



# FLIGHT

EDUCATOR GUIDE

## UEN CORE STANDARDS ADDRESSED IN FLIGHT:

### Kindergarten Science:

#### Standard 3, Objective 1

Identify how non-living things move.

- Observe and record how objects move in different ways, e.g., fast, slow, zigzag, round and round, up and down, straight line, back and forth, slide, roll, bounce, spin, swing, float, and glide.
- Compare and contrast how physical properties of objects affect their movement, e.g., hard, soft, feathered, round, square, cone, geometric shapes.

#### Standard 3, Objective 2

Describe parts of non-living things.

- Describe how parts are used to build things and how things can be taken apart.
- Explain why things may not work the same if some of the parts are missing.

#### Standard 4, Objective 1

Investigate living things.

- Construct questions, give reasons, and share findings about all living things.
- Compare and contrast young plants and animals with their parents.
- Describe some changes in plants and animals that are so slow or so fast that they are hard to see (e.g., seasonal change, "fast" blooming flower, slow growth, hatching egg).

#### Standard 4, Objective 2

Describe the parts of living things.

- Differentiate between the five senses and related body parts.
- Identify major parts of plants, e.g., roots, stem, leaf, flower, trunk, branches.
- Compare the parts of different animals, e.g., skin, fur, feathers, scales; hand, wing, flipper, fin.

### First Grade Science:

#### Standard 3, Objective 1

Analyze changes in the movement of nonliving things.

- Describe, classify, and communicate observations about the motion of objects, e.g., straight, zigzag, circular, curved, back-and-forth, and fast or slow.
- Compare and contrast the movement of objects using drawings, graphs, and numbers.
- Explain how a push or pull can affect how an object moves.

#### Standard 3, Objective 2

- Analyze objects and record their properties.
- Sort, classify, and chart objects by observable properties, e.g., size, shape, color, and texture.
- Predict measurable properties such as weight, temperature, and whether objects sink or float; test and record data.
- Predict, identify, and describe changes in matter

when heated, cooled, or mixed with water.

#### Standard 4, Objective 1

Communicate observations about the similarities and differences between offspring and between populations.

- Communicate observations about plants and animals, including humans, and how they resemble their parents.
- Analyze the individual similarities and differences within and across larger groups.

#### Standard 4, Objective 2

Living things change and depend upon their environment to satisfy their basic needs.

- Make observations about living things and their environment using the five senses.
- Identify how natural earth materials (e.g., food, water, air, light, and space), help to sustain plant and animal life.
- Describe and model life cycles of living things.

### Second Grade Science:

#### Standard 3, Objective 1

Communicate observations about falling objects.

- Observe falling objects and identify things that prevent them from reaching the ground.
- Communicate observations that similar objects of varying masses fall at the same rate.

#### Standard 3, Objective 2

Compare and contrast the differences in how different materials respond to change.

- Model physical changes of various materials.
- Investigate and provide evidence that matter is not destroyed or created through changes.

#### Standard 4, Objective 1

Tell how external features affect an animals' ability to survive in its environment.

- Compare and contrast the characteristics of living things in different habitats.
- Develop, communicate, and justify an explanation as to why a habitat is or is not suitable for a specific organism.
- Create possible explanations as to why some organisms no longer exist, but similar organisms are still alive today.

#### Standard 4, Objective 2

Identify basic needs of living things (plants and animals) and their abilities to meet their needs.

- Communicate and justify how the physical characteristics of living things help them meet their basic needs.
- Observe, record, and compare how the behaviors and reactions of living things help them meet their basic needs.
- Identify behaviors and reactions of living things in response to changes in the environment including seasonal changes in temperature and precipitation.

### Third Grade Science:

#### Standard 3, Objective 1

Demonstrate how forces cause changes in speed or direction of objects.

- Show that objects at rest will not move unless a force is applied to them.
- Compare the forces of pushing and pulling.
- Investigate how forces applied through simple machines affect the direction and/or amount of resulting force.

#### Standard 3, Objective 2

Demonstrate that the greater the force applied to an object, the greater the change in speed or direction of the object.

- Predict and observe what happens when a force is applied to an object (e.g., wind, flowing water).
- Compare and chart the relative effects of a force of the same strength on objects of different weight (e.g., the breeze from a fan will move a piece of paper but may not move a piece of cardboard).
- Compare the relative effects of forces of different strengths on an object (e.g., strong wind affects an object differently than a breeze).
- Conduct a simple investigation to show what happens when objects of various weights collide with one another (e.g., marbles, balls).
- Show how these concepts apply to various activities (e.g., batting a ball, kicking a ball, hitting a golf ball with a golf club) in terms of force, motion, speed, direction, and distance (e.g. slow, fast, hit hard, hit soft).

#### Standard 4, Objective 1

Demonstrate that gravity is a force.

- Button to show lessons.
- Demonstrate that a force is required to overcome gravity.
- Use measurement to demonstrate that heavier objects require more force than lighter ones to overcome gravity.

#### Standard 4, Objective 2

Describe the effects of gravity on the motion of an object.

- Compare how the motion of an object rolling up or down a hill changes with the incline of the hill.
- Observe, record, and compare the effect of gravity on several objects in motion (e.g., a thrown ball and a dropped ball falling to Earth).
- Pose questions about gravity and forces.

### Sixth Grade Science:

#### Standard 4, Objective 2

Describe the appearance and apparent motion of groups of stars in the night sky relative to Earth and how various cultures have understood and used them.

- Locate and identify stars that are grouped in

patterns in the night sky.

- Identify ways people have historically grouped stars in the night sky.
- Recognize that stars in a constellation are not all the same distance from Earth.
- Relate the seasonal change in the appearance of the night sky to Earth's position.
- Describe ways that familiar groups of stars may be used for navigation and calendars.

### Sixth Grade Social Studies:

#### Standard 1, Objective 4

Analyze how the earliest civilizations created technologies and systems to meet community and personal needs.

- Identify innovations in manmade structures over time (e.g. irrigation, roads, building materials) and their influence on meeting needs.
- Examine the evolution and importance of writing.
- Identify cultural expressions that reflect these systems (e.g. architecture, artistic expression, medicine, philosophy, drama, literature).
- Compare social classes, vocations, and gender roles within ancient civilizations.

### Eighth Grade Science:

#### Standard 4, Objective 1

Investigate the transfer of energy through various materials.

- Relate the energy of a wave to wavelength.
- Compare the transfer of energy (i.e., sound, light, earthquake waves, heat) through various mediums.
- Describe the spread of energy away from an energy-producing source.
- Compare the transfer of heat by conduction, convection, and radiation and provide examples of each.
- Demonstrate how white light can be separated into the visible color spectrum.

#### Standard 4, Objective 2

Examine the force exerted on objects by gravity.

- Distinguish between mass and weight.
- Cite examples of how Earth's gravitational force on an object depends upon the mass of the object.
- Describe how Earth's gravitational force on an object depends upon the distance of the object from Earth.
- Design and build structures to support a load.
- Engineer (design and build) a machine that uses gravity to accomplish a task.



# FLIGHT

## **EXHIBIT OBJECTIVE:**

FLIGHT is a permissive, interactive exhibit that allows visitors and students to explore the history, culture, science and technology of the phenomenon of flight.

## **EXHIBIT COMPONENTS/TABLE OF CONTENTS**

- 1 Leonardo Da Vinci Wall
- 1 Dream Tunnel
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## LEONARDO DA VINCI WALL

### Student Walkthrough:

As with any exhibit at The Leonardo, our first objectives are to support The Leonardo's mission and make connections to our namesake, Leonardo da Vinci. The Da Vinci Wall makes many direct connections to one of Leonardo's principle fascinations: the project of human flight.

Students will first be introduced to this historical fact and then peruse the contents of the wall, which will present engaging evidence of it. Students will see the actual sketches da Vinci did of wing designs, an ornithopter, an aerial screw, a hang glider, and a parachute — with quotes about these designs from da Vinci himself, stories about his life and the relevant notes about his varied sources of inspiration.

### Learning Objectives:

- Learn why there is an exhibit on the subject of flight here at The Leonardo.

## DREAM TUNNEL

### Student Walkthrough:

The only entrance to FLIGHT is through the Dream Tunnel and 1969 Room components, which are designed to be experiential, with implicit learning objectives.

In studying the intricate ceiling of the Dream Tunnel, students will learn that for as long as we have been here on Earth, human beings have marveled at birds and other creatures that soar through the skies — the drive to fly is universal across time and place. The constellational images were carefully curated, designed and arranged to demonstrate that every culture, in its own way, has dreamt of flight.

### Learning Objective:

- Observe that the project of flight is connected deeply to human history, science, and technology.

## 1969 ROOM

### Description:

The Dream Tunnel component will lead students into the 1969 Room component, where two child mannequins sit looking at the original footage of the famous 1969 moon landing. This historic moment was specifically chosen as a moment when something that was previously a dream was made a reality. Students can imagine themselves as the child mannequins and wonder what future events they might experience (the first person on Mars, for example.) The exhibits staff at The Leonardo call this component the "beating heart of the exhibit."

### Learning Objective:

- Highlight a historic moment that captures the emotion of inspiration animating the entire exhibit.

## INTERACTIVES

### Conceptual Organization:

There are seven core interactives (labeled "Flight Tests") within the exhibit structure. Four of the seven are devoted to covering one of the four forces of flight each: lift, drag, thrust and weight. The remaining three are each devoted to the three principle modes of flight: buoyant flight (e.g. balloons), projectile flight (e.g. rockets), and aerodynamic flight (e.g. airplanes.)

## FLIGHT TEST: THRUST

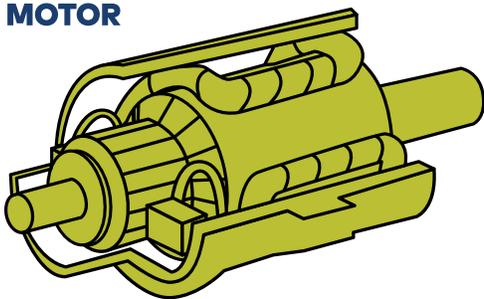
### Student Walkthrough:

Students will engage a race between three airplanes with different motor powers on a skytrack and watch who wins.

### Central Concept:

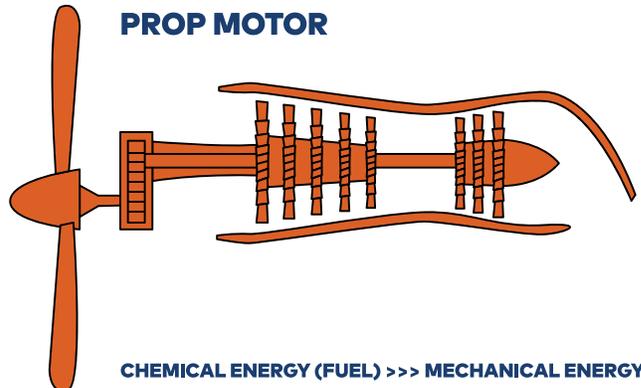
Thrust is the force that moves an aircraft through the air. Newton's 3rd law says that if you push on something it pushes back with equal force. So if an airplane pushes on the air, the air pushes back, thrusting us through the sky.

#### ELECTRIC MOTOR



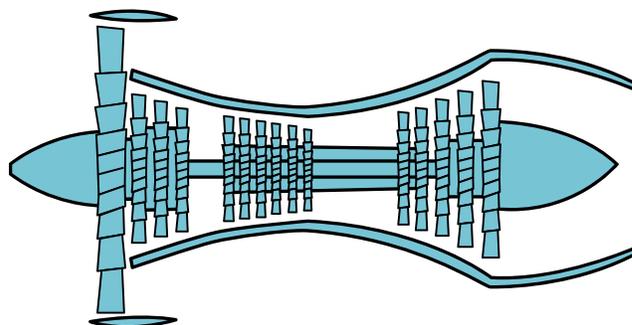
ELECTRICAL ENERGY >>> MECHANICAL ENERGY

#### PROP MOTOR



CHEMICAL ENERGY (FUEL) >>> MECHANICAL ENERGY

#### JET ENGINE



CHEMICAL ENERGY (FUEL) >>> MECHANICAL ENERGY

## FLIGHT TEST: LIFT

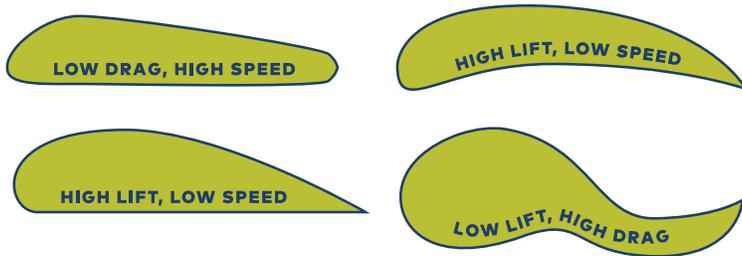
### Student Walkthrough:

Students will make controlled adjustments to an airfoil, testing which factors contribute to an effective or ineffective airfoil.

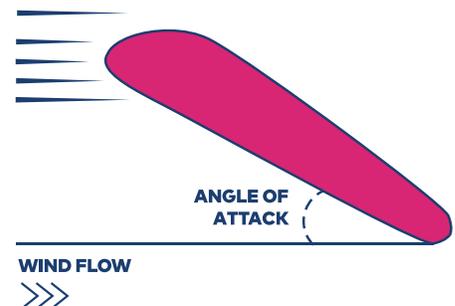
### Central Concept:

The amount of lift a wing creates depends on three crucial factors: airfoil shape, wing area and angle of attack.

Airfoil shape examples:



Angle of Attack diagram:



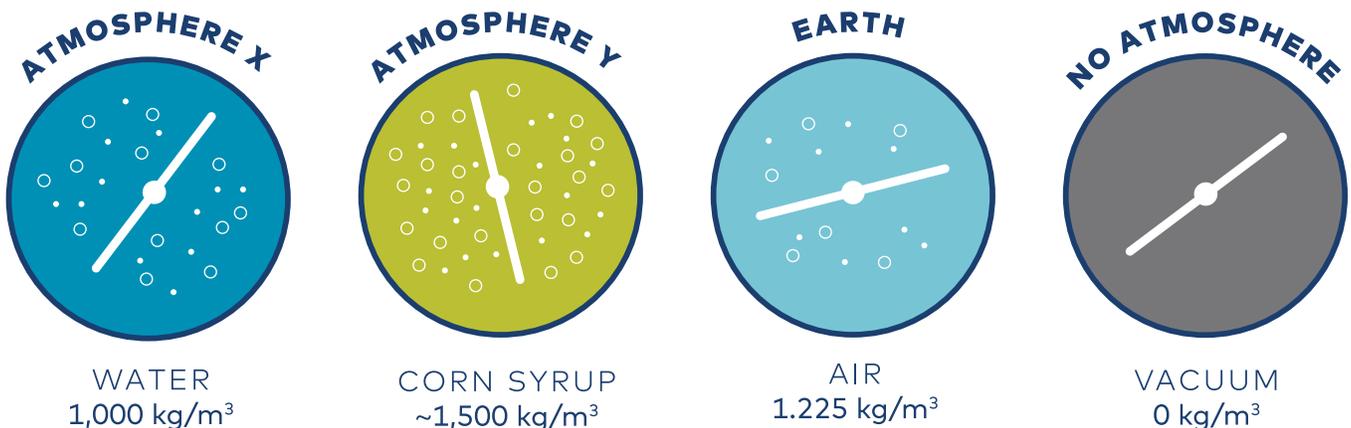
## FLIGHT TEST: DRAG

### Student Walkthrough:

Students will spin paddles and physically feel the resistance generated by different "atmospheres" (in this case, corn oil, water, air and a vacuum.)

### Central Concept:

Drag is the force felt moving through a substance, like the resistance we feel swimming through water. Airplanes flying through the Earth's atmosphere also experience drag, because air acts just like a liquid.



