a variety of materials, from the first wood and fabric bi-planes to the carbon fiber composite planes of today. Each material used in the aviation industry is chosen based on its specific characteristics, including weight, strength, flexibility, and resistance to corrosion.

Key Information:

Ages: Appropriate for ages five and older.

Key Concept: Properties of materials.

Objectives: Museum visitors will be able to understand that materials have different characteristics, such as weight and strength.

Standards:

National Science Education Standards for Grades K-4

- **Properties of Objects and Materials:** Students develop the ability to observe and describe the properties of objects and materials.
- **Science and Technology:** Students develop an understanding about science and technology.

National Science Education Standards for Grades 5-8

- **Properties and Changes of Properties in Matter:** Students develop the abilities to observe and describe properties of substances.
- **Science and Technology:** Students develop an understanding about science and technology.

National Science Education Standards for Grades 9-12

- **Science and Technology:** Students develop an understanding about science and technology.

Summary of Supplies:

Item	Description	Quantity
Wood sample	Piece of spruce wood. Labeled as "Spruce Wood."	1
Fabric sample	Piece of strong linen fabric. Labeled as "Linen Fabric."	1
Steel sample	Piece cut from a sheet of steel. Labeled as "Steel."	1
Aluminum sample	Piece cut from a sheet of aluminum. Labeled as "Aluminum."	1
Titanium sample (optional)	Piece of titanium. Labeled as "Titanium." (This is optional, as titanium can be quite expensive to purchase).	1
Fiberglass epoxy sample	Piece of fiberglass epoxy. Labeled as "Fiberglass Epoxy."	1
Carbon fiber laminate sample	Piece of carbon fiber epoxy. Labeled as "Carbon Fiber Laminate." Can be purchased from www.robotmarketplace.com.	1
Carbon fiber sandwich sample	Piece of honeycomb-shaped material sandwiched between two carbon fiber sheets. Labeled as "Carbon Fiber Sandwich." Can be purchased from www.robotmarketplace.com.	1
Strength-Weight Chart	A chart comparing the "specific strength" and the "relative weight per unit volume" for the following materials: carbon fiber epoxy, fiberglass epoxy, aluminum, titanium, and steel.	1
Boeing 787 Materials Poster	Poster that shows the types of construction materials used on the Boeing 787 aircraft. See "Special Note" below for more details.	1
Airplane Cards	A set of flashcards. One side has a large photograph of an airplane. The other side has the years that the airplane was manufactured and a smaller version of the photograph of the airplane. See "Special Note" below for more details.	1 set of 7 cards
Materials Cards	A set of flashcards. One side has information about the materials used to construct an airplane. The other side has the name of that airplane. See "Special Note" below for more details.	1 set of 7 cards
Model Airplane (optional)	Scale-model of an airplane. If possible, choose an airplane that is featured in the film.	1 or more

Special Note:

The Boeing 787 Materials Poster should be created using the following information:

- 50% Composites
- 20% Aluminum
- 15% Titanium
- 10% Steel
- 5% Other materials

The Airplane Cards should be created using the following information:

- Boeing Stearman Kaydet Bi-plane (1936 – 1948)
- Lockheed Constellation (1937 – 1967)
- Schleicher ASW-20 Glider (1977 – 1990)

- Boeing Harrier V/STOL Jump Jet (1980 – present)
- Boeing F/A-18 Hornet (1983 – present)
- Airbus A380 (2007 – present)
- Boeing 787 Dreamliner (Under development)

The Materials Cards should be created using the following information:

- This plane was built with steel, spruce wood, and fabric. (Boeing Stearman Kaydet Bi-plane)
- This plane was built with steel and a lot of shiny aluminum. (Lockheed Constellation)
- This plane was built with light-weight fiberglass. (Schleicher ASW-20 Glider)
- This jet was built with aluminum, composites (including graphite/epoxy and carbon fiber), steel, and titanium. (Boeing Harrier V/STOL Jump Jet)
- This jet was built with aluminum, titanium, carbon fiber epoxy, and steel. (Boeing F/A-18 Hornet)
- This new plane is being built from new materials, including carbon fiber reinforced plastic, GLARE (a material made from layers of fiberglass and aluminum), and thermoplastics. (Airbus A380)
- Half of this new plane will be built from carbon fiber composites. Other materials include aluminum, titanium, steel, and fiberglass. (Boeing 787 Dreamliner)

Set-up:

- Lay out the sample materials on the top of the cart in no particular order. Mix up the order of the Airplane Cards and the Materials Cards and set both “decks” aside.
- If at all possible, it is best to have sample materials that are all approximately the same size. This allows visitors to hold each material and compare the weight.

Safety Guidelines:

Be sure that the sample materials are prepared so that all edges are sanded and smooth, or else covered.

Procedure:

1. Invite museum visitors to the cart program by asking:
   - *Would you like to help me build an airplane? I need your help to determine what material to use for a new airplane design.*

ACTIVITY #1: MATERIALS EXPLORATION (Ages 5+)

2. Explain that the materials on the cart are all samples of materials that have been used to build airplanes throughout history, from the earliest wooden bi-planes to modern commercial jets.
3. Encourage the visitor to explore each material’s properties, by asking:
   - *Does the material feel light or heavy?*
   - *Does the material feel strong or weak?*
   - *Does the material feel flexible or rigid?*
   - *Do you think this material could be damaged over time by cold, heat, or moisture?*

ACTIVITY #2: STRENGTH-TO-WEIGHT COMPARISON
(Ages 5+)