## FLIGHT TEST: WEIGHT (TERMINAL VELOCITY)

### Student Walkthrough:

Students determine the terminal velocity of an object in a wind tube by increasing wind speed until that object floats.

### Central Concept:

The speed of the wind in the tube is the fastest speed the object could reach falling from the sky! Terminal velocity is the maximum speed an object reaches when falling. It depends on the medium the objects falls through, the shape of the object and its weight!

Just like in the atmosphere, the forces in the tube cancel each other. The weight of the object is in balance with the force of the wind from the fan. In the atmosphere, the object travels at the terminal velocity, but in our simulation, the wind travels at that velocity.



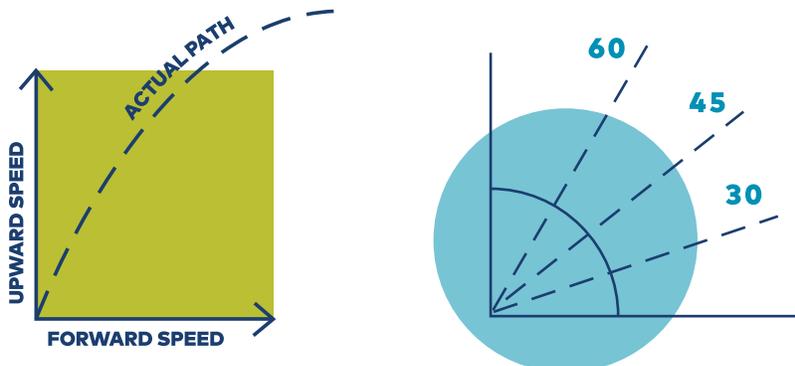
## FLIGHT TEST: PROJECTILE TRAJECTORIES (ROCKET)

### Student Walkthrough:

Students will launch soft projectiles through an air cannon which they will be able to aim. The process of aiming will allow them to explore the central concept: the effect of trajectory angle on distance travelled.

### Central Concept:

There's a connection between angles and how far something will go! Imagine an object's path being split into two parts: an upward part and a forward part. The upward part determines how much time the object stays in the air. The forward part determines how far the object will go, as long as it stays in the air. If our object only goes upwards it won't go anywhere. If it only goes forward, it won't get off the ground. Is there a middle ground between these two?



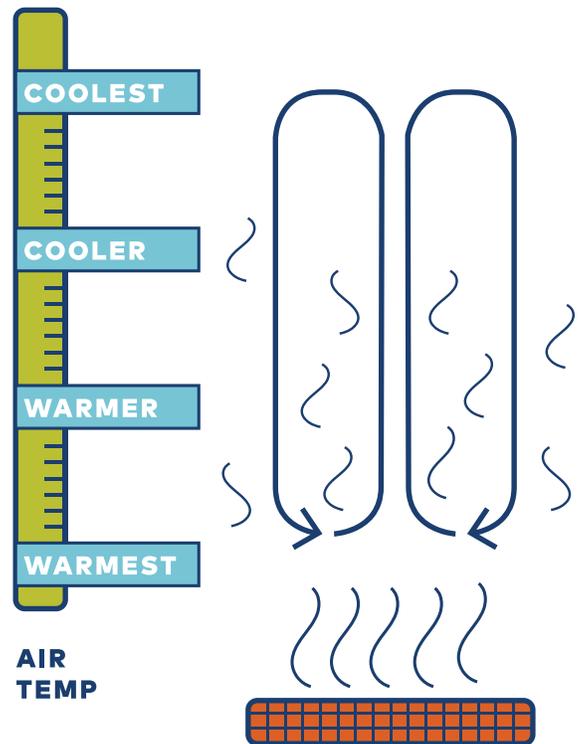
## FLIGHT TEST: BUOYANT FORCE (BALLOONS)

### Student Walkthrough:

Students will control the delivery of heat to a balloon, causing it to rise.

### Central Concept:

Air is made of molecules. Heat is a form of energy. When air molecules are heated they become more energetic. They zip around and move away from each other – the air expands. In a hot-air balloon, the air molecules collide with the inside of the balloon, creating pressure, while the outside air presses against the balloon surface in the opposite direction. When the inside pressure is greater than the outside pressure, the balloon will begin to rise.



## FLIGHT TEST: AIRFOILS (AIRPLANES)

### Student Walkthrough:

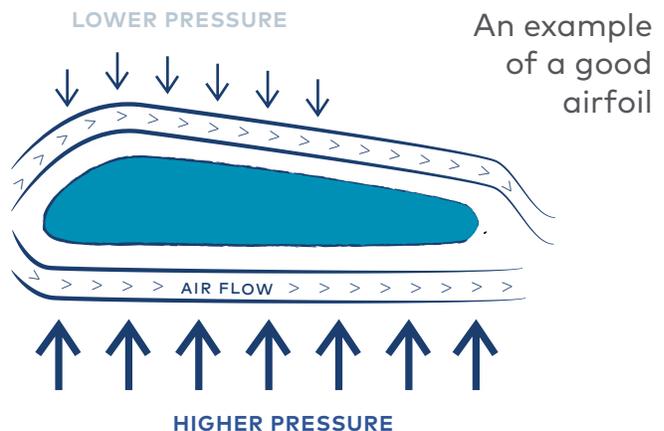
Students will choose different airfoils to test and compare in a wind tunnel.

### Central Concept:

An airfoil is any shape that generates lift when moving through the air. A wing is an airfoil. Bernoulli's Principle says that when pressure goes up, velocity (or speed) goes down. When the air above a wing moves quicker, the pressure decreases. As air below the wing slows down, the pressure increases. The net difference between these pressures produces lift.

The math behind Bernoulli's Principle:

$$P \propto \frac{1}{V}$$



# INNOVATORS, AVIATORS, EXPLORERS

## Description:

It took all kinds of people to get humanity airborne, and it will take those same kinds of people to transform the way we fly today. Innovators solve stubborn problems in aviation by thinking about them in different ways, even if their solutions seem a little crazy. Aviators daringly master the technology of aircraft and learn things about them no one else knows. Explorers are intrepid souls who look to new frontiers and feel the ambition to be the first to get there.

## Learning Objectives:

- Students will read about the varied personality types highlighted by the history of flight so that they can more easily identify with them.



## Did You Know?

There are two people on this wall from Utah; Aviator Gail Halvorson and Explorer Jake Garn. Can your students find them?

## C131

### Description:

The C131 Convair Samaritan proved to be a highly reliable aircraft throughout its 40 years of use by the U.S. Air Force and Navy (from 1950 to 1990.) The C131 in this exhibit was used for transporting important military personnel and was found in a huge airplane graveyard in the desert of Arizona.

### Did You Know?

The Davis-Monthen Air Force Boneyard where our C131 is from is the largest in the world! Check the Teacher Resources section at the end of this guide for the URL.

## MIG 21 MONOLITH

### Description:

The MiG family is made up of versatile and speedy fighter jets that the Soviet Union used to defend its vast airspace. When they were first being produced in 1940, MiGs spurred Soviet innovation in supersonic technology, cabin pressurization and radar. The MiG that hangs from this exhibit's ceiling is decades old, but MiG jets are still being built — the newest batch arrived in 2007.

### Did You Know?

The MiG above you is a MiG-21UM, released in 1968 as a two-seat training version of the MiG-21MF. "UM" means "Uchebny Modenizovanny," or "Modernized Training."

## BIPLANE & THE CULTURE OF FLIGHT WALL

### Description:

The Oldfield Baby Great Lakes is a build-it-yourself biplane. A biplane is simply a plane with two wings stacked one above the other. Even though most planes now have one set of wings, the biplane is still a source of inspiration for the many people who love to look at, fly, learn about, and build airplanes. As a tribute to this wonderful culture of flight, The Leonardo — with the help of our community — will build our very own biplane, right here in this exhibit.

### Learning Objective:

- Students will observe the ways in which flight has affected broader cultures and has inspired whole subcultures.

### Did You Know?

The biplane was brought here with the help of the Experimental Aircraft Association, which promotes and supports interest and exploration in aviation for all ages.

## KIOSKS

### Conceptual Organization:

- Each kiosk focuses on a particular mode: buoyant, aerodynamic and projectile modes.
- All kiosks are divided into history, science and technology.

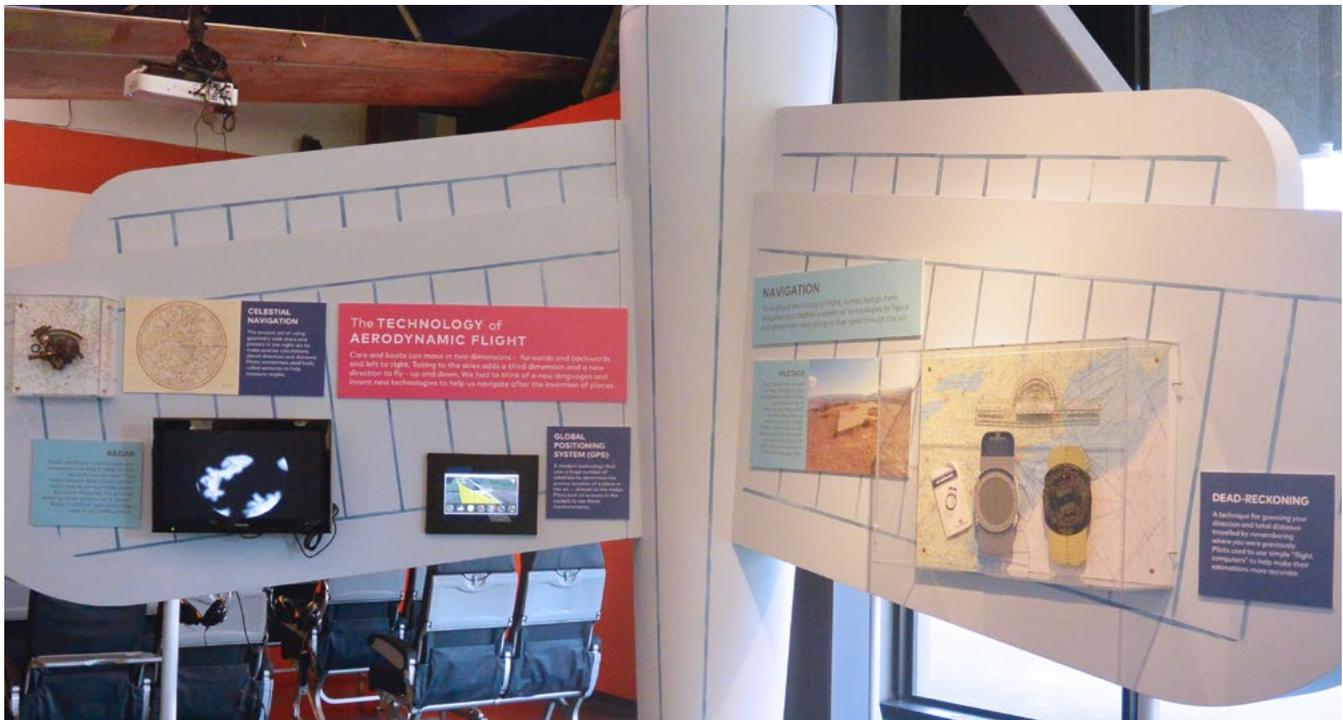
### AERODYNAMIC KIOSK:

#### Student Walkthrough:

Here students focus on the mode of winged, or aerodynamic flight, mostly within the time period of American aviation during the early 20th century. Students will explore the science, technology and history of this era through the language and mood of feverish competition and intrepidity – conveyed by keywords like Bigger, Larger, Faster, Higher. Scientific subjects like Newtonian forces, the geometry of navigation, air pressure and the Doppler effect are presented to the student in this context. They will also learn about the technologies developed for moving through the air – such as airfoil function and plane flap types – and historical methods of navigation, from dead-reckoning to radar. Finally, students will explore the history of this mode through ten or so key “moments” in this period, high points in the long list of accomplishments and feats in the development of the modern airplane.

#### Learning Objectives:

- In covering aerodynamic (winged) flight, the student will explore the history, science and technology of this flight mode.



## ROCKET KIOSK:

### Student Walkthrough:

This kiosk introduces the mode of rocket flight to the student, with a thematic emphasis on ingenuity and problem solving. It presents the science, technology and history of rocketry while figuratively suggesting that space is the new frontier that the skies once were. Scientific concepts are distilled for the student into four major obstacles that are unique to rocket/space flight, such as the speed required to escape Earth's gravity and the uniquely dangerous properties of the environment of space. Technology, again focused on tactile experiences, will convey to the student a simple dichotomy between the amount of energy needed to leave Earth and the amount of energy required to move through space, while covering the relevant technologies on either side. The rocket history the student surveys will introduce a dozen historic moments in which human beings brought their "Earthly" knowledge to bear on the myth-like ambition of space flight.

### Learning Objectives:

- In covering rocket flight, the student will explore the history, science and technology of this flight mode.



## BUOYANT KIOSK:

### Student Walkthrough:

At this kiosk students will explore the mode of lighter-than-air, or buoyant flight, with themes of simplicity and inspiration. The kiosk presents the science, technology and history of this mode with an emphasis on taking cues from the natural world. In the science section, students will see the story of three natural gases – air, hydrogen and helium – and how they enable different kinds of buoyant flight, such as a recreational hot-air balloon or a dirigible (airship) like the Hindenburg. Technologies are conveyed to the student in a highly tactile way, presenting (literally) the basic materials needed to form different kinds of balloons (featuring canvas and silk) and different materials that modern baskets are made from, like rattan (wicker) or aluminum. Students will peruse the history of buoyant flight, which selects roughly 10 separate moments from its long development (stretching back at least to the 16th century), while focusing on the necessity to study nature in order to fly.

### Learning Objective:

In covering buoyant flight, the student will explore the history, science and technology of this flight mode.



## THE IMAGINATION OF FLIGHT

### Description:

Viewing a short, entertaining film, students will learn that to get off the ground we had to experience many failures--sometimes very funny ones. But it was our willingness to experiment and fail that made human flight a reality. All the machines and gizmos we created over the centuries offer a unique window into the human imagination.

### Learning Objectives:

- Students will observe that failure and funny ideas are necessary to make grander achievements in flight.

## ANIMAL FLIGHT

### Description:

Nature figured out how to fly before humans. Leonardo da Vinci believed that the only way we could ever fly was by copying what we saw in the natural world. Birds, bees, bats squids and even squirrels each offer their own secrets for reaching the skies.

### Learning Objectives:

- Even the youngest students can learn a wide variety of solutions nature has imagined for the problem of flight.

## FUTURE OF FLIGHT

### Student Walkthrough:

Students will explore a large-scale infographic that outlines some of the problems that exist in the realm of terrestrial flight and frontier of spaceflight.

### Description:

The larger project of human flight is never over. There are problems we need to solve soon: What new materials can help us build better aircraft? Could solar-powered aircraft help protect our environment? What kinds of things can we do with drones?

Then there are the captivating questions about the future of flight: When will human feet touch down on Mars? How soon before commercial space travel is here? How can we travel at the incredible speeds necessary to reach other planets, other stars?

These and other questions will keep the heart of human flight beating for centuries to come.

### Learning Objectives:

- Students will learn what problems exist on the horizon of flight, and point to how they could solve them.

# THIRD GRADE PRE- AND POST-VISIT GUIDE

## Description

Students will "defy gravity" by participating in a lively experiment using their own sense of movement to understand the basics of flight. Students will do an experiment in which they "fly" for short periods and then evaluate factors that might either decrease or increase their "flight duration."

Students will gain a greater understanding of the four forces of flight, which include:

- Drag
- Thrust
- Lift
- Weight

## Objectives:

Science Standards 3.3.1, 3.3.2, 3.4.1, 3.4.2. Refer to inside cover of this guide for detailed descriptions of these standards.