4. Explain that aviation engineers choose materials based on many different qualities, including: weight, strength, rigidity, and resistance to corrosion. For the airplane we are designing, we’re going to focus on weight and strength. We want to find the material that has the best combination of low weight and high strength. Put more simply, we need a material that is light, but strong.
5. Challenge the visitor to pick up each material and weigh it in their hand. Then, challenge the visitor to consider the weight of the material in comparison to its size and to organize the materials in order of their weight, from light to heavy.
6. Show the Strength-Weight Chart, which compares the strength of each material to its weight. Ask:
   - *Which material would you choose for our airplane, which must be light, but strong?*
7. Show the Boeing 787 Materials Poster, which illustrates how steel, titanium, aluminum, fiberglass, and carbon fiber composites are being used to build the new Boeing 787 Dreamliner. This is one of the first plane that has a fuselage shell, and many other parts, built from carbon fiber composites instead of aluminum. By using carbon fiber composites, Boeing engineers have been able to create a strong, light plane. A lighter plane means that it burns less fuel, and gives off fewer emissions.
8. You can also use the airplane scale-model to point out where different materials are used on modern planes.

Amount of Materials Used in the New Boeing 787 vs. 777 (by weight)

	Materials used in the Boeing 787 Dreamliner	Materials used in the Boeing 777
Composites	50%	12%
Aluminum	20%	50%
Other materials	30%	38%

Adapted from: Boeing. 2007. 787 Program Fact Sheet.

ACTIVITY #3: MATCHING AIRPLANES & MATERIALS
(Ages 10+)

9. First, lay out the Airplane Cards with the photo side facing up. Lay out the Materials Cards with the materials side up.
10. Explain that scientists and engineers have changed the design of airplanes over time, making them faster, lighter, and better. As new materials have been developed, these scientists and engineers have learned how to apply them in the construction of airplanes.
11. Challenge the visitor to match the airplanes with their construction materials by trying to match each Airplane Card with a Materials Card.
12. You can help the visitor check his/her answers by turning over the Materials Cards. The back of each Materials Card has the name of the correct airplane.

ACTIVITY #4: AIRPLANE TIMELINE (Ages 5+)

13. First, lay out the Airplane Cards, in no particular order.
14. Challenge the visitor to create an airplane timeline by organizing the Airplane Cards in order of earliest plane to most recent plane. Encourage the visitor to look at the design and materials used on each plane.
15. You can help the visitor check his/her answers by turning over the Airplane Cards. The back of each Airplane Card has the dates that the airplane was—or is being—manufactured.

Notes to Presenter:

The cart is geared for ages eight and older. Here are some ways to adapt the cart for different age groups:

5-8 year olds: Younger visitors can participate in the Materials Exploration and the Airplane Timeline. You can adapt the Strength-to-Weight Comparison by challenging younger visitors to feel the different materials and place them in order by approximate weight. Focus the experience of younger children on making observations and describing the characteristics of the different materials.

8-12 year olds: These visitors can participate in all activities, but may need some help reading the Airplane Cards and Materials Cards.

13+ year olds: Older children and adults can participate in all the activities.

Career Link:

- Material scientists
- Aerospace engineer

DEMONSTRATION ACTIVITY FOR MUSEUM DOCENTS

One-Breath Bernoulli Bag

(5 minutes)

Can you blow up an eight foot long bag with just one breath? If you use Bernoulli's Principle of air pressure, you can! (This demonstration element can be used as part of a larger demonstration program on the forces of flight).

Key Information:

Ages: Appropriate for all ages.

Key Concept: Air pressure and Bernoulli's Principle.

Objectives: Museum visitors will be able to: Understand the basic concept of Bernoulli's Principle: that as the speed of air increases, the pressure of the air decreases.

Standards:

National Science Education Standards for Grades K-4

- **Position and Motion of Objects:** Students develop abilities to describe the position and motion of objects.
- **Properties of Earth Materials:** Students develop an understanding of earth materials, including the gases of the atmosphere.

National Science Education Standards for Grades 5-8

- **Motions and Forces:** Students develop abilities to describe the position, direction, motion, and speed of objects.

National Science Education Standards for Grades 9-12

- **Motions and Forces:** Students develop abilities to describe and measure the position, direction, motion, and speed of objects.

Summary of Supplies:

Durable Supplies:

Item	Description	Quantity
Bernoulli's Principle	Poster, chart, or slide of Bernoulli's Principle: "As the velocity of a fluid increases, the pressure exerted by that fluid decreases" with this simplification printed below it: "As the speed of the air increases, the air pressure decreases."	1
Newton's Third Law	Poster, chart, or slide of Newton's Third Law: *"For every action there is an equal and opposite reaction."*	1
Scissors	Scissors are needed only if you are using the Diaper Genie® refill.	1
Model airfoil	Model airplane, bird wing, or other model that demonstrates the shape of an aifoil.	1

Consumable Supplies:

Item	Description	Quantity
Diaper Genie® refill or Windbags®	Platex® Diaper Genie® refills can be found at large department stores. The product is a tube of plastic that can be cut to size for the Bernoulli Bag demonstration. One refill costs about $6.00. Windbags® are a product that can be purchased from science supply companies, such as Steve Spangler Science (www.stevespanglerscience.com). A 4-pack is $5.00, a 32-pack is $25.00, and a 100-pack is $50.00.	2 Windbags® or 2 – 8' (2.44m) long sections of a Diaper Genie® refill
Balloon	Party-style balloon	1

Set-up:

- If you are using the Diaper Genie® refill, pull out an 8' (2.44 m) long piece of the plastic tube and cut it off using scissors. Tie a knot in one end of the tube, leaving the other end open. Repeat to make two bags.
- If you are using a Windbag®, tie a knot in one end of the tube, leaving the other end open. Repeat to make two bags.
- Set aside one Bernoulli Bag for visitors to use and one for you to use.

Safety Guidelines:

When a volunteer audience member is attempting to blow up the bag, limit them to five breaths to avoid overexertion.