## Explore: Let Students Work On Problems with Minimal Direct Instruction

Materials:

- Large sheet of paper
- Tape
- Dirt or stamp pad
- Ruler or meter stick.
- Colored markers to differentiate each student
- Timer/stopwatch with a second hand

Preparation:

Activity is to be done in groups of 3-4 students each. Tape a large piece of paper to the wall for each group of students (brown wrapping paper or sheets of newspaper will do). Each student will need an ink pad, pencil, ruler or meter stick and tape

## Pre-Visit Experiment #1

- Tell students: "Today we are going to DEFY GRAVITY and see how high we can fly!"
- Divide students into cooperative groups and instruct students to gather by the paper on the walls, then number the students in the order they will take turns.
- Instruct students to observe you as you model the following:
  - Dip one finger in ink and while standing with feet flat on the floor, stretch arms out as far as they can and mark the highest point you can reach on the paper. Instruct students to put initials on paper. Tell students "I will count to three and then say JUMP! At that moment you will need to jump and mark the paper by touching it at the top of your jump. You will then need to initial you mark.
  - Prep the students and then begin the activity with enthusiasm, giving students three turns each and reminding them to initial each time.
  - Instruct students to then work cooperatively and use a ruler or meter stick to measure the vertical difference in height between their standing and jumping marks, explaining that this is how high they can jump. Record answers and observations.
  - You probably noticed that taller kids did not necessarily have higher jumps. Remember, you measured the jump height from your reach. (The standing mark) and not the ground. The best jumpers in the world can clear heights up to 2.4 meters, but they lift their center of mass considerably higher than that distance!

Ask the students/Turn and Talk: Is jumping really flying? Have students share out responses. Some things like rockets, cannonballs, and baseballs fly like jumping kids. They are pushed into the air by engines or muscles. Airplanes are more complex! Engines push them forward, and air pushes and holds them up. Thrust, drag, weight, and lift are the four forces.

Remind students that these are forces they will learn about in their visit to the FLIGHT exhibit.

## Pre-Visit Experiment #2

Now that we have compared how high we can jump to objects like rockets, cannonballs and baseballs, let's ask two new questions:

1. How long do you think you can fly?
2. How long do you think you can stay in the air when you jump?

At this time call 1-3 students and then one at a time instruct them again with a countdown and when you say "JUMP!" Be sure to time their jump and record it, using a stopwatch.

## Explain: Get Students to Explain Concept in Their Terms, Then Provide Formal Definitions

When activity is completed, ask students the following two questions:

1. What do you think might help you jump higher?
2. What else could you do to make your jumps last longer?

Create whiteboard or anchor chart of responses. Refer to key vocabulary terms below as you share out responses as a class.

### Vocabulary:

**Thrust:** The force developed by a propeller or jet engine that drives an airplane through the air. In the jumping activity, student's leg muscles provided thrust.

**Weight:** A measure of the heaviness of an object.

**Drag:** The resistance caused by the shape of an object and its movement throughout the air.

**Lift:** The upward force created by a difference in air pressure. Moving air creates this difference as it moves around an airfoil (e.g., a wing).

### Further Questions:

"If you were thinking of jumping off a trampoline or diving board; launching yourself with a pole vault, catapult, or a rocket, or exercise to get stronger muscles, springy shoes or a rocket booster might help your jump, then you were thinking about thrust. (The force that pushes you during flight).

"If you were thinking that you needed to wear lighter clothing, lose weight, or travel to a planet with smaller gravity than earth's (the moon), you were thinking about weight (the force that holds you to the ground)

If you thought that wearing skin-tight clothing or that a slick suit or helmet would make you jump higher or that a parachute would keep you in the air longer, then you were thinking about drag (the resistance of air against things that fly).

"Most people have experienced how thrust, drag and weight can help them jump higher, or "fly", but few people are familiar with lift. Lift is a push that comes from the air. You were thinking about this force if you decided that wearing wings or holding helium balloons would help you jump higher. While planes and birds have to be moving to get enough of this push to fly, hot-air balloons are light enough for their size that the air will lift them up whether or not the balloon is moving."

Ask students: "Do you think that everything that flies uses all four forces?" The answer is no. Only two forces - weight and thrust - act on spacecraft. Lift and drag are not factors in spacecraft flight, because there is no air in space.

## Evaluate: Assess Students' New Knowledge or Skills

**Post-Visit Activities: Refer to our Teacher Resources page at the end of this guide for helpful links and instructions.**

- Build a timeline of the history of flight or aviation.
- Have students create a "Living Museum" of aviators and explorers in the gym or cafeteria of your school (see resources). Invite students, parents and teachers to the live museum one day during their recess or PE time.
- Have students partner with another student and write a short paragraph of what life would be like if we traveled to Mars one day as a bell ringer activity in writing .
- Have them keep the following questions in mind:
  1. Could it be possible to land on Mars one day? Why or why not?
  2. Could it be possible to travel at incredible speeds one day? Why or why not?
- Have students research in cooperative groups the history of what a MIG and C131 is. Have them list different times they were used throughout history. Research maps in the US that contain aviation boneyards/graveyards. Take a virtual field trip if possible.
- Discuss the Flight Simulator, the MiG and C131. Ask the kids to imagine themselves flying from one point to another. Complete the map and distance activity with your student using technology where they measure possible distances from one city to another, a great activity to do around Math Lessons!

# SIXTH GRADE PRE- AND POST-VISIT GUIDE

## Description:

Students will enjoy learning about Leonardo da Vinci and his fond interest in flight while simultaneously exploring throughout the exhibit and gaining a greater understanding of contributions that have been made by humankind throughout history.

## What objectives are met?

Science Standard 6.4.2 and Social Studies Standard 6.1.4. Refer to inside cover of this guide for detailed descriptions of these standards.

## Engage: Get Students To Ask Questions and Show Prior Knowledge

### Pre-Visit Activities

Ask Students to brainstorm if they know what cultures or civilizations had an early interest in flight.

- Chinese kite flying in 400 BC

Ask the students if they know of any examples of early flying machines, real or imagined.



- Greek mathematician and engineer, Hero of Alexandria (sometimes known as "Heron of Alexandria") created an "aeolipile" (seen left), an invention which used jets of steam and air pressure to create rotary motion.

- Evidence of man's desire to fly appears in Myths and Legends, like the Greek Legend of Pegasus, a winged horse. Another ancient Greek legend, Icarus and Daedalus made wings of wax and feathers and attempted to fly.

Ask students if they know how Leonardo da Vinci, made a contribution to flight.

- During the 15th century Da Vinci developed plans for an Ornithopter, and although it was never created, today's helicopter is based on the concept.

- Optional: Show timeline that outlines the history of flight. Refer to Teacher Resources at the end of this guide.

Ask students to brainstorm any examples of modern developments in flight.

- Airplanes, biplanes, jets, drones
- Rockets, stealth fighters, etc.
- Hot air balloons, hang gliders

Throughout history, civilizations and societies have continued to create technologies to meet their needs. Ask students to keep this in mind as they learn about navigation. Ask students: How did people navigate during ancient times?

- Maps, Compasses, Stars

Before we had maps and GPS, before there were complex math instruments to guide pilots, there were "reference points" used to assist in navigation. Constellations were used as "reference points".

Ask students if they can brainstorm any cultural examples of constellations used as "reference points."

1. Sailors guiding ships through the night that transported African Americans who were fleeing slavery. Refer to the song The Drinking Gourd which represented the Big Dipper (see right), found near the North Star and explain that African Americans used the Gourd as their ticket to freedom.
2. Oregon Trail Pioneers used constellations during their migration west.

Remind students that during their visit they will be introduced to the history, technology and science of flight and to look for early examples of flight and navigational tools. Then, compare and contrast these with modern day flight.

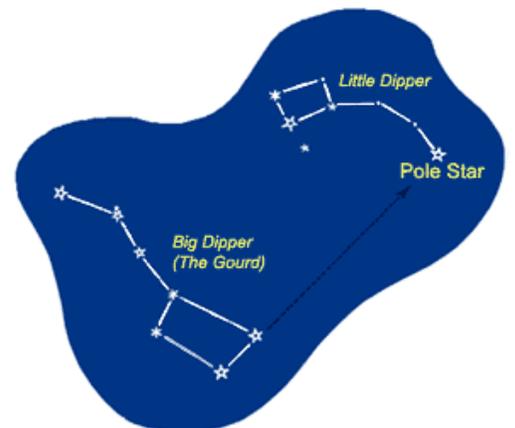


Image from [www.parents-choice.org](http://www.parents-choice.org)

## Explore: Let Students Work On Problems with Minimal Direct Instruction

During your visit be sure to begin at our Da Vinci Wall (refer to the education guide). From this starting point you will be able to:

- Enter the exhibit through the Dream Tunnel while observing constellations and early examples of imaginary flight machines. Refer to the "resources" section to get detailed explanations of what you are actually viewing!
- Observe various instruments used historically in aviation. Hear a sonic boom and the first sounds to ever come from space.
- Study the history of aviation, rocket technology and buoyancy.
- Practice using Flight Simulators that were donated by Rockwell Collins and used for real pilot trainings.
- Experience one of our "Flight Test" interactive displays that focuses on the four forces of flight as well as various modes of flight.
- Get up close to a C131, view a MiG, and learn about their origin.
- Pause at the Future of Flight wall and learn about NASA's plans for space exploration within the next decade and see some drones.

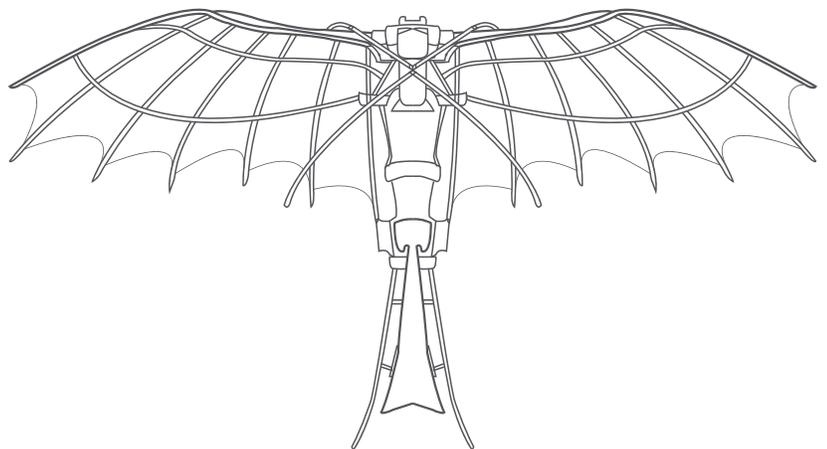
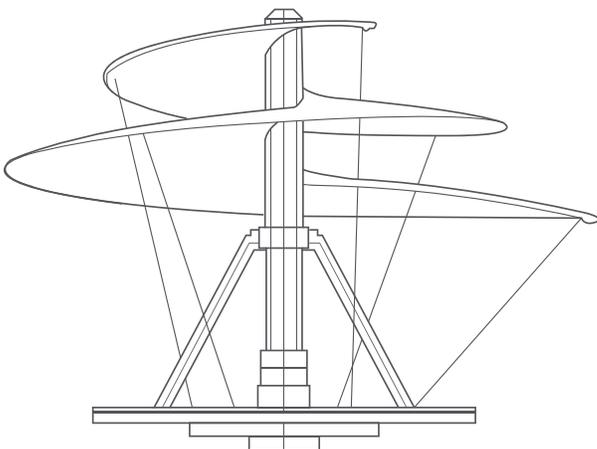
## Explain: get students to explain concept in their terms, then provide formal definitions

**Post-Visit Activities: Refer to our Teacher Resources page at the end of this guide for helpful links and instructions.**

After the visit to the Leo, ask students the following questions:

1. What is a constellation? *A pattern in the stars that has been identified and named.*
2. What is the name of the song that was used by the Underground Railroad in which the star Polaris and the Big Dipper is used as a "reference point?" *"Follow The Drinking Gourd."*
3. Define navigation and provide an example of a flight instrument that is used in modern times. *Navigation: the process or activity of accurately ascertaining one's position and planning and following a route. Radio navigation, Automatic Direction Finder, GPS or Global Positioning System.*
4. Give one example of a complex math instrument that was used to guide pilots in earlier times. *Example: sextant - a device which helped pilots measure angles.*
5. What is pilotage? *The process of directing the movement of a ship (image of pilotage) or aircraft by visual or electronic observations of recognizable landmarks.*
6. List the Four Forces of Flight. *Lift, drag, thrust, and weight.*
7. What are the Three Modes of flight? Give one example of each. *Buoyancy - hot air balloons; projectile flight - rockets; aerodynamic - airplanes.*
8. What is the name of the flight machine that inspired the building of our modern helicopter? Who developed the sketches for this? *Ornithopter; Leonardo da Vinci.*
9. What culture first developed early attempts at flight and in what century? *China - 400 B.C.*

Below: Leonardo's Aerial Screw and Ornithopter



## Elaborate: Let Students Apply New Knowledge or Skills to a New Project

### TCHART on Cultural and Scientific uses of GPS and Constellations

1. Have students generate a list of examples for each and share out.
2. Review the responses given as a class and refer to resources for more information if needed.

GPS: Cultural Uses	GPS: Scientific Uses
<ul style="list-style-type: none"><li>• Geocaching (using clues and GPS tracking to find hidden caches)</li><li>• Recreational: hiking, biking, skiing, etc.,</li><li>• Cars, boats, planes, navigation (ex. Garmin is a company that sells navigation devices)</li><li>• Smart phone: navigation</li></ul>	<ul style="list-style-type: none"><li>• Dept. of Defense uses it to track land, sea and airborne vessels to determine their three dimensional position, velocity and time in any type of weather. This is far better method than radio navigation systems.</li><li>• Meteorologists can track weather balloons</li><li>• Surveying: Measuring how buildings might shift in an earthquake or after a disaster like Oklahoma bombings</li><li>• Marine archeology: Used to help guide boats that are tracking shipwrecks</li><li>• Geologists: Used data to determine Mt. Everest is getting taller</li><li>• Used in Minnesota by scientists to track migration patterns and feeding habits of deer</li></ul>

Constellations: Cultural Uses	Constellations: Scientific Uses
<ul style="list-style-type: none"><li>• Religion</li><li>• Storytelling: Myths, legends, tales told by Greeks, Mayans, Native Americans, Celts, Asians</li><li>• Agriculture: Calendars</li><li>• Astrology</li><li>• As navigation: Served as sky map for Underground Railroad, westward expansion</li></ul>	<ul style="list-style-type: none"><li>• Astronomy: Tracking bright stars, locating galaxies and nebulae (clusters of gas and dust)</li></ul>

### Writing Activity:



Have students write a short narrative in which they identify themselves as a "Dystopian Protagonist" struggling to survive in a dystopian society. Tell students they are attempting to escape this society by planning a secret flight mission and the story should include sensory language and dialogue between characters. View the following resource for a definition of dystopian society.

[http://www.readwritethink.org/files/resources/lesson\\_images/lesson926/DefinitionCharacteristics.pdf](http://www.readwritethink.org/files/resources/lesson_images/lesson926/DefinitionCharacteristics.pdf)

Ask students to generate a short list of some dystopian novels written for middle-schoolers (e.g. *Hunger Games* series by Suzanne Collins, *Among the Hidden* by Margaret Peterson Haddix, *City of Ember* by Jeanne DuPrau, *Divergent* series by Veronica Roth, *Maze Runner* by James Dashner)

Before students write about their experiences, ask them to think about the following questions, keeping their visit to the Flight exhibit in mind.

- What is their final destination? Mars? A space station? Another part of the planet? Were there any aviators or explorers that inspired them or that could be potential characters in their narratives?
- What kinds of examples of modern day or ancient flying machines that they saw in the museum might be useful, if any? (Ask students to recall what they saw in the Dream Tunnel, or on our Future of Flight wall as a warm-up.) A hot air balloon? A rocket suit? Animal-like wings made from the forest? An ornithopter re-engineered?
- Would it be possible to use modern navigation systems or would they need to rely on constellations? Would they need to adapt and build an extraordinary device to navigate with?

## Evaluate: Assess Students' New Knowledge or Skills

**Post-Visit Activities:** Refer to our Teacher Resources page at the end of this guide for helpful links and instructions.

## TEACHER RESOURCES

Timeline of flight:

<https://www.loc.gov/exhibits/treasures/wb-timeline.html>

The History of Aviation

[https://www.grc.nasa.gov/www/k-12/UEET/StudentSite/historyof flight.html](https://www.grc.nasa.gov/www/k-12/UEET/StudentSite/historyof%20flight.html)

Famous firsts in Aviation

[https://www.teachervision.com/tv/printables/uk/Famous\\_Firsts\\_Aviation.pdf](https://www.teachervision.com/tv/printables/uk/Famous_Firsts_Aviation.pdf)

Flight Navigation systems

<http://virtualskies.arc.nasa.gov/navigation/3.html>

What is a GPS?

<https://www.loc.gov/rr/scitech/mysteries/global.html>

Students can examine the language scientists have created since the invention of flight. Ask students what "GPS" stands for and explain that it did not exist 100 years ago (now used for things like air traffic control). Discuss with students when the first GPS was introduced.

[http://www.nasa.gov/directorates/heo/scan/communications/policy/policy\\_pnt.html](http://www.nasa.gov/directorates/heo/scan/communications/policy/policy_pnt.html)

A middle schooler's guide to the history of GPS and its impact on society:

[http://www.mainemaritimemuseum.org/media/docs/resources/2013/03/08/Global\\_Positioning\\_Systems.pdf](http://www.mainemaritimemuseum.org/media/docs/resources/2013/03/08/Global_Positioning_Systems.pdf)

Constellations as a Guide: NASA Quest has provided an informative link if you want to share the song "Follow The Drinking Gourd"

<http://quest.arc.nasa.gov/ltc/special/mlk/gourd2.html>

The History behind "Follow The Drinking Gourd"

<http://www.followthedrinkinggourd.org/>

Virtual Field trip to Mars

<http://www.youvisit.com/tour/ryan.lee/87131>

Review an example of navigational equipment.

[http://www.brighthubengineering.com/seafaring/31615-marine-navigational-equipment-the-sextant/#imgn\\_3](http://www.brighthubengineering.com/seafaring/31615-marine-navigational-equipment-the-sextant/#imgn_3)

View how a Navigational Flight Plotter is used in Aviation training

<https://www.youtube.com/watch?v=5igMoXj8Nqiew>

Take a virtual tour of the Monthen-Davis boneyard where our c-131 is from.

<http://www.airplaneboneyards.com/davis-monthan-afb-amarg-airplane-boneyard.htm>

View this cool interactive map of airplanes and post WW2 aircraft boneyards and storage facilities in the United States!

<http://www.airplaneboneyards.com/map-of-plane-boneyards-united-states.htm>





**EXPLORE. ENGAGE CREATE.**

Book a field trip to The Leonardo today!

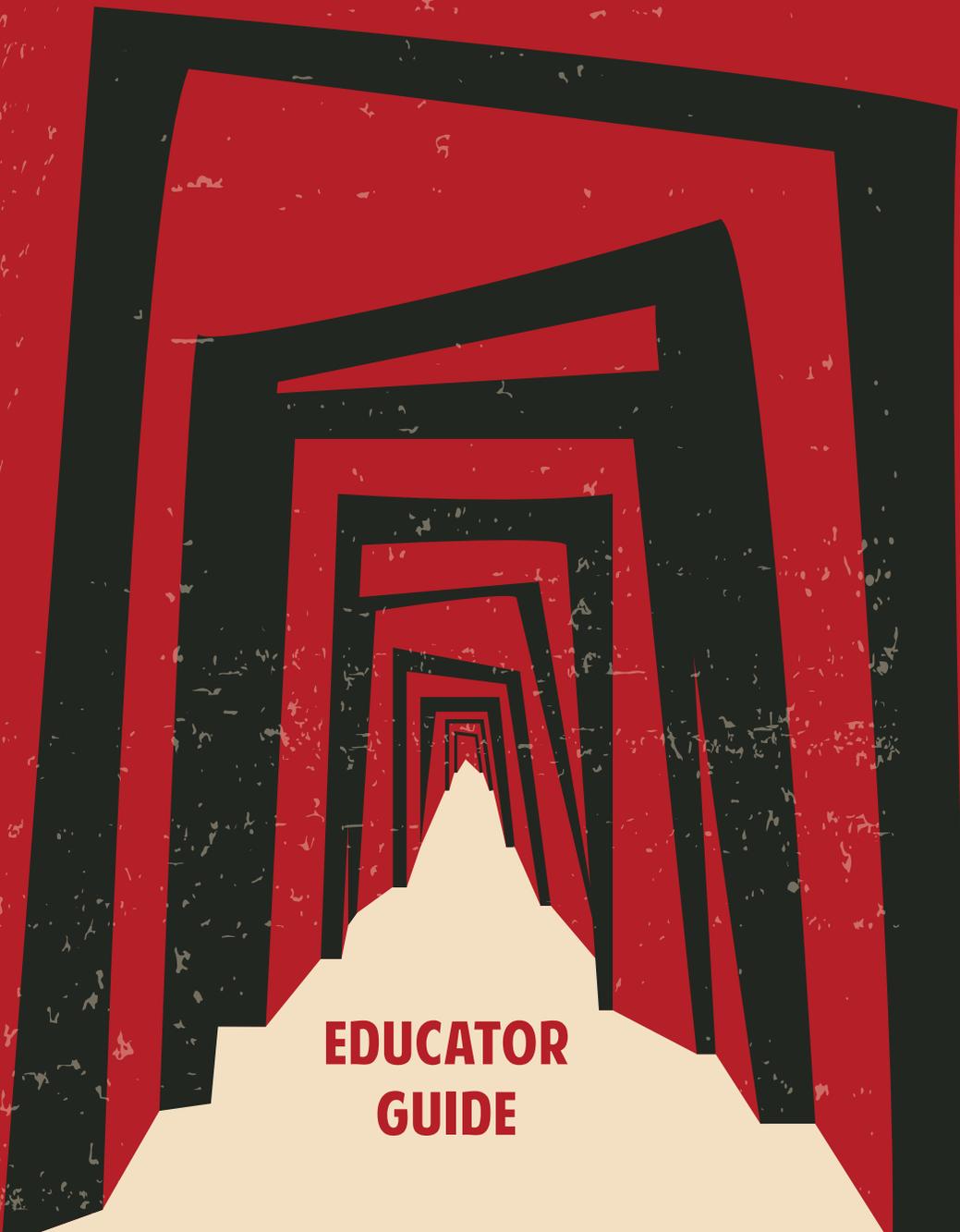
801.531.9800 ext. 103

[education@theleonardo.org](mailto:education@theleonardo.org)

[theleonardo.org/field-trips](http://theleonardo.org/field-trips)

# PERCEPTION

*the* ILLUSION  
*of* REALITY



**EDUCATOR  
GUIDE**

# HEARING

Close your eyes and the auditory sense becomes its own world. In this section, visitors put headphones on and sit for a Virtual Haircut, a carefully soundscaped experience that eerily simulates a haircut in a barbershop. Visitors will have the opportunity to master Foley art, the technique of movie sound effects. If they're up for a challenge, visitors can also try delivering an oration while wearing a Speech Jammer.

## VIRTUAL HAIRCUT

The Virtual Haircut is an immersive and passive experience that allows students to isolate their sense of hearing. The audio has been carefully soundscaped to create an eerily realistic sensory experience.

**HOW TO INTERACT** Have a seat in a real barber's chair and don the headphones. How real can it feel when your hair isn't actually being cut?

## SPEECH JAMMER

The Speech Jammer was designed to demonstrate how self-perception of our voices determines how we speak. If this process is concomitantly disrupted, it becomes extremely difficult to orate, which brings attention to the feedback loop the student normally uses to speak and takes for granted.

**HOW TO INTERACT** Put on the headphone and read a speech into the microphone. Your speech will be delayed just a fraction of a second before you hear it. How much does a change in timing affect your ability to speak?

**CORE CONNECTIONS** 3rd Theater 2.2.3.a

## FOLEY STUDIO

Foley artists reproduce everyday sound effects and add them to visual media using all sorts of props. These sounds can be anything from footsteps to breaking bones to thunder. The best Foley art is so well integrated into a film that it goes undetected by the audience. In the Foley Studio, students create sound effects and match their timing with events in real movie scenes.

**HOW TO INTERACT** Explore the world of sound effects! Foley artists use different machines and tricks to make many sound effects. Can you make the sound of a galloping horse...without a horse?

**CORE CONNECTIONS** 3rd-6th Theater 3.2



*You will find these objects in the Foley Studio - what sounds could they make?*



# SIGHT

Humanity's dominant sense can produce boggling effects and paradoxes. Visitors will peruse some of the world's most stunning illusions, use their bodies to create shadowy scenarios, and learn linguistics by seeing the amusing ways language misleads us.

## ILLUSION GALLERIES

### COGNITIVE ILLUSIONS

This illusion gallery offers a series of categories (comprising two illusions each) that demonstrate a relatively simple cognitive principle. Students can explore subtler yet profound illusions like Gestalt psychology or more striking and intricate illusions such as apparent motion and/or lateral inhibition.

### EXPERIENTIAL ILLUSIONS

This illusion gallery offers more immersive illusions with complicated effects that are extremely difficult to explain. Each illusion likely involves multiple cognitive principles—especially illusions from *MagicEye* or the colored Hermann Grid (“Blue Scintillating Dots”)—and so yield a richer, albeit mysterious experience for the student.

**HOW TO INTERACT** Observe the images on the walls. Explore illusory examples of perspective and color that trick the mind. Do you see anything that isn't really there?

**CORE CONNECTIONS** K-2nd Science 1.1-3; 3rd-4th Visual Arts 2.1; 5th Visual Arts 1.1; 5th Visual Arts 2.2.c

### PLATO'S WALL OF SHADOWS

Plato's Wall of Shadows is modelled after Plato's famous “Allegory of the Cave.” It invites students to use geometry, motion and shadows to create the appearances of objects—a.k.a. charades—and to contemplate the way reality can be hidden and distorted.

**HOW TO INTERACT** Explore light and shadow. Create shadow puppets and silhouettes with your hands, body, or props. What shadowy shapes can you create? Higher level students can consider Plato's understanding about perceptions.

**CORE CONNECTIONS** K-2nd Science 1.1-3; 3rd-4th Visual Arts 2.1; 5th Visual Arts 1.1; 5th Visual Arts 2.2.c; K Science 2.2.c; 6th Science 6.2; 3rd Visual Arts 1.1.g-h

## ANAMORPHOSIS

Anamorphosis is a distorted projection or perspective requiring the viewer to use special devices or occupy a specific vantage point to reconstitute the image. This effect can be found on the table-top activities and in two pieces of art—an untitled sketch by da Vinci and Holbein's “The Ambassadors”—near the end of the exhibit.

**HOW TO INTERACT** Observe each image or picture. Place a reflective cylinder into the focal point of each image and observe the image's reflection. How does the shape of a surface affect the way we perceive it?

**CORE CONNECTIONS** K-2nd Science 1.1-3; 3rd-4th Visual Arts 2.1; 5th Visual Arts 1.1; 5th Visual Arts 2.2.c; 6th Science 6.2.b-c

## STEREOSCOPIC IMAGES

Stereoscopy is a technique for creating or enhancing the illusion of depth in an image by means of binocular vision. Most stereoscopic methods present two offset images separately to the left and right eye of the viewer. These two-dimensional images are then combined in the brain to give the perception of depth.

**HOW TO INTERACT** Create a 3-dimensional image from two flat images. Place a pair of stereoscope glasses above a pair of images. Does looking through the glasses create the illusion of 3 dimensions?

**CORE CONNECTIONS** K-2nd Science 1.1-3; 3rd-4th Visual Arts 2.1; 5th Visual Arts 1.1; 5th Visual Arts 2.2.c; 6th Science 6.2.b-c

# TOUCH

Your skin is the largest organ of the body, a landscape of feeling. This section will allow visitors to navigate the world solely with their sense of touch. Visitors who dare to put their naked hand in the Tactile boxes can feel for what surprise awaits them. Visitors will also navigate our dimmed obstacle course, and do activities that reveal futures of their nervous system they never knew.

## TACTILE BOXES

**Tactile Boxes** are a means of isolating one sensory modality in the student, their sense of touch. Each box offers a different sensory experience or challenge. Best explored slowly, the Tactile Boxes demonstrate how largely the student depends upon sight, while giving them an opportunity to explore the details of their somatosensory world.

**HOW TO INTERACT** Explore the sense of touch without the distraction of vision. Reach into a Tactile Box to feel different objects. Can you figure out what they all are? For added difficulty, try a Tactile Challenge!

## BODY HACKS!

### DRAWBACK

The **Drawback**, one of the **BodyHacks!** elements, is a two-person activity that asks students to translate one sensory input into another, namely, from the sense of touch to the visual sense. What makes the **Drawback** activity interesting is that much of the input is lost in translation.

**HOW TO INTERACT** One person “draws” a shape or pattern onto a second person’s back while the second person tries to recreate the image on a chalkboard. Can you draw something that you’ve never seen?

**CORE CONNECTIONS** K-2nd Integrated Core 1.2.a-c



# 50/50 DAY

## PRINTABLE DISCUSSION KITS

This is a PDF version of the 50/50 Day Discussion Kit package. You can use digitally or print them and cut each card out (each page is front and back of one card).



## 50/50 INSTRUCTIONS PRINT OUT

# GETTING TO 50/50

## INSTRUCTIONS

Included in this deck are three types of cards to delve deeper into conversation around #Gettingto5050, a more gender-balanced world that's better for everyone:

- 25 Issue Cards
- 14 Question Cards
- 4 Discussion Guides for different ages

There are countless ways to engage. Begin by dividing the cards into the three types of cards, then follow the instructions on the back of this card. Use with friends, family, colleagues, classrooms, or let your mind wander alone.

## 3 WAYS TO PLAY:

1

Hand out the ISSUE CARDS to participants. A QUESTION CARD reader reads a question aloud. Going around the room, each participant answers the same question based on their ISSUE CARD. Repeat with each new question and have participants trade cards at any time.

2

One person begins by selecting one QUESTION CARD and one ISSUE CARD. Read both aloud and answer the question in regards to the issue. Take turns for as many rounds as you'd like.

3

After watching the 20 minute 50/50 film together, use the supplied DISCUSSION GUIDE appropriate for your group.

WATCH 20 MIN FILM 50/50 AND FIND MORE RESOURCES [50-50PROJECT.ORG](http://50-50PROJECT.ORG)

50/50 ISSUE CARDS PRINT OUT  
ISSUE: PAY EQUALITY



Equal pay for work of equal or comparable value, regardless of sex, gender, race, ethnicity, sexual orientation, age, or other factors. Includes all types of payment and benefits.