Procedure:

1. Gather an audience.
2. Pull out the Bernoulli Bag and stretch it out to its full length, so that the audience can see how large it is.
3. Ask for a volunteer who is full of hot air.
4. Hold the knotted end of the bag. Hand the open end to the volunteer. Challenge the volunteer to inflate the bag, using big, deep breaths.
5. After the volunteer has given five breaths into the bag, pinch the balloon closed and ask them to stop.
6. Run your hand quickly down the length of the bag, from the open end down to the knotted end, so that you push all of the captured air to the bottom of the bag. Show the audience the amount of air that filled the bag after five big breaths.
7. With the audiences help, estimate how many total breaths it would take for your volunteer to fully inflate the bag.
8. Now, tell the audience that you can blow up the bag with just one breath. That's right, with just one breath, you can fully inflate the bag.
9. Ask the audience if they believe it is possible for you to blow up the bag with just one breath. Ask the audience to raise their hands if they believe you can do it. Now, ask them to raise their hands if they think it is impossible.
10. Before you blow up the Bernoulli Bag, tell the audience that you will give them a hint as to how to blow up the Bernoulli Bag using only one breath. Blow up the party balloon. Pinch the neck of the balloon closed. Explain that the balloon is now filled with air under high pressure. Ask the visitors:
    - *What will happen if I let go of the balloon? Why?*
11. Explain that the high pressure air inside the balloon wants to move toward the lower pressure air in the room.
12. Now, tell the audience that you will show them the concept of how "higher pressure air moves to where there is lower pressure air" by blowing up the Bernoulli Bag with just one breath.
13. Stretch out your lungs by taking a few noisy, deep breaths. Then, proceed to fully inflate the bag in just one breath, as promised!
    - Hold the opening of the bag wide open.
    - Hold the opening of the bag about 10" (25.4 cm) away from your mouth.
    - Take a deep breath and forcefully blow in the direction of the bag, completely emptying your lungs.
    - Use your hand to close the end of the bag. Tie a knot to keep the air contained inside.
14. Ask the visitors:
    - *Where did the air come from that just filled up the bag?*
    - *Do I have enough air in my lungs to fill up an eight foot long bag?*
15. The audience will want to know how you managed the impossible and inflated an eight foot long bag with just one breath. Explain that you used a scientific principle discovered by an eighteenth century Swiss scientist named Daniel Bernoulli.
16. Show the poster, chart, or slide of Bernoulli's Principle. Read Bernoulli's Principle and the simplified statement below that relates directly to how the principle applies to lift and flight.
17. Explain the secret to the One-Breath Bernoulli Bag. The secret is to open the mouth of the bag and hold it about 10" (25.4 cm) away from your mouth. When you exhale a large breath toward the bag, which is air moving at a fast speed, you were able to create a zone of low pressure at the mouth of the bag. The nearby air, which is at atmospheric pressure, was drawn into the zone of low air pressure. With one breath, you were able to harness the power of all the air around you, drawing the nearby air into the bag to inflate it.
18. Explain that the same phenomenon that allows us to blow up the bag in one breath is the same phenomenon that creates lift on an airplane wing. Show the visitors the airfoil model and explain that airplanes and birds have wings that have the airfoil shape.
19. Explain that scientists have several explanations of how lift is created by an airfoil. One explanation is based on Bernoulli's Principle, as was just seen with the one-breath demonstration. An airfoil has a curved top surface which causes the air traveling above the wing to take a longer path. The longer path means the air above the airfoil must travel faster than the air below it. Faster moving air is lower in pressure than slower moving air. The slower moving air, with greater pressure, pushes the underside of the airfoil up into the faster air flow. When the force of lift is greater than the force of gravity on that object, then that object takes flight.
20. Show the poster, chart, or slide of Newton's Third Law. A second, compatible explanation is that as air moves over and underneath the airfoil, it is directed downward by the trailing edge of the wing. This is called a downwash. Newton's Law states that there must be an equal and opposite reaction to the downward force of the air, which forces the wing upward and creates lift.
21. If there is time, allow your volunteer to give the bag one more try using Beroulli's Principle to inflate the bag.

Notes to Presenter:

This demonstration activity is appropriate for all ages. Younger children will be amazed by the trick and your explanation of how it works. Older children and adults will be able to understand the underlying concepts and the importance of Bernoulli's Principle to flight.

Career Link:

- Physicist

WORKSHOP #1
FOR MUSEUM EDUCATORS

Carbon Fiber: A New Kind of Weave

(90 minutes)

Workshop participants will investigate the amazing properties of carbon fiber composites in five different activities. Participants will begin by examining everyday composites. They will discover the process of creating carbon fiber composites by using an analogy to the textile industry. The participants then examine weave patterns of different fabrics and then will have a chance to add their own unique weave patterns to a **Lap Loom**. In the **Composite Factory**, participants will make their own woven mats to model the process of making carbon fiber composite materials for airplane construction. Then, participants will put their woven mats to the test in the **Composite Testing Laboratory**.

Key Information:

Ages: Appropriate for ages nine to eleven (grades 3-5).

Key Concept: Carbon fiber composites.

Objectives: Workshop participants will be able to:

- Define and give examples of a composite.
- Model one way in which carbon fiber composites are manufactured.
- Understand the connection between carbon fiber composites and the textile industry.
- Determine the tensile strength of weave patterns of their own design.

Standards:

National Science Education Standards for Grades K-4

- **Science as Inquiry:** Students develop abilities necessary to conduct scientific inquiry.
- **Properties of Objects and Materials:** Students develop the ability to observe and describe the properties of objects and materials.
- **Science and Technology:** Students develop the abilities of technological design.
- **Science and Technology:** Students develop an understanding about science and technology.