---

To Consider:

- salaries, hourly, and bonuses
- family/medical leave
- health insurance
- retirement
- full/flex time
- negotiation skills
- pay transparency

*Stat: Iceland is the first country to officially require pay equality regardless of gender, ethnicity, sexuality, or nationality.  
Source: The New York Times*

## ISSUE: EMPLOYMENT/LABOR



ISSUE CARD

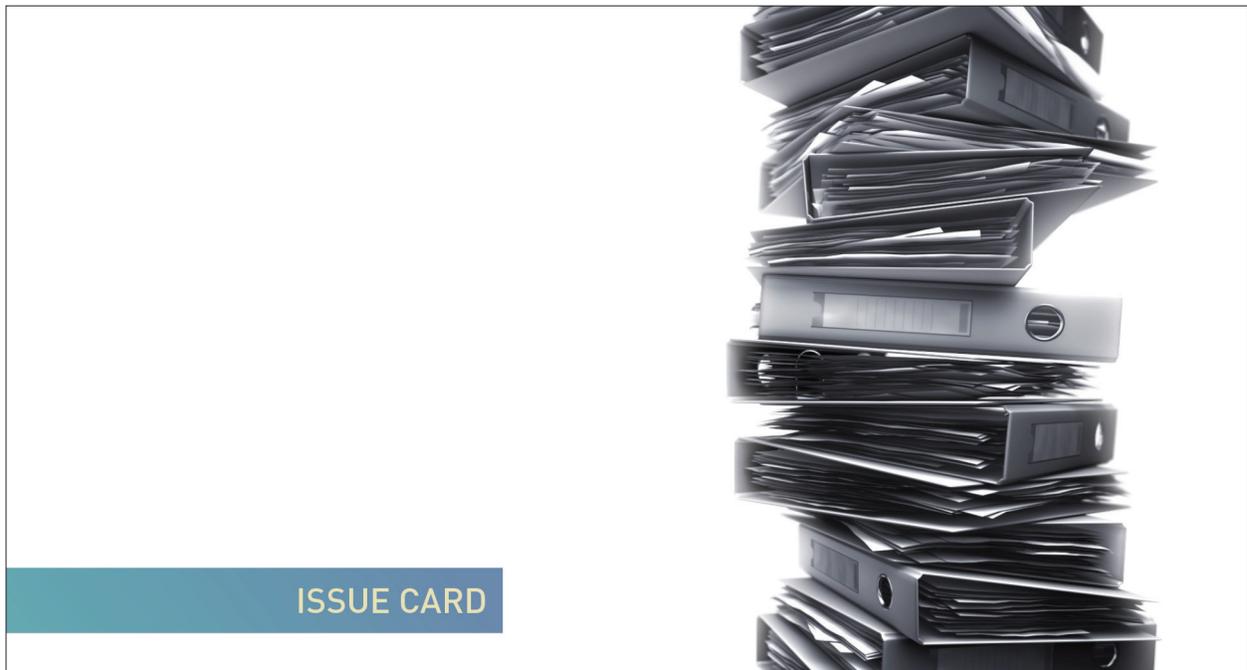


Having paid work, or the act of giving paid work to someone.

- To Consider:
- hiring/promotions
  - pay, benefits, schedule
  - workplace environment
  - management and leadership
  - mentorship
  - immigration
  - health risks
  - unconscious bias

*Stat: In 1969, one third of the workforce was female. Today, one half is. Source: Center for American Progress*

# ISSUE: BUSINESS LEADERSHIP



Individual(s) founding or leading a company or organization, or the activity of leading or managing a company or organization.

---

To Consider:

- entrepreneurship
- hiring and promotions
- mentorship/training
- investment
- quotas
- opportunity
- unconscious bias
- work/life balance

*Stat: A 2015 study showed that companies led by women outperformed S&P 500 companies (most are led by men) by 300%.  
Source: Quantopian*

# ISSUE: INVESTMENT



**INVESTMENT**

1. The investing of resources (money, time, goods) in order to multiply them over time. 2. Offering a percentage ownership of company or project in exchange for resources.

---

To Consider:

- access to investment
- privilege and wealth
- investing in values
- investing in women/girls
- social impact
- micro investments
- savings and retirement
- mentorship/advising

*Stat: Only 7% of private equity firms are owned by women or people of color. Source: Fairview Capital*

## ISSUE: POVERTY



ISSUE CARD



A multifaceted concept referring to the lack of means necessary for basic needs such as food, clothing, and shelter.

- To Consider:
- access to education
  - opportunity to work
  - child care
  - health
  - institutional barriers
  - cycle of poverty

*Stat: In countries where women aren't allowed to own land, the number of malnourished children averages 60% higher.  
Source: United Nations Development Programme*

## ISSUE: POLITICAL LEADERSHIP

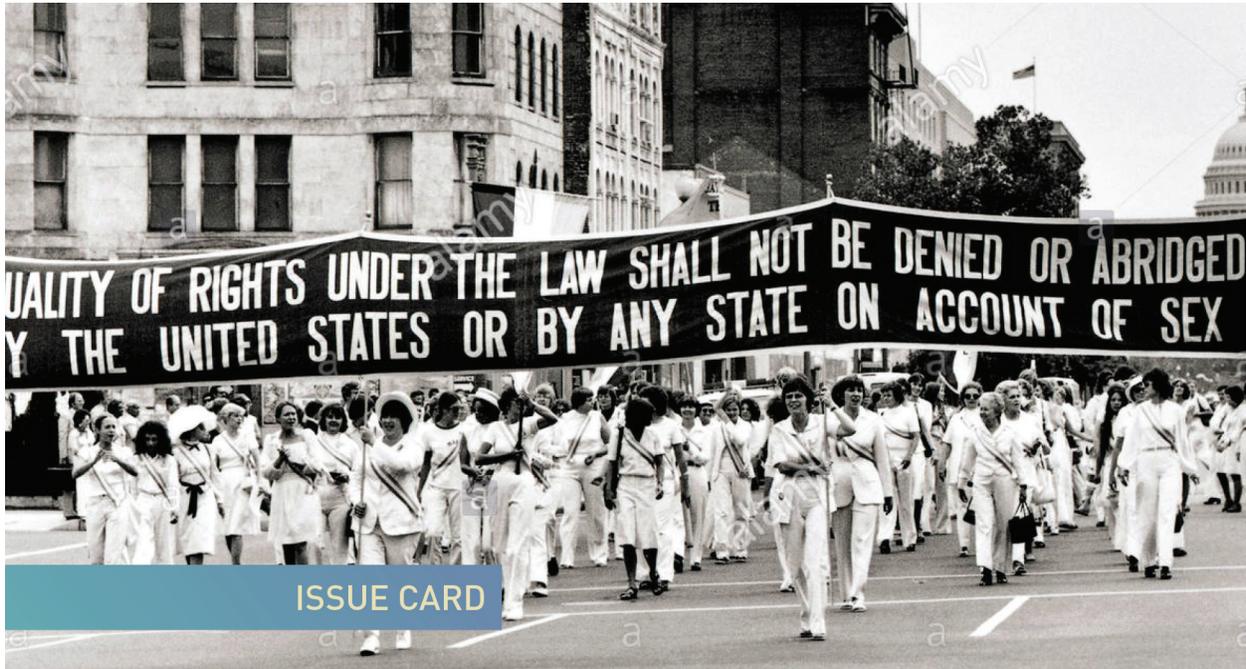


Being active in politics, or making a diversity of voices and perspectives “present” in public-policy-making processes through elections or organizing.

- 
- To Consider:**
- local, state, national
  - gender-balanced leadership
  - incumbency
  - quotas
  - diverse candidates
  - candidate recruitment
  - grassroots power
  - financial backing

*Stat: Vermont and Colorado have lead the U.S. in gender parity in state legislatures. Source: Washington Post*

## ISSUE: LAW



A system of rules created and enforced through social or governmental institutions to regulate behavior and protect human rights.

To Consider:

- equal rights
- policy
- law enforcement
- lack of enforcement
- diversity/bias
- harassment/hate crimes
- sexual and domestic violence
- marriage and personal status law

*Stat: New Zealand was the first country to give women the right to vote (in 1893). Saudi Arabia was the last (2015).*

*Source: US News & World Report*

## ISSUE: VOTING ACCESS



ISSUE CARD



A complex network of laws, restrictions, barriers, and other circumstances that enable or disable a person from being able to vote.

### To Consider:

- citizenship
- identification documents
- age
- institutional disenfranchisement
- mass incarceration
- automatic voter registration
- disabilities
- language barriers

*Stat: Millennials are among the largest population in the U.S. affected by voter restrictions. In 2012, lack of required identification prevented 17% of young black voters, 8% of Latino youth, and 4% of white youth. Source: Advancement Project*

## ISSUE: HEALTHCARE



Access to the maintenance or improvement of health, including diagnosis, treatment, and prevention of physical or mental disease, illness, injury, or other impairment.

---

**To Consider:**

- health/sex education
- reproductive choice
- geographic location
- doctor/patient interactions
- gender informed research
- cost
- employer coverage
- government subsidies

*A 2016 study showed that patients treated by women fared better, estimating that 32,000 lives would be saved each year if male doctors performed as well as their female peers. But female doctors still earn an average of \$20,000 less than male doctors each year. Source: JAMA, The New York Times*

# ISSUE: IMMIGRATION



The action of coming or going to live permanently in a foreign country.

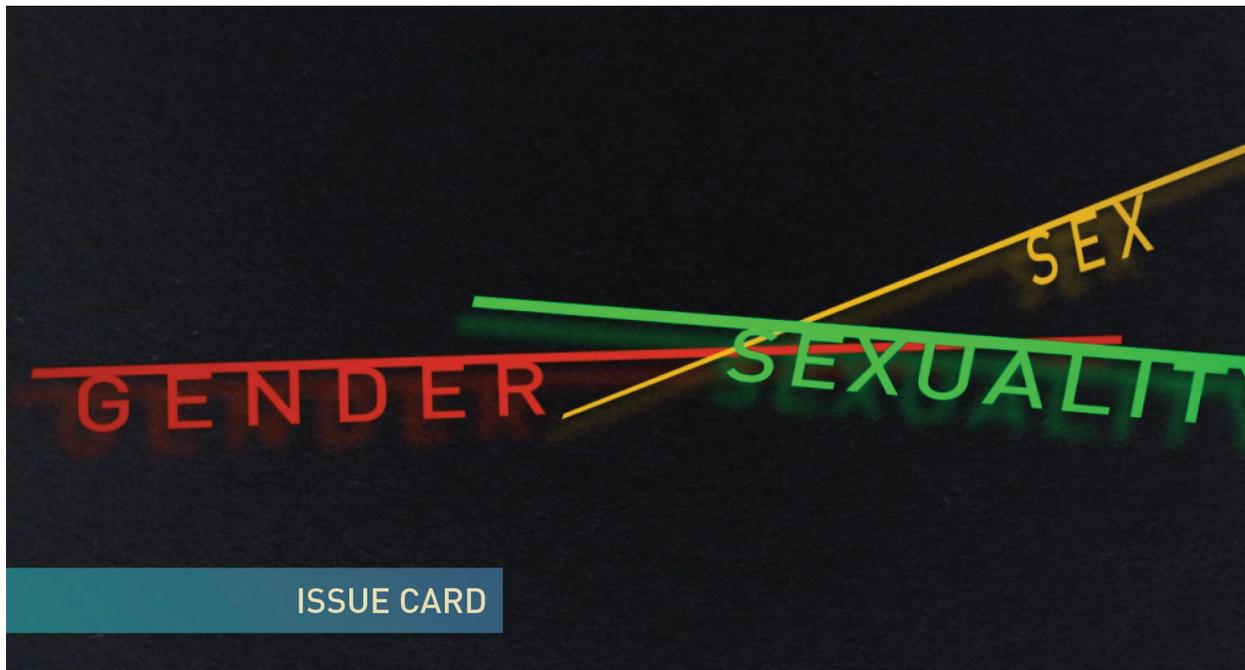
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**To Consider:**

- legal, undocumented, refugee, asylum
- different gender norms
- employment
- children
- language
- child/eldercare
- trafficking

*Immigrant women make up 7% of the total U.S. workforce. One third of these women work in business, management, arts, and science. Another third work in the service industry. Source: Migration Policy Institute*

## ISSUE: GENDER IDENTITY

A circular graphic with a dark green background and a white border, containing the text "GENDER IDENTITY" in white, bold, sans-serif letters.

A person's perception of self as male, female, a blend of both, or neither, which may or may not correspond with their sex assigned at birth.

---

**To Consider:**

- gender norms
- (non) binary/spectrum
- transgender/cisgender
- birth sex: female, male, intersex
- pronouns/gendered language
- bathrooms
- healthcare
- role models

*Stat: "They" as a singular pronoun was voted the 2015 word of the year. Source: American Dialect Society*

## ISSUE: SEXUAL ORIENTATION



Pattern of romantic or sexual attraction to persons of the opposite sex or gender, the same sex or gender, or to multiple sexes and genders.

---

**To Consider:**

- legal protection
- cultural norms
- heterosexual privilege
- family
- marriage
- healthcare
- employment
- role models

*Stat: The first same-sex marriage bill to become law was signed by Queen Beatrix of the Netherlands in 2001.  
Source: The New York Times*

## ISSUE: RACE/ETHNICITY



A group of people united or classified together on the basis of common history, nationality, or geographic distribution.

---

**To Consider:**

- cultural/gender norms
- multi-racial
- social justice movements
- stereotypes
- geography/origin
- privilege
- conformity/assimilation
- awareness/articulation

*By 2050, 62% of American women will be women of color. Source: U.S. Census Bureau*

## ISSUE: RELIGION



An organized system of beliefs, traditions, rituals, and rules, often used to worship a god, group of gods, or higher power.

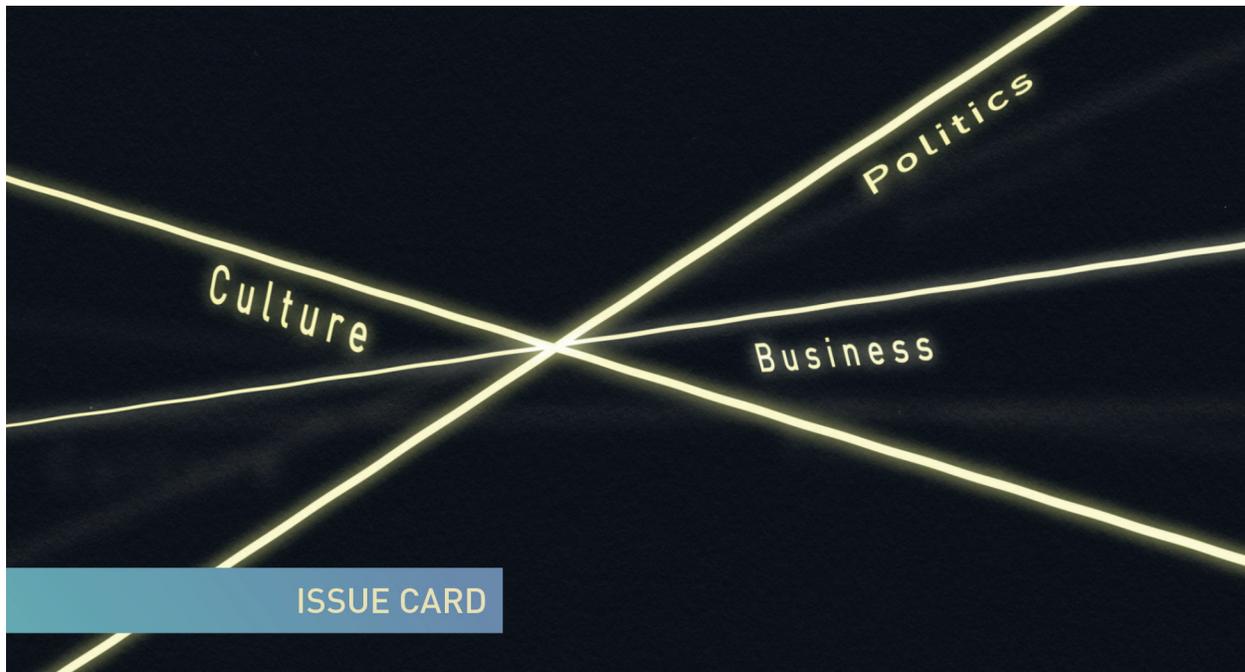
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**To Consider:**

- matriarchal/patriarchal
- gender norms/hierarchies
- goddesses/gods/higher powers
- reimagining traditions
- fundamentalism
- affiliation
- inclusion/exclusion

*Stat: Of the 81% of Americans who believe in God, 39% believe God is male; 31% believe God is genderless; 10% believe God is both male and female; and 1% believe God is female. Source: Harris Polls*

## ISSUE: CLASS



One's current social and economic status. While class generally refers to one's generally stable economic class over time, one's socioeconomic status may be more changeable.