Summary of Supplies:

Durable Supplies:

Item	Description	Quantity
Carbon fiber laminate sample	Piece of carbon fiber epoxy. Labeled as "Carbon Fiber Laminate." Can be purchased from www.robotmarketplace.com.	1 or more
Carbon fiber sandwich sample	Piece of honeycomb-shaped material sandwiched between two carbon fiber sheets. Labeled as "Carbon Fiber Sandwich." Can be purchased from www.robotmarketplace.com.	1 or more
Samples of consumer products that are made from carbon fiber composites	Includes certain types of: baseball bats, golf club shafts, fishing rods, archery bows and arrows, bicycle frames, hockey sticks, canoe and kayak paddles, skateboards, and the interior components of some basketball shoes.	As many as you can provide
Whiteboard, chalkboard, or chart paper		1
Magnifying tools	Magnifying glasses or loupes. Stereo microscopes, digital microscopes, or digital microcameras can also be used.	1/participant
Cotton thread	Black. Cut into 6" (15.24 cm) pieces	2 pieces
Spool of cotton yarn	Black	1
Knitted cotton hat, scarf, or sweater	Black	1
Lap loom (aka potholder loom)	Plastic loom, approximately 7 x 7" (17.78 x 17.78 cm). Loom sets can be purchased at craft or fabric stores. Alternatively, lap looms can be created from a wood frame with 18 finishing nails evenly spread across each of the four sides.	1/participant
Scissors		1/participant
Ruler (optional)		1/participant
Pennies	100 pennies are needed for each group. This correlates to 2 banker rolls.	100/group of 3 participants

Consumable Supplies:

Item	Description	Quantity
Samples of different types of fabric	Linen, wool, denim, nylon, acrylic, silk, etc. Pieces should be at least 3 x 3" (7.62 x 7.62 cm)	1/participant
Cotton weaving loops or a variety of different types of fabric, ribbon, twin, raffia, and/or yarn	Loom sets often come packaged with cotton weaving loops. Alternatively, a selection of textiles can be provided. Pieces should be at least 8" (20.32 cm) long	40 pieces/ participant
Paper towel	Roll of kitchen-quality paper towels, separated into sheets	4 sheets/ participant
Cellophane tape	Roll	1/participant
Corrugated cardboard	Cut into pieces at least 3 x 6" (7.62 x 15.24 cm). Pieces can be cut from cardboard boxes.	1 piece/ participant

ACTIVITY #1: EVERYDAY COMPOSITES *(15 minutes)*

Activity Materials:

Item	Quantity
Carbon fiber laminate sample	1 or more
Carbon fiber sandwich sample	1 or more
Samples of consumer products that are made from carbon fiber composites	As many as you can provide
Whiteboard, chalkboard, or chart paper	1
Magnifying tools	1/participant

Procedure:

1. Welcome participants to the workshop, Carbon Fiber Composites: A New Kind of Weave. Tell participants that today they are going to take on the job of material scientists. A material scientist uses their knowledge of chemicals and the physical properties of materials to create brand new materials.

2. Begin by telling the Greek myth of Icarus. This myth tells one of the first stories of human flight and explains how a new material was created by combining two ingredients.

   The architect Daedalus and his young son Icarus were imprisoned by the angry King Minos in an open-air labyrinth that Daedalus himself had designed. They were provided with some food and candles. The maze of the labyrinth was terribly complicated and it was hopeless that they would find their way out. Even if they did find the exit, the labyrinth was completely surrounded by guards. The only option for escape was through the air.

   Each night, Daedalus told his son to carefully collect the soft wax from their candles. Each day, they carefully explored the maze, collecting feathers that had been dropped by birds flying over the labyrinth.

   Over time, Daedalus formed two sets of wings out of the wax and feathers, one for father and one for son. Before taking to the sky, Daedalus offered his son a warning: "Follow me on the middle course." Daedalus warned Icarus not to fly too close to the sun or the wax would melt. He warned Icarus not to fly too close to the ocean or the moisture would wet the feathers.

   Daedalus beat his wings and took off, with Icarus following after him. Icarus loved flying. He glided, zoomed, circled, and looped through the sky. He felt amazing and never, ever wanted to stop flying. He wondered how high he could go and started upward.

   Daedalus heard a cry and looked upward to see what looked like a shooting star. It was his son, falling from the sky, hopelessly flapping his bare arms since his wings had melted away. Icarus plunged through the sky, splashed into the sea, and sunk out of sight. The sea was later named the Icarian Sea.

   Adapted from Martin, R. 2003. *Myths of the Ancient Greeks*.

3. Explain that the combination of organic fibers in the feathers with the wax created a composite structure for Icarus' wings. Icarus was warned by his father not to fly too close to the sun, or too close to the ocean, for fear that his fragile wings would melt or dissolve. Fortunately, today's composites can withstand both high temperatures and corrosion from humidity.

4. Ask the participants if anyone can define "composite." Listen to participants' responses and offer additional information until the class can agree to the following definition:

   *A **composite** is a combination of two or more different ingredients. When combined, the features of each ingredient are shared and the composite benefits beyond the individual parts. In a composite, there must be a **reinforcement** ingredient, which provides the structure, and a **matrix** ingredient, which is the binding agent.*

5. Explain that a composite can be anything that is made of two or more ingredients that when combined create something entirely new. For example, in the myth of Icarus, the feathers were the reinforcement and the wax was the matrix. Bricks used to be formed from a mixture of straw and mud that was then baked. The straw was the reinforcement and the mud was the matrix.

6. Elicit participants' preconceptions and existing knowledge about composites by asking them: How many real life examples of composites can you list? As participants brainstorm everyday composites, record their suggestions on the whiteboard, chalkboard, or a piece of chart paper. Encourage participants to consider what ingredients make up each material, and if possible, identify which ingredient(s) is the reinforcement and which ingredient(s) is the matrix. Some example answers include:
   - Concrete (cement matrix; gravel and/or sand reinforcement)
   - Fiberglass (plastic polymer matrix; glass fiber reinforcement)
   - Plywood and strand board (glue matrix; wood fiber reinforcement)
   - Peanut brittle candy (corn syrup and sugar water matrix; peanut reinforcement)
   - Bamboo (lignin matrix; cellulose fiber reinforcement)
   - Automobile tires (rubber matrix; steel or nylon reinforcement)

7. Explain that although modern composites are much more advanced than Icarus' feathers and wax, carbon fiber composites are made out of similar basic ingredients: fibers and resin. Share the following definition with the participants:

   ***Carbon fiber composites** are a combination of very fine carbon fibers (the reinforcement) and polymer epoxy resin (the matrix), which is a liquid that hardens into a plastic with the help of high temperatures and/or specific hardening chemicals.*

8. If possible, try to obtain several objects made from carbon fiber composites so that you can share this material with participants. In some instances, you will be able to see the carbon fiber weave in these materials. Pass the materials around so the participants can examine the weave of the materials, and also experience their strength to weight ratio.

9. Next, pass around the carbon fiber composite laminate and sandwich samples. Encourage participants to use magnifying glasses or loupes to examine the weave patterns.

ACTIVITY #2: TEXTILE TESTS *(10 minutes)*

Workshop participants discover the process of creating carbon fiber composites by using an analogy to the textile industry. The participants then examine weave patterns of different fabrics.

Activity Materials:

Item	Quantity
Cotton thread (black), cut into 6" (15.24 cm) pieces	2 pieces
Spool of cotton yarn (black)	1
Knitted hat, scarf, or sweater (black)	1
Samples of different types of fabric (linen, wool, denim, nylon, acrylic, silk, etc.)	1/participant
Magnifying glasses or loupes. Stereo microscopes, digital microscopes, or digital microcameras can also be used.	1/participant
Scissors	1

Set-up:

- Cut two 6" (15.24 cm) pieces of cotton thread. Separate the fibers from one piece of thread so that you have one individual fiber.
- Cut one 6" (15.24 cm) piece of cotton yarn.

Procedure:

1. In the previous activity, participants were able to see visible weave patterns in the samples of carbon fiber composites. Explain to participants that the technology for creating carbon fiber composites was first learned in the textile industry, where thread, yarn, ribbons, and fabrics are manufactured. Carbon fiber composites can be made in a variety of ways. One way to manufacture carbon fiber composites is similar to how a knitted hat, scarf, or sweater is created.
2. Pass around the piece of black fiber. Explain that it all begins with the creation of extremely fine carbon filaments, which can be many times thinner than the diameter of a single human hair.
3. Pass around the piece of black thread. Explain that many pieces of filaments are then twisted together into fibers called threads.
4. Pass around the piece of black yarn. Explain that the threads are then woven together to create a material called a yarn or tape. When a carbon fiber tape yarn or tape is being created, it is mixed with an epoxy resin to bind the fibers together.
5. Pass around the spool of yarn. Explain that the yarn or tape is wound on spindles. These spindles can be placed on a machine called a prepregger, which is like a huge, mechanical loom.
6. Pass around the black knitted hat, scarf, or sweater. Encourage participants to use their magnifying glasses or loupes to examine the weave in the knitted fabric.
7. Explain that the loom-like prepregger pulls yarn from multiple spindles and weaves them together using a series of combs to create a woven mat, like a huge sheet of fabric. Knitted clothing is formed in the correct shape to create a hat or a sweater. Carbon fiber composites can be woven around a form to create the correct shape, or the woven fabric can be mixed with a polymer epoxy resin, pressed into a mold, and cooked in an industrial oven, called an autoclave.
8. Distribute one piece of fabric to each participant. Encourage participants to examine the weave of the fabric with their magnifying glasses or loupes. Also challenge participants to test to strength of each fabric by pulling, stretching, and trying to rip it along both its width and its length.
9. After a few minutes, ask each participant to switch fabric samples with another participant. Depending on time, have participants switch several times, so that each participant has the opportunity to examine several fabric samples.
10. Ask the participants:
    - *What do you notice about the different weave patterns?*
    - *Which fabrics do you think are strongest? In what way?*
    - *Which fabrics do you think are softest?*
    - *Which fabrics do you think stretch the most?*

ACTIVITY #3: MAKE & TAKE—LAP LOOM *(20 minutes)*

In the previous activity, participants examined different types of weave patterns. The weave pattern of a carbon fiber composite can create a material that meets the designers' specifications for weight, strength, rigidity, and flexibility. In this activity, participants are challenged to add their own unique weave pattern to a Lap Loom to create an art piece that they can take home.

Activity Materials:

Item	Quantity
Lap loom	1/participant
Cotton weaving loops or a variety of different types of fabric, ribbon, twin, raffia, and/or yarn	40/participant
Scissors	1/participant

Set-up:

- If you are using cotton weaving loops, separate into piles of about 40 loops each, so that you have a pile for each participant.
- If you are not using cotton weaving loops, cut the ribbon, yarn, twine, raffia, and other supplies into pieces at least 8" (20.32 cm) long. You will also need to provide each participant with a piece of yarn long enough to wrap around the hooks on two sides of the loom.

Procedure:

1. In the previous activity, participants modeled the process of creating one type of carbon fiber composite and they examined different types of weaves in fabric. In this activity, participants will be exploring the essential question: What kinds of weave patterns can we create?