---

To Consider:

- geography
- history
- education
- health
- employment
- childcare
- institutional barriers
- generational wealth/poverty

*Stat: In 2015 29% of Americans lived in a lower income household, but only 8% identified themselves as lower income.  
Source: Pew Research Center, Gallup*

# ISSUE: EDUCATION



**EDUCATION**

The process of offering or gaining knowledge and skills, developing reason and judgment, and generally preparing oneself for life.

---

**To Consider:**

- access
- art and culture
- science, technology, engineering, math
- educator salaries
- public vs private
- framing of history
- quotas
- language barriers

*Stat: Men make up 62% of college professors; 42% of high school teachers; 18.3% of elementary and middle school teachers; and 2.3% of preschool and kindergarten teachers. Source: Chronicle of Higher Education, Bureau of Labor Statistics*

## ISSUE: MEDIA REPRESENTATION



ISSUE CARD



People, voices, and identities—gender, race, sexuality, class, nationality, age, ability, beliefs—represented through media.

---

### To Consider:

- film, tv, art, music, comedy
- museums and public spaces
- textbooks, literature, news
- stereotypes
- advertisements
- industry leadership
- glorification of violence
- social media
- celebrity culture

*Stat: In 2015, male characters got almost twice as much screen time as female characters.  
Source: Geena Davis Institute on Gender in Media*

# ISSUE: MEDIA CREATION



**MEDIA  
CREATION**

Creators of film, television, radio, comedy, literature, art, music, and educational materials that we consume and that help define culture.

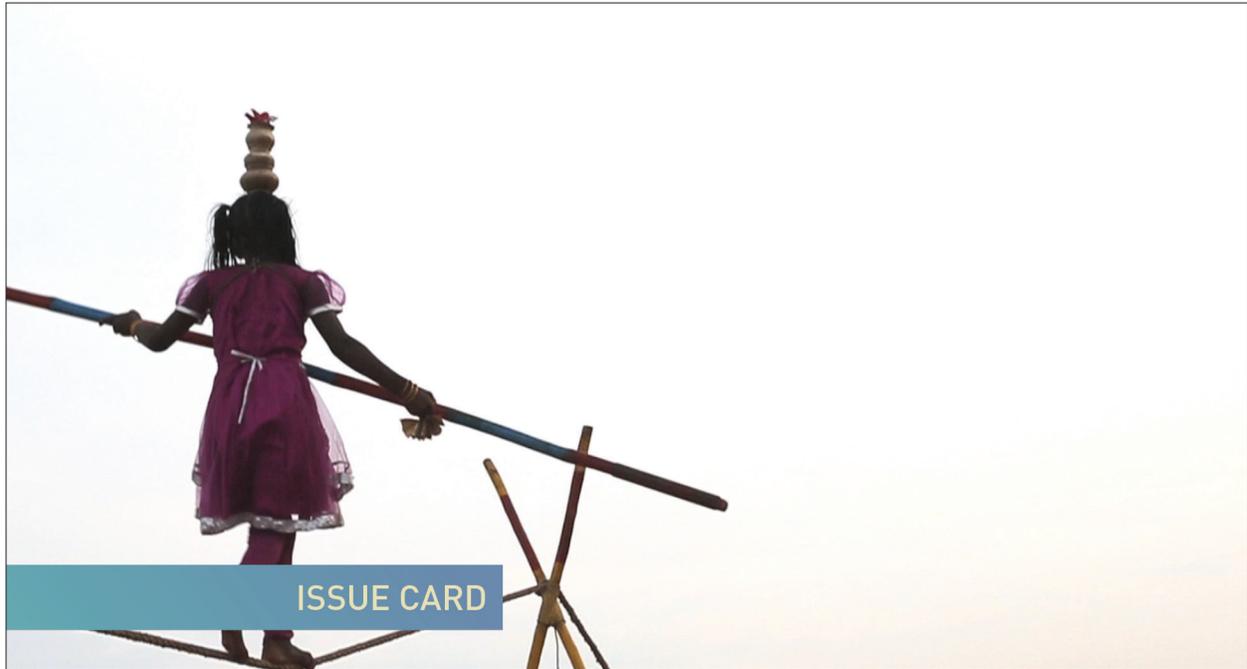
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**To Consider:**

- financing and opportunity
- mentorship
- networking
- education
- quotas
- social media
- industry leaders
- ownership/credit

*Stat: Of the 800 most popular films from 2007-2015, only 4.1% were directed by women. That means 24 male directors for every female one. Source: Media, Diversity and Social Change Initiative - USC Annenberg School*

## ISSUE: GENDER NORMS



Assumptions, expectations, and stereotypes about behaviors, appearance, profession, or knowledge one should have based on perceived gender.

- To Consider:
- home, work, school, media
  - cultural differences
  - masculinity/femininity
  - spectrum of gender
  - role models
  - social emotional skills
  - clothing/hobbies

*Stat: Pink and blue didn't become "girl" and "boy" colors until the 1940s, and still aren't in much of the world.  
Source: Jo B. Paoletti, Pink and Blue: Telling the Boys from Girls in America, Indiana University Press, 2012.*

## ISSUE: SPORTS

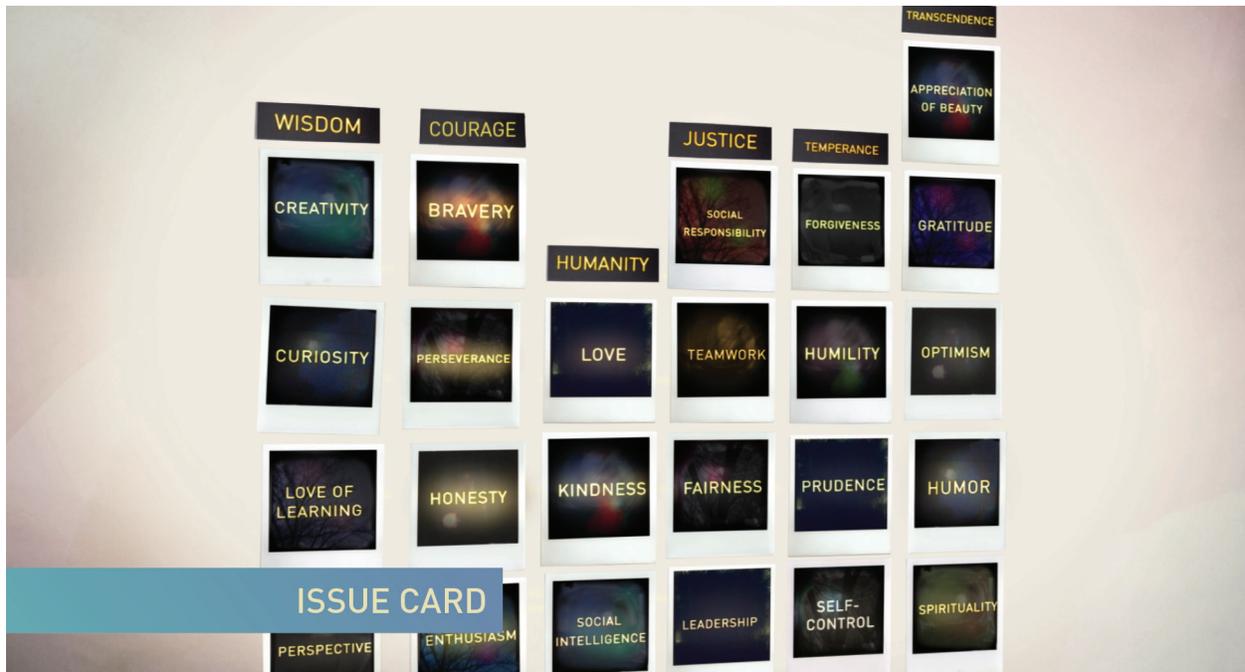


Opportunity to participate in any athletic endeavor regardless of gender identity, sexual orientation, race, ethnicity, or religion.

- To Consider:
- Title IX access
  - women's professional leagues
  - media coverage
  - budget disparity
  - gender norms
  - transgender participation
  - violence and hazing

*Before Title IX, 3% of girls played varsity high school sports. By 2001, 40% of girls played. Source: National Coalition for Women and Girls in Education*

# ISSUE: RELATIONSHIPS

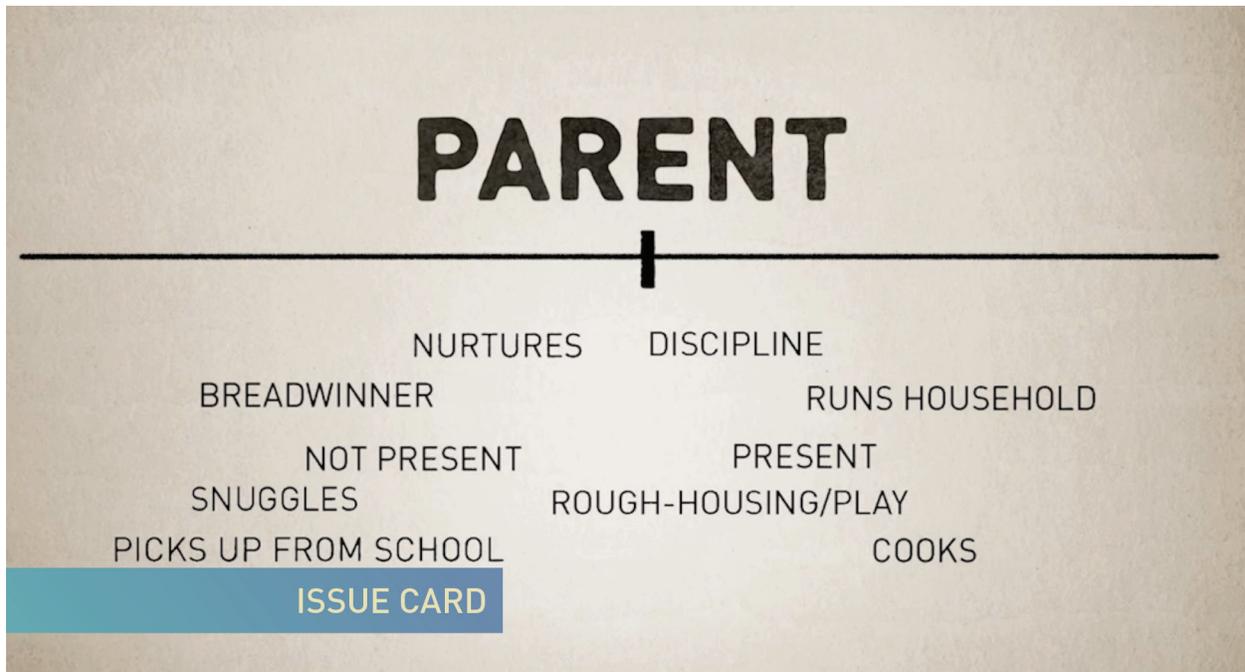


Dynamic between two or more people, including but not limited to romantic partnership, marriage, friendship, and family. These relationships often create the rules and structure of a household.

- To Consider:
- decision making
  - division of labor
  - breadwinning/finances
  - gendered expectations
  - time management
  - violence/abuse
  - sex
  - values

*Stat: In 1960, the average age of first marriage was 20 for women and 22 for men. In 1990, it was 23 for women and 26 for men. Today, it's 27 for women, 29 for men. Source: National Campaign to Prevent Teen and Unplanned Pregnancy*

## ISSUE: PARENTING



**PARENTING**

Primary adults involved in caring for young.

---

**To Consider:**

- single parenting/co-parenting
- paid/unpaid childcare
- donor/surrogate/adoption/foster
- divorce/custody
- financial obligations
- paid parental leave
- division of labor
- work/life balance

*Stat: The world fertility rate is currently 2.47 births per woman—down from a high of 4.96 in the 1950s.  
Source: United Nations*

## ISSUE: ELDERCARE/CARETAKING



The caring of other individuals unable to care for themselves.

- To Consider:
- aging
  - child care
  - sandwich generation
  - multi-generations
  - housing
  - employment
  - paid family leave
  - health insurance

*Stat: 29% of the U.S. population provides care for a chronically ill, disabled, or aged family member or friend during any given year, at an average of 20 hours per week. Source: Caregiver Action Network*

## ISSUE: UNPAID DOMESTIC WORK



ISSUE CARD



Work that is done to maintain a home, including child care, cleaning, laundry, cooking, and more.

- To Consider:**
- division of labor
  - gender expectations
  - employment
  - socioeconomic status
  - work/life balance
  - privilege and hired labor
  - race/immigration
  - media representation
  - impact on GDP

*Stat: If unpaid domestic work were counted in the Gross Domestic Product (GDP), it would raise the GDP by 26%.  
Source: Forbes*

## SAFETY/VIOLENCE



Physical, emotional, verbal, or psychological threat or abuse against a person, in the home or in society. Includes threats from individuals or the state.

---

**To Consider:**

- hate crimes
- domestic violence
- harassment
- bullying
- reporting
- intergenerational cycle of abuse
- mass incarceration
- media desensitization

*Stat: The U.S. incarcerates more people than any other country. Between 1980 and 2008, this number quadrupled. African-Americans are six times more likely to be incarcerated than whites, and men are about ten times more likely to be incarcerated than women. Source: NAACP*

# 50/50 DISCUSSION GUIDES PRINT OUT

## AGES 7-9

1. How would you define fairness? What do you think that means in terms of gender equality? What about fairness around race, ethnicity, age, or socioeconomic class?
2. Who is someone in history—or maybe in a film or book—that has stood up for gender equality? What did they do?
3. Think about when your grandparents or parents were growing up. How do you think opportunities based on gender were different for them?
4. Take a look at the GETTING TO 50/50 poster.
  - a. Choose one circle and think about how it relates to your life. Do you think your experience would be different if you were a different gender? How?
  - b. What's one circle you want to learn more about? Why?

AGES 7-9

50/50 DISCUSSION GUIDES

WATCH 20 MIN FILM AND FIND MORE RESOURCES [5050PROJECT.ORG](http://5050PROJECT.ORG)

5. The film 50/50 talks a lot about mentors—people who help us become what and who we want to be. Who in your life helps you learn and grow?
6. How do you feel when people are being treated unfairly? What can you do when that happens?

AGES 7-9

50/50 DISCUSSION GUIDES

WATCH 20 MIN FILM AND FIND MORE RESOURCES [5050PROJECT.ORG](http://5050PROJECT.ORG)

# 50/50 DISCUSSION GUIDES PRINT OUT

## AGES 10-14

1. How would you define equality? What about equity? What do you think that means in terms of gender? What about in terms of race, ethnicity, age, or socioeconomic class?
2. Who is someone in history—or maybe in a film or book—that has stood up for gender equality? What did they do?
3. Take a look at the GETTING TO 50/50 poster.
  - a. Choose one circle and think about how it relates to your life. Do you think your experience would be different if you were a different gender? How?
  - b. What's one circle you want to learn more about? Why?
  - c. Choose any two circles that are not next to each other. How do they relate to each other?

AGES 10-14

50/50 DISCUSSION GUIDES

WATCH 20 MIN FILM AND FIND MORE RESOURCES [5050PROJECT.ORG](http://5050PROJECT.ORG)

4. Think about when your grandparents or parents were growing up. How do you think opportunities based on gender were different for them? What do you think the world will be like in 20 years in terms of gender equality?
5. The film talks a lot about mentors. Do you have mentors? What qualities do you admire about them? If you don't have mentors, what qualities would you look for? What difference would a mentor's gender make to you?
6. How much gender balance do you see in your home? What about your school? What are some rules or policies that could lead to more gender balance in either place?
7. If you could have any job in the world when you grow up, what would it be? Do you think that job is mostly held by people of a certain gender? Why?
8. Do you think the world would be different if there were more gender balance in politics (presidents, congress members, senators, local leaders)?