2. Invite participants to help create their own woven art piece by adding their own unique weave patterns to a lap loom. Each participant can choose their own textile (cotton weaving loops or fabric, yarn, ribbon, twin, and raffia) to add to their loom using a weave pattern of their own design. Challenge participants to think beyond the over-under weave pattern to come up with something all their own, or a combination of different weave patterns.
3. If you are using cotton weaving loops, then follow the directions that came with the loom set to begin weaving and to finish the project. If you are not using cotton weaving loops, then follow the directions below to begin weaving and to finish the project.
4. To create the warp threads, tell participants to take a long piece of yarn and tie it around the hook on one corner of their loom. Then, participants should thread the yarn back and forth to the hooks on the opposite side of the loom, creating rows of warp threads. When they reach the last hook, tell participants to tie the yarn onto the last hook and then trim it with scissors.
5. Tell participants to choose a textile. Tie one end of their chosen textile onto the first hook on one of the sides adjacent to the warp threads. The participant can then begin weaving the other end of their textile across the warp threads. These rows are called weft threads.
6. When a participant has come to the end of their piece of textile, they can connect it to the next piece of textile with a knot and continue weaving.
7. Continue in this pattern, until all the hooks have been used up. Tie the end of the last weft thread onto the last remaining corner hook.
8. You can remove the weaving by cutting the warp threads. Then, create a fringed border by tying off the warp threads. Choose one corner, and then work from left to right, tying the first two warp threads together with a square knot. Then tie the second and third warp threads together, then the third and forth, and so on, continuing around each corner. Trim the warp threads just past the knots to create fringe.
9. You may choose to share with participants some of the traditional weave patterns used by textile artists and basket makers. These traditional weave patterns include:
   - **Plain:** One under, one over.
One over, one under.
   - **Basket:** Two under, two over.
Two over, two under.
   - **Twill:** One under, two over, one under, two over.
One over, one under, two over, one under.
Two over, one under, two over, one under.
One under, two over, one under, two over.

ACTIVITY #4: COMPOSITE FACTORY

(20 minutes)

Participants will model a carbon fiber composite by creating mats with different weave patterns.

Activity Materials:

Item	Quantity
Paper towel, kitchen-quality	4 sheets/participant
Scissors	1 pair/participant
Cellophane tape	1 roll/participant
Ruler (optional)	1/participant

Set-up:

Take the roll of paper towels and tear it into separate sheets, so that you have four per participant.

Procedure:

1. In the previous activity, participants created different weave patterns on their own design. In this activity and the following Composite Testing Laboratory activity, participants will be exploring the essential question: *How does the weave pattern affect the strength of a material?*
2. Distribute the materials to each student.
3. Ask students to cut uniform strips from three of the paper towels. Strips that are _ to 1" (1.3 to 2.5 cm) wide will work well. It is important that the edges of the strips are as straight as possible, so you might want to encourage students to use a ruler to measure the strip intervals and to draw straight lines before cutting. One paper towel will be left uncut for the experiment control.
4. Explain that students will be weaving the strips together to form two mats. For accurate testing, weaving must be as tight as possible. Discuss possible weave patterns:
   - One over; one under
   - Two over; two under
5. Encourage students to weave two mats. They can use one of the example weave patterns for one mat, and design their own weave pattern for the second mat.
6. Each weave mat should be at least six strips wide and long. Have students use the cellophane tape to secure the edges of each weave mat. Tape should not be added to the mats anywhere except for the edges. Also, have students place tape along the edges of the uncut paper towel.

ACTIVITY #5: COMPOSITE TESTING LABORATORY

(25 minutes)

Participants will discover three different types of material strength while trying to destroy a piece of corrugated cardboard. Then, participants will design and conduct an investigation to test the tensile strength of their own woven mats created in the previous Composite Factory activity.

Activity Materials:

Item	Quantity
Corrugated cardboard, cut into pieces at least 3 x 6" (7.62 x 15.24 cm). Pieces can be cut from cardboard boxes.	1 piece/participant
Woven mats from previous activity	2/participant
Uncut paper towel (experiment control) from previous activity	1 sheet/participant
100 pennies (2 banker rolls)	100/each group of 3 participants
Whiteboard, chalkboard, or chart paper	1
Markers or chalk	Assorted

Set-up:

1. Cut the corrugated cardboard into pieces at least 3 x 6" (7.62 x 15.24 cm)
2. Create a data table on the whiteboard, chalkboard, or a piece of chart paper. The table should have enough rows for each small group of three participants. The table should have four columns, labeled as: Names, Control, Variable #1, and Variable #2. Make sure the data table is not out of the participants' reach. The table needs to be located so that participants can add their own data to it.

Procedure:

1. Welcome participants to the **Composites Testing Laboratory**. Explain that in this activity, participants need to think like a material scientist. When material scientists develop materials, they need a material that meets specific design specifications. A material scientist might need a material that is strong in one direction, but the strength of the material in another direction might not matter. After developing a material, the material scientists then has to test it to determine if the design specifications were met, and if the material is safe for its intended use.
2. Distribute one piece of cardboard to each participant. Explain that their challenge is to determine what the design specifications were for the material scientist that created this corrugated cardboard. What type of strength do you think the material scientist was trying to achieve?
3. Challenge the participants to try to destroy their piece of cardboard by bending, tearing, or crunching it. Allow time for participants to test the cardboard. Then, discuss what the participants discovered.
   - *In what ways was the cardboard strong?*
   - *In what ways was the cardboard weak?*
4. Explain the three types of material strength:
   - **Compressive Strength:** The maximum amount of compression (squishing, crunching, etc.) that a material can handle before it fails. An example of compressive strength is stomping on an aluminum soda can.
   - **Tensile Strength:** The maximum amount of loading that a material can handle before it fails. Some materials will stretch before breaking. An example of tensile strength is piling pennies on top of a paper towel until the towel tears.
   - **Shear Strength:** The maximum amount of stress along a plane that a material can handle before it fails. An example of shear strength is tearing a piece of fabric into strips. Shear strength can be measure across the width, length, and diagonal of a material.
5. Challenge participants to test the tensile strength of the woven mats that they created in the previous activity. Each of their woven mats will serve as the variables in the investigation. A regular piece of paper towel will serve as the control in the investigation. Ask the participants what questions they might be able to answer through the investigation. Sample questions might include:
   - *What weave pattern was the strongest?*
   - *Does weaving a paper towel make it stronger than a regular paper towel?*
   - *Can a mat be strong in one way, but weak in another?*
6. Ask each participant to team up in groups of three. Distribute the pennies to each small group.
7. Encourage each group to test the tensile strength of their woven mats and the uncut paper towel using one of the following directions:
   - Two students hold the corners of the mat about 6" (15.24 cm) above to table top while a partner places coins onto the center. How many coins can the mat support before failing by either tearing or allowing the coins to slide through the weave?
   - Two students sit on the floor and hold the corners of the mat a few inches from the floor. Next, their partner tries dropping pennies from different heights into the center of the mat. Try dropping a single penny from various heights or tape 2-3 pennies together to change the mass. How high or how much mass can the weave catch before failing by either tearing or allowing the coins to slide through the weave?
8. Discuss what "failure" of the weave means, i.e. coins sliding through the weave and/or tearing of the paper. Then, have each group test the tensile strength of the control, and then take turns helping each other test the tensile strength of each of their own woven mats.
9. When finished with the investigation, each group should add their data to the data table.
10. When all the groups have added their data to the table, examine it as a whole group. Whose designs were the strongest? Gather the strongest three to five mats and display them (or at least, the remaining pieces of them) to allow all the participants to examine the weave patterns of each.

Notes to Presenter:

The workshop is designed to follow the process of inquiry-based science. While the activities in this workshop could be used à la carte, or rearranged, the workshop as it is written brings participants through the steps of inquiry, which includes:

- Eliciting participants' preconceptions and existing knowledge
- Modeling the concept
- Making casual observations
- Developing essential questions
- Investigating and collecting data
- Compiling and analyzing data

Career Link:

- Material scientist
- Chemical engineer
- Aeronautical engineer
- Sporting good designer
- Textile artist
- Fabric designer

WORKSHOP #2 FOR MUSEUM EDUCATORS

Lighting Design Studio

(45 minutes)

Can the lighting in an airplane cabin make travelers happy, sleepy, or hungry? Investigate the impacts of lighting in the Lighting Design Studio and discover how modern lighting helps travelers arrive at their destinations fresh and rested. (Depending on how you present the Lighting Design Studio workshop, it could be used as part of a longer program focused on light and color, or on aeronautical engineering and aircraft design).

Key Information:

Ages: Appropriate for ages twelve to fourteen (grades 6-8).

Concept: Color psychology and airplane cabin design.

Objective: Workshop participants will be able to understand that color can impact how people feel and can be used to minimize jet lag.

Standards:

National Science Education Standards for Grades 5-8

- **Science as Inquiry:** Students develop abilities necessary to conduct scientific inquiry.
- **Science and Technology:** Students develop an understanding about science and technology.
- **Science and Technology in Society:** Students develop an understanding of the roles of science and technology in society.

Summary of Supplies:

Durable Supplies:

Item	Description	Quantity
Colored acetate sheets	8.5 x 11 in. (21.59 x 27.94 cm) plastic sheets in red, blue, green, yellow, and orange. Available from Boreal (http://boreal.com), Item #WW6672093. A 30-pack of all five colors costs about $30.00.	1 sheet of each color: red, blue, green, yellow, and orange.
Scissors		1/participant
Overhead projector		1

Consumable Supplies:

Item	Description	Quantity
Design Board	11 x 17" (72.94 x 43.18 cm) or larger piece of cardboard, tag board, or other stiff paper.	1/participant
Glue	Non-toxic white glue.	1 bottle/participant
Collage materials	A variety of collage materials, including: • Wallpaper samples • Fabric remnants • Paint chip samples • Upholstery samples • Carpet samples • Buttons • Ribbons • Old magazines Some material samples may be obtained from fabric, hardware, and carpet stores, which may have outdated sample books.	A large assortment of different collage materials
Airplane snacks	Some assortment of durable food items, such as: • Pretzels • Colorful hard candies • Raisins	1 small handful/ participant
Newspaper	Old newspaper cut into small pieces, about 3 x 3" (7.62 cm)	1 small piece/ participant
Index card	4 x 6" (10.16 x 15.24 cm) index card or paper cut into that size.	1/participant

ACTIVITY #1: COLOR PSYCHOLOGY

(15 minutes)

Activity Materials:

Item	Quantity
Colored acetate sheets in red, blue, green, yellow, and orange.	1 sheet of each color
Overhead projector	1

Set-up:

- Set up the overhead projector so that it will project onto a screen or a white wall.

Procedure:

1. Welcome workshop participants to the **Lighting Design Studio**. Explain that they have an interesting challenge: to design the interior cabin of a brand new commercial airplane. The airline executives want an airplane that focuses on the passengers' comfort. Your challenge is to design the interior cabin so that passengers feel safe, comfortable, and relaxed during the five phases of the flight:
   - Boarding
   - Cruising (when passengers relax, read, and watch movies)
   - Meal Service
   - Sleep
   - Take-off and Landing
2. In order to design the new airplane cabin, workshop participants need to understand the impacts of color on people's mood. This is called "color psychology."
3. Begin by projecting a color on the screen by using a colored acetate sheet on the overhead projector. Ask the participants:
   - *How does this color make you feel?*
   - *What words can you use to describe how this color affects your mood?*

Continue by projecting different colors, until you have discussed all five colors: red, blue, green, yellow, and orange.