AGES 10-14

50/50 DISCUSSION GUIDES

WATCH 20 MIN FILM AND FIND MORE RESOURCES [5050PROJECT.ORG](http://5050PROJECT.ORG)

# 50/50 DISCUSSION GUIDES PRINT OUT

## AGES 15-18

1. How did you feel when you heard that there have been more than 50 elected women presidents and prime ministers? What, if anything, was surprising to you about that number?
2. How would you define equality? What about equity? Justice? What do you think that means in terms of gender? How do race, ethnicity, religion, or socioeconomic class factor into this?
3. Take a look at the poster GETTING TO 50/50.
  - a. Choose one circle and think about how it relates to your life. Do you think your experience would be different if you were a different gender? How?
  - b. What circles do you want to learn more about in terms of gender equality? Why?
  - c. Choose any two circles that are not next to each other. How do the two issues relate to each other?
  - d. What, if any, issues do you feel are missing from this poster? Why?

AGES 15-18

50/50 DISCUSSION GUIDES

WATCH 20 MIN FILM AND FIND MORE RESOURCES [5050PROJECT.ORG](http://5050PROJECT.ORG)

4. The film talks a lot about mentors—people who help us become what we want to be. Do you have mentors? If so, what qualities do you admire about them? If you don't have mentors, what qualities would you look for in a mentor? Would their gender be important? Why?
5. How do you think the world would change if there more gender balance in politics? What about more gender balance in business leadership? Or in homes?
6. How much gender balance do you see in your home? School? What are some rules or policies that could lead to more gender balance in either place?
7. Think about when your grandparents or parents were growing up. How do you think opportunities based on gender were different for them? What do you think the world will be like in 20 years in terms of gender equality?
8. Knowing that gender is on a spectrum, how would you define your gender? Why? Do you have qualities that are typically considered masculine? Typically considered feminine? Why are they considered that way?

AGES 15-18

50/50 DISCUSSION GUIDES

WATCH 20 MIN FILM AND FIND MORE RESOURCES [5050PROJECT.ORG](http://5050PROJECT.ORG)

# 50/50 DISCUSSION GUIDES PRINT OUT

## AGES 19-99+

1. How did you feel when you heard that there have been more than 50 elected women presidents and prime ministers? What, if anything, was surprising to you about that number?
2. How would you define equality? How about equity? Justice? How would you define them regarding gender?
3. How do race, ethnicity, religion, or socioeconomic class relate to gender equality?
4. The film talks a lot about mentors. Who are your mentors? Is their gender important? Why?
5. Take a look at the poster GETTING TO 50/50.
  - a. Choose one circle and think about how it relates to your life. Do you think your experience would be different if you were a different gender? How?
  - b. What circles do you want to learn more about in terms of gender equality? Why?
  - c. Choose two circles not next to each other. How do the two issues relate to each other?
  - d. What, if any, issues do you feel are missing from this poster? Why?

AGES 19-99+

### 50/50 DISCUSSION GUIDES

WATCH 20 MIN FILM AND FIND MORE RESOURCES [5050PROJECT.ORG](http://5050PROJECT.ORG)

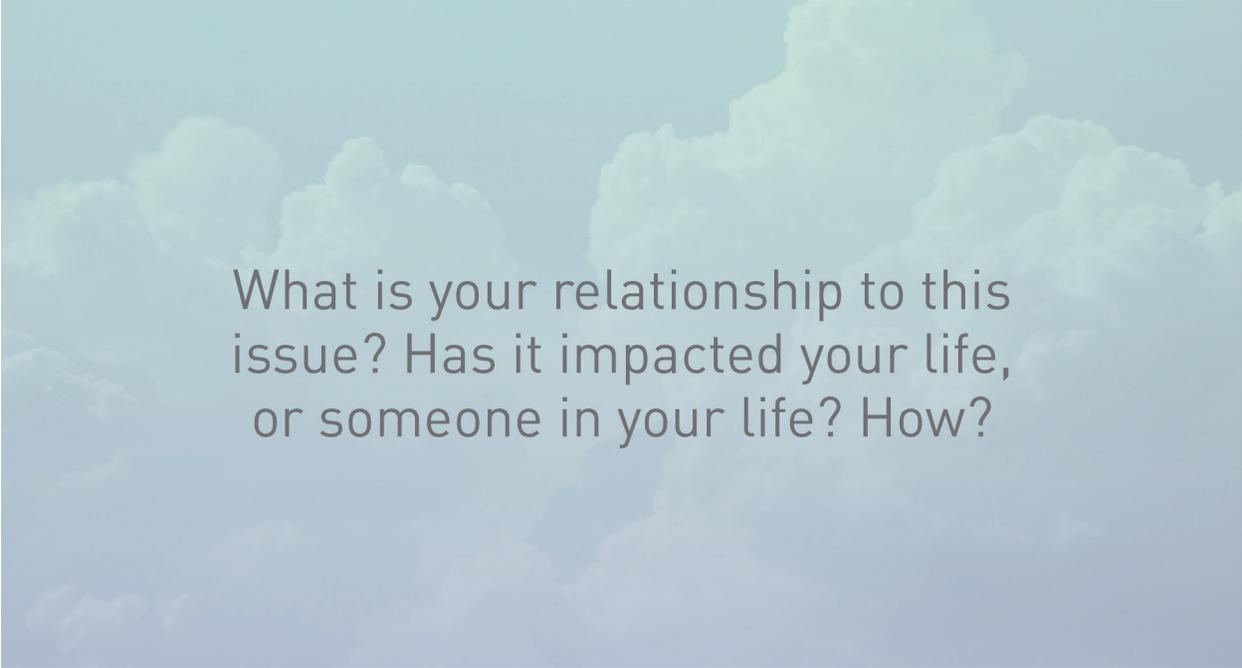
6. We've thought of the story of women in power as a story of scarcity. How can we shift that to telling a story of abundance? How might that shift change things?
7. How do you think the world would change if there was more gender balance in politics? What about more gender balance in business leadership? Or in homes?
8. How's the gender balance in your own home? What about your workplace? What are some rules or policies that could lead to more gender balance in either place?
9. How has the world changed in terms of gender equality in your lifetime? What about since your parents' or grandparents' generation? Where do you think we'll be 20 years from now?
10. Studies show fifty percent of men with paid parental leave feel they can't take it. Why do you think that is? What would change if more men took parental/family leave?
11. Knowing that gender is on a spectrum, how would you define your gender? Why? Do you have qualities that are typically considered masculine? Typically considered feminine? Why are they considered that way?

AGES 19-99+

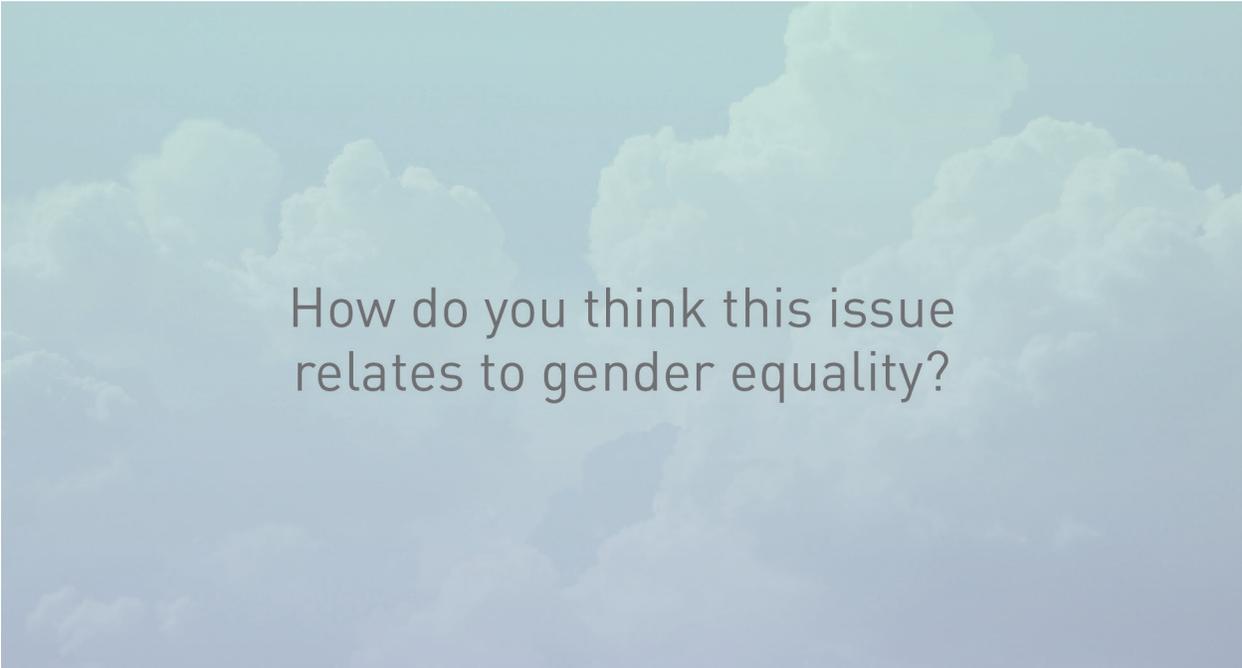
### 50/50 DISCUSSION GUIDES

WATCH 20 MIN FILM AND FIND MORE RESOURCES [5050PROJECT.ORG](http://5050PROJECT.ORG)

## 50/50 QUESTION CARDS PRINT OUT

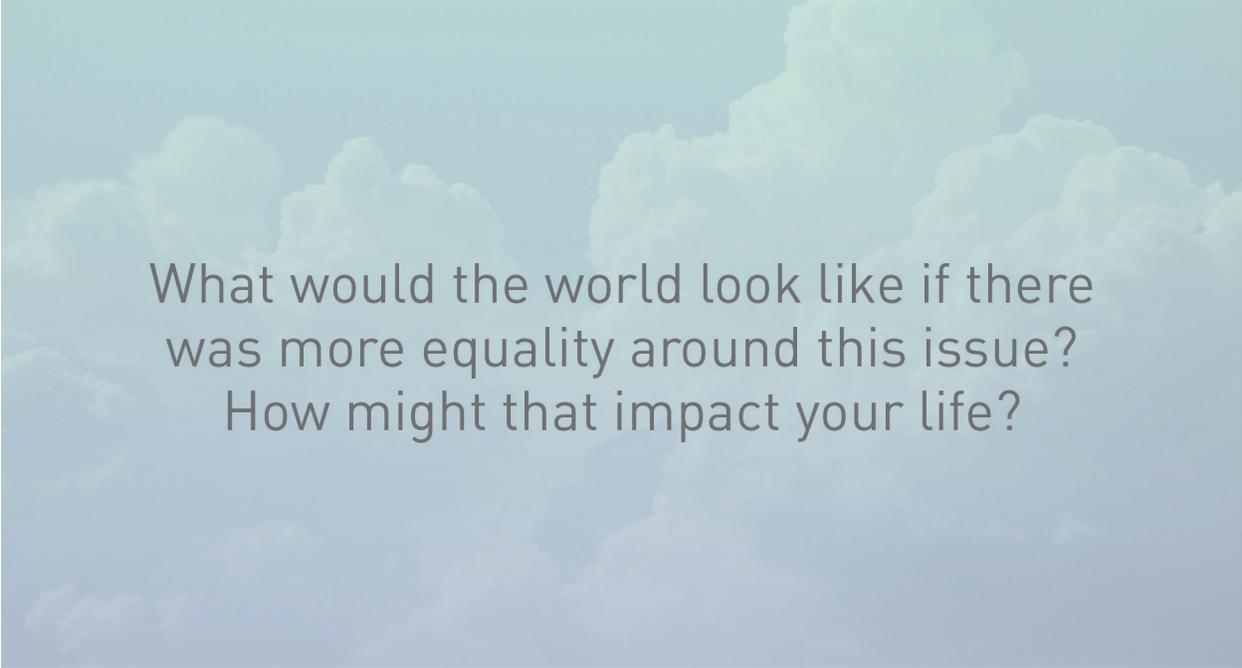


What is your relationship to this issue? Has it impacted your life, or someone in your life? How?

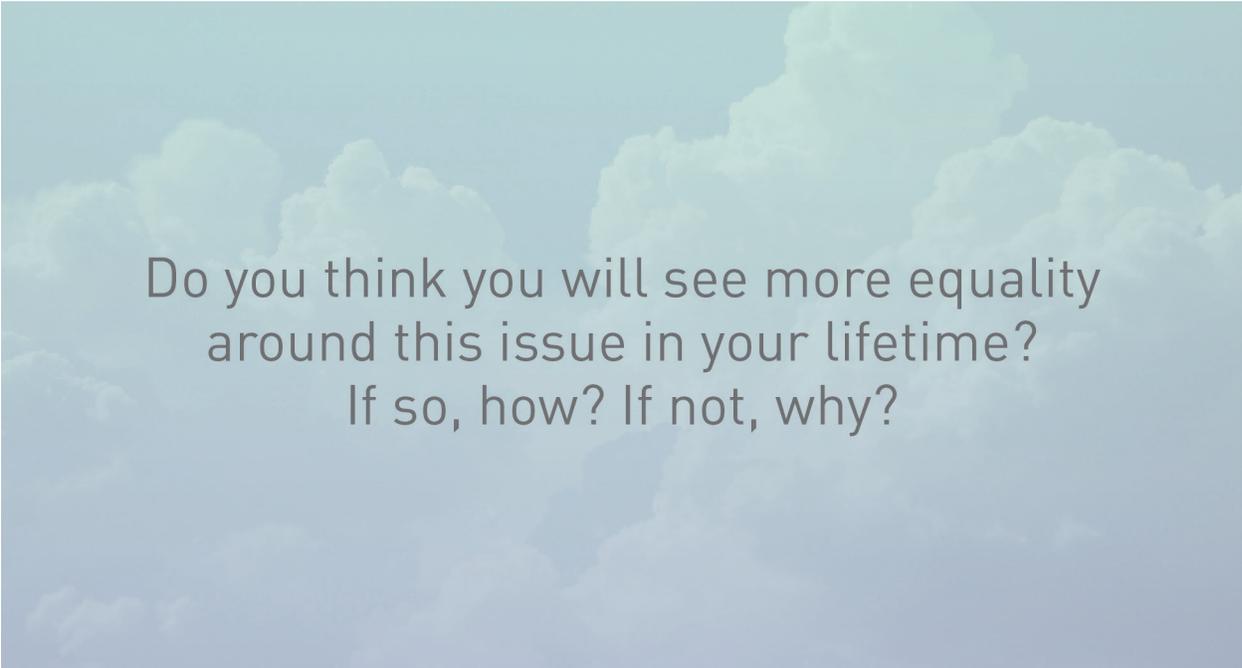


How do you think this issue relates to gender equality?