4. Explain that psychologists have studied the ways that colors affect people's moods. As you project each color onto the screen, share the following information with the participants, linking it back to what the participants' said in the previous discussion:

   The emotion triggered by a color depends on a person's nationality, past experiences, and, sometimes, personal preference. However, studies have shown that specific colors and color combinations can psychologically affect the majority of people, regardless of their culture or past. Generally speaking:

   Red triggers a sense of power and impulsiveness, and increases one's appetite. Be careful how you use red. It can also trigger anger, forcefulness, impatience, intimidation, conquest, violence, and revenge.

   Yellow has a stimulating impact on your memory. (Consider the popularity of the yellow notepads and Post-It® notes.) Yellow stimulates the intellect and promotes organization. It triggers joy, but when used in the wrong manner, or with the wrong combination of other colors, it can create feelings of criticism, laziness, and cynicism.

   Blue generates feelings of tranquility, love, acceptance, patience, understanding, and cooperation. If used inappropriately, its negative qualities are fear, coldness, passivity, and depression.

   Orange triggers steadfastness, courage, confidence, friendliness, and cheerfulness. Its opposite effects are ignorance, inferiority, sluggishness, and superiority.

   From: Bloomsburg University, 2002.

   Green generates feelings of hope, growth, good health, freshness, soothing, sharing, and responsiveness. Its negative effects are envy, greed, constriction, guilt, jealousy, and disorder.

5. Explain that color is used by advertisers and interior designers to affect people's mood in deliberate ways. Ask the participants to suggest what color(s) they would choose for the following places:
   - Doctor's office
   - School classroom
   - Hotel room
   - Fast food restaurant

ACTIVITY #2: CABIN DESIGN CHALLENGE

(20 minutes)

Activity Materials:

Item	Quantity
Scissors	1/participant
Design Board	1/participant
Glue	1 bottle/ participant
Collage materials	A large assortment
Airplane snacks	1 small handful/ participant
Newspaper	1 small piece/ participant
Index card	1/participant

Set-up:

- Set-up the room so that there is one table for all the collage materials and the flight snacks.
- Each workshop participant will need to have their own space at a table, with room to spread out their materials and Design Boards. Distribute the following materials to each participant's workspace: one pair of scissors, one bottle of glue, one Design Board, one index card, and one newspaper piece.

Procedure:

1. Provide the following background information on the Boeing 787 Dreamliner:

   When Boeing began designing the interior cabin of its new 787 Dreamliner jet, the company wanted to create the best possible atmosphere for the passengers. The airplane designers carefully chose the colors and textures of the walls, seats, and carpet to create just the right feel inside the cabin. The airplane designers also chose to use light-emitting diodes (LED) lights throughout the cabin of the plane. The flight attendants are able to control both the brightness and the color of the LED lights, depending on the mood they want to create inside the cabin.
2. Issue this challenge to the participants:

   Your challenge is to work as an interior designer to choose the colors, textures, and fabrics to be used in the cabin of a new airplane. You will use a Design Board on which to glue material samples to help communicate your vision for the cabin design.

You are free to use any of the materials on the table. In addition, you must include a piece of newspaper, an index card (leave it blank), and some flight snacks on your Design Board. I'll explain later how we will use these materials.

3. Allow time for participants to choose materials and assemble their Design Boards. Make sure each participant includes a piece of newspaper, an index card, and some flight snacks on their boards. Also be sure each participant writes his/her name on the Design Board.

ACTIVITY #3: COLOR LAB

(10 minutes)

Activity Materials:

Item	Quantity
Colored acetate sheets in red, blue, green, yellow, and orange.	1 sheet of each color
Overhead projector	1

Set-up:

- Set up the overhead projector so that it will project onto a screen or a white wall.

Procedure:

1. Compliment the participants on their excellent work as interior designers. Explain the next challenge:

   *Now, the airline executives want to test your designs in the **Color Lab**. The executives want you to determine what color lighting you will use inside the cabin at the five different flight phases. They want to know how colored light will interact with your cabin design to create the right moods for the passengers.*

2. Revisit the five flight phases. Ask participants to determine what mood should be created during each flight phase:
   - Boarding (comfort, relaxation, calm)
   - Cruising (relaxation, ability to read or work)
   - Meal Service (hunger, alertness, food should look appetizing)
   - Sleep (quiet, calm, relaxed)
   - Take-off and Landing (confident, calm, safe)
3. Take turns projecting each color onto the screen. As each color is projected, allow each participant the chance to hold their Design Board up in the colored light. Encourage participants to consider how the colored light affects their design and what mood is created. Ask:
   - *How does this color of light make you feel?*
   - *Does the food look appetizing?*
   - *Can you comfortably read the newspaper?*
4. Now that the participants have tested their Design Boards in the **Color Lab**, ask them to write down their "color plan" for the flight. On the index card that they have already glued onto the Design Boards, they should write down the color of light that they have chosen for each of the five flight phases.
5. Ask each participant to present his/her Design Board and color plan to the entire group.

Notes to Presenter:

This workshop program can be presented as a stand-alone activity, or can be incorporated into a longer workshop program focused on airplane design, interior design, or light and color.

Career Link:

- Interior designer
- Psychologist
- Artist
- Advertising/marketing designer

Credits

The *Legends of Flight Informal Educator's Toolkit* was developed by Kristen Clapper Bergsman and Matthew Merritt for Pacific Science Center, under the direction of project manager Heather Gibbons.

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LEGENDS OF FLIGHT

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