## 50/50 QUESTION CARDS PRINT OUT

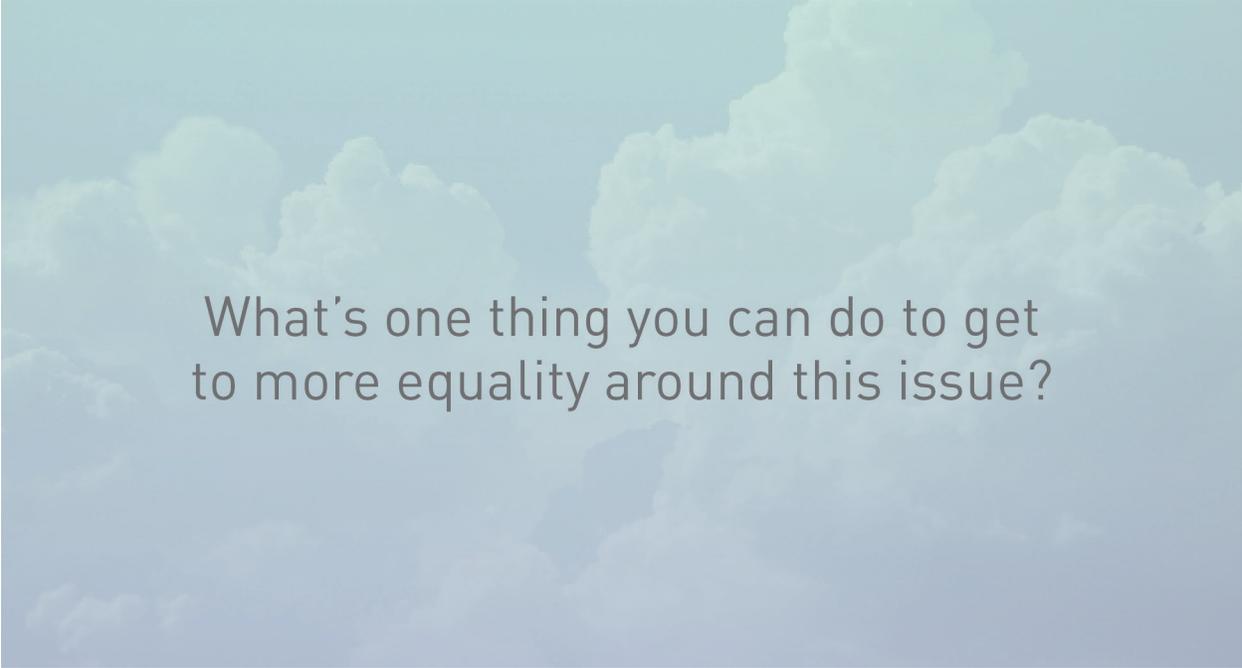


What would the world look like if there was more equality around this issue?  
How might that impact your life?

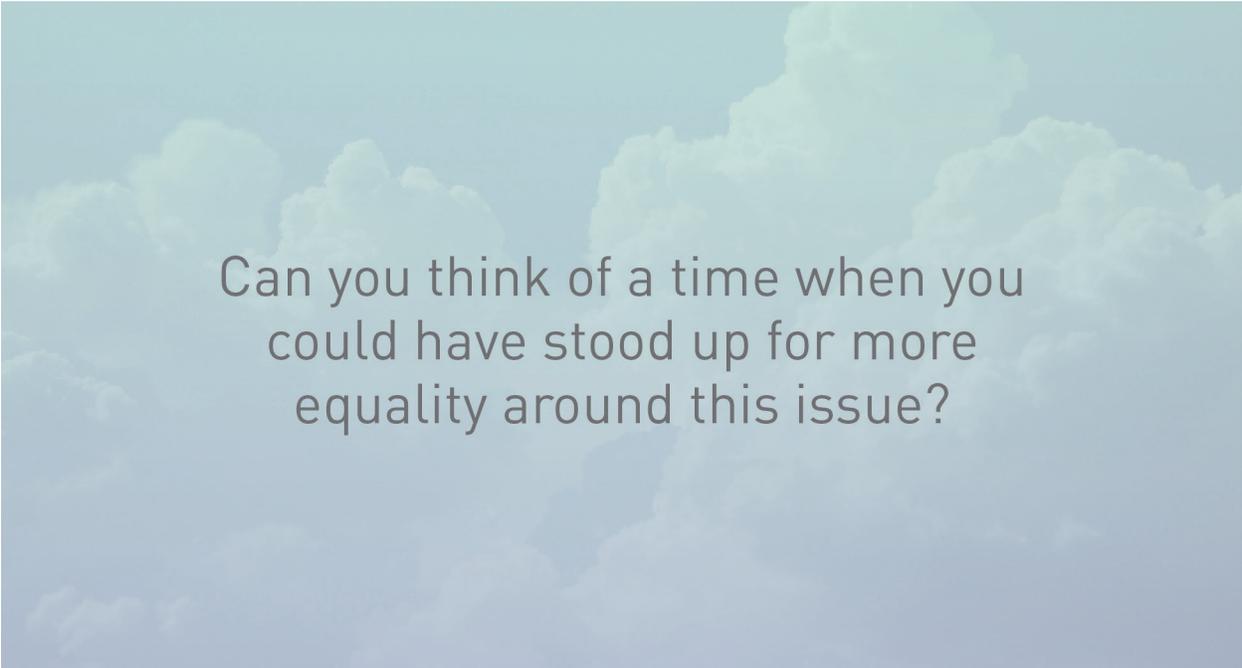


Do you think you will see more equality around this issue in your lifetime?  
If so, how? If not, why?

## 50/50 QUESTION CARDS PRINT OUT

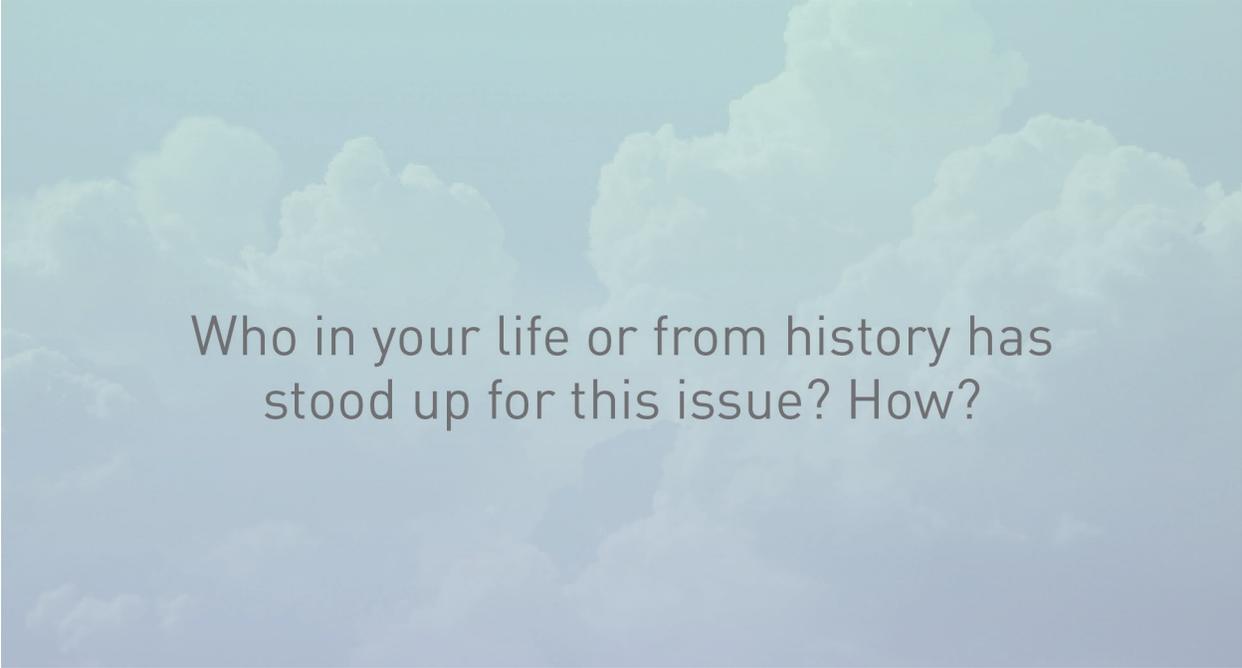


What's one thing you can do to get to more equality around this issue?



Can you think of a time when you could have stood up for more equality around this issue?

## 50/50 QUESTION CARDS PRINT OUT

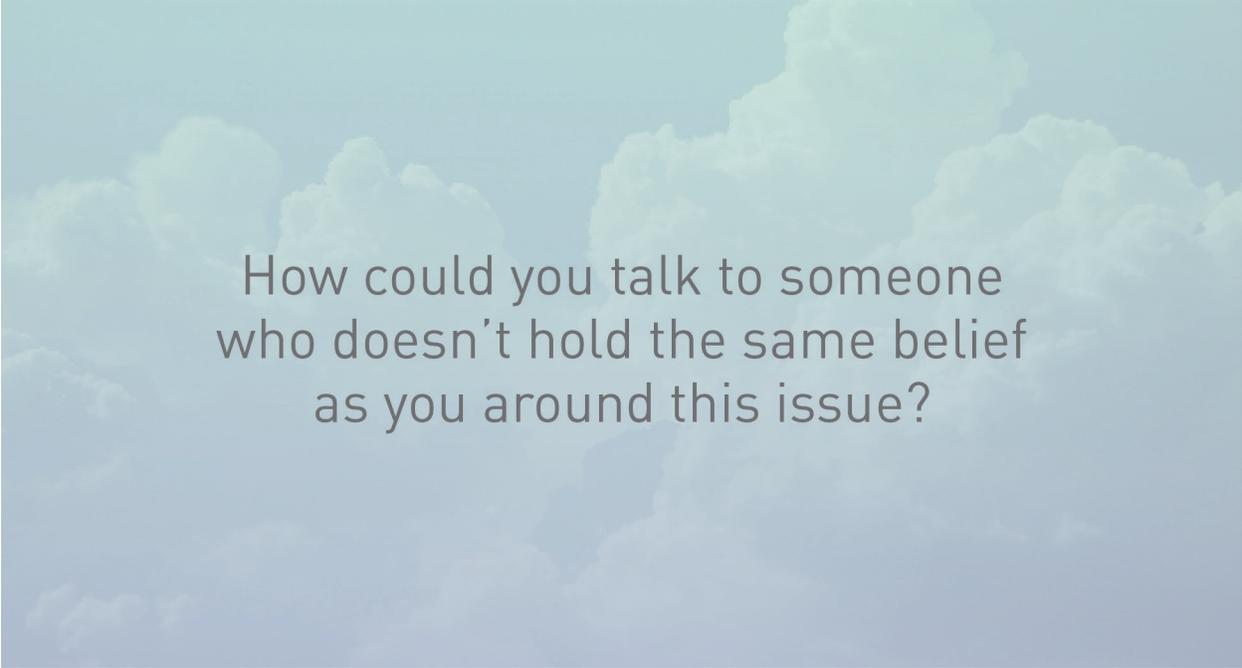


Who in your life or from history has stood up for this issue? How?

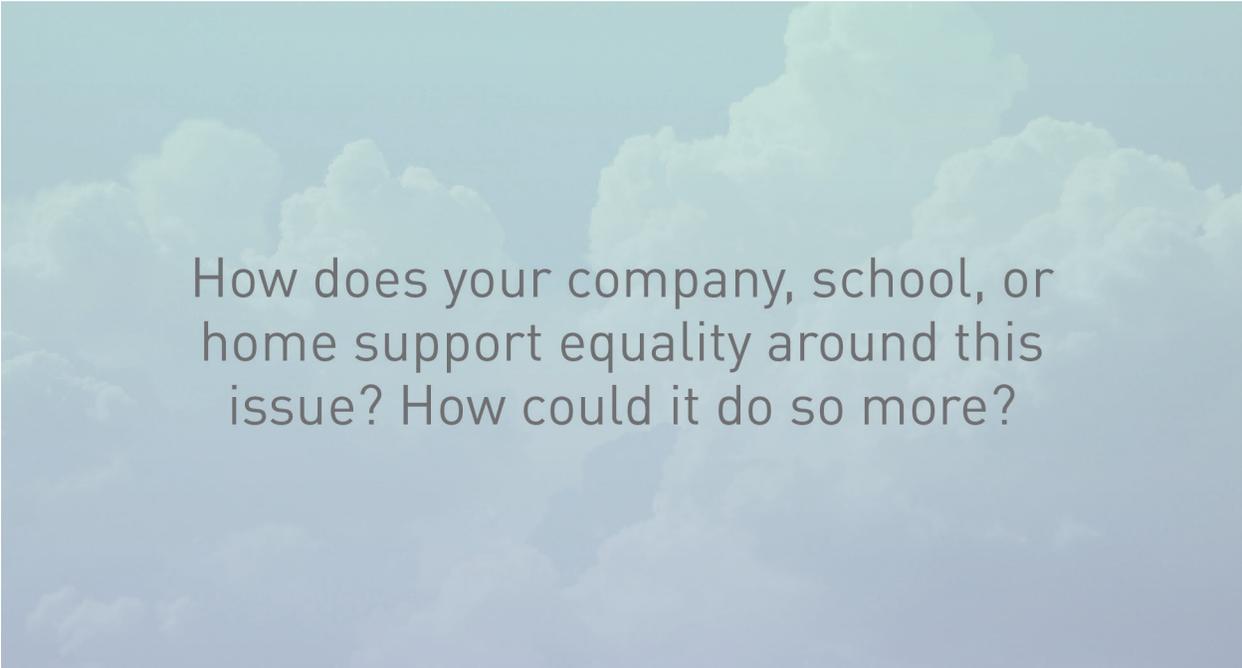


What kind of bill or policy could ensure more equality around this issue?  
Can you think of an example happening now?

## 50/50 QUESTION CARDS PRINT OUT

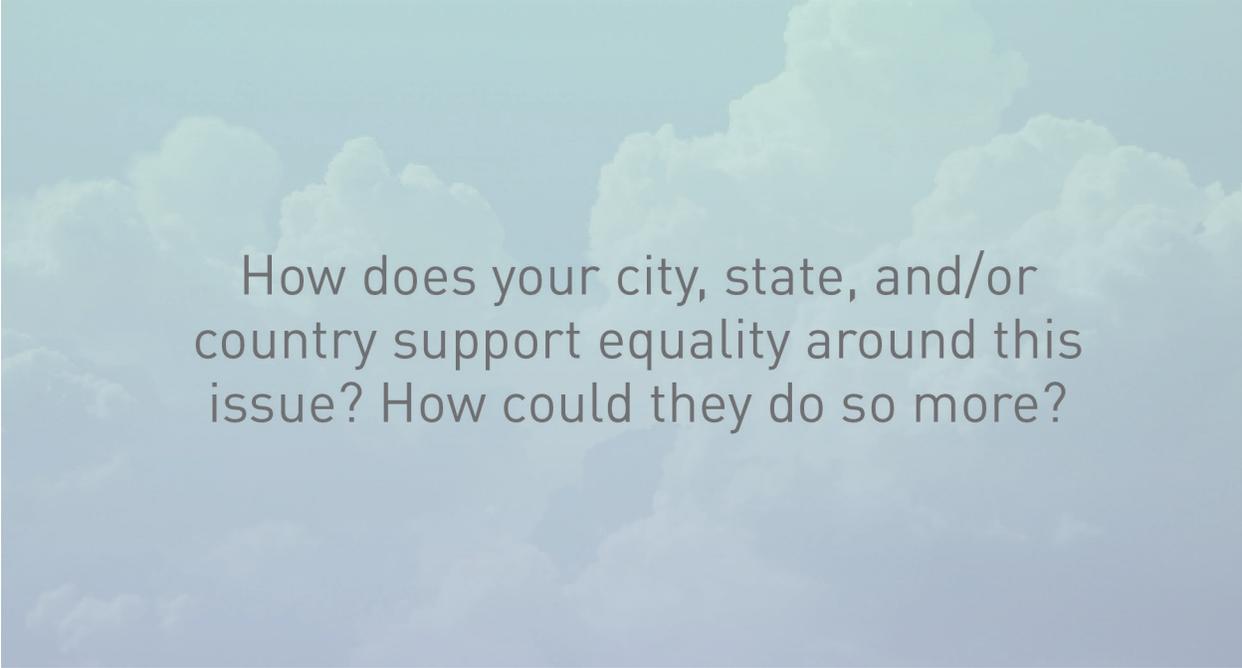


How could you talk to someone who doesn't hold the same belief as you around this issue?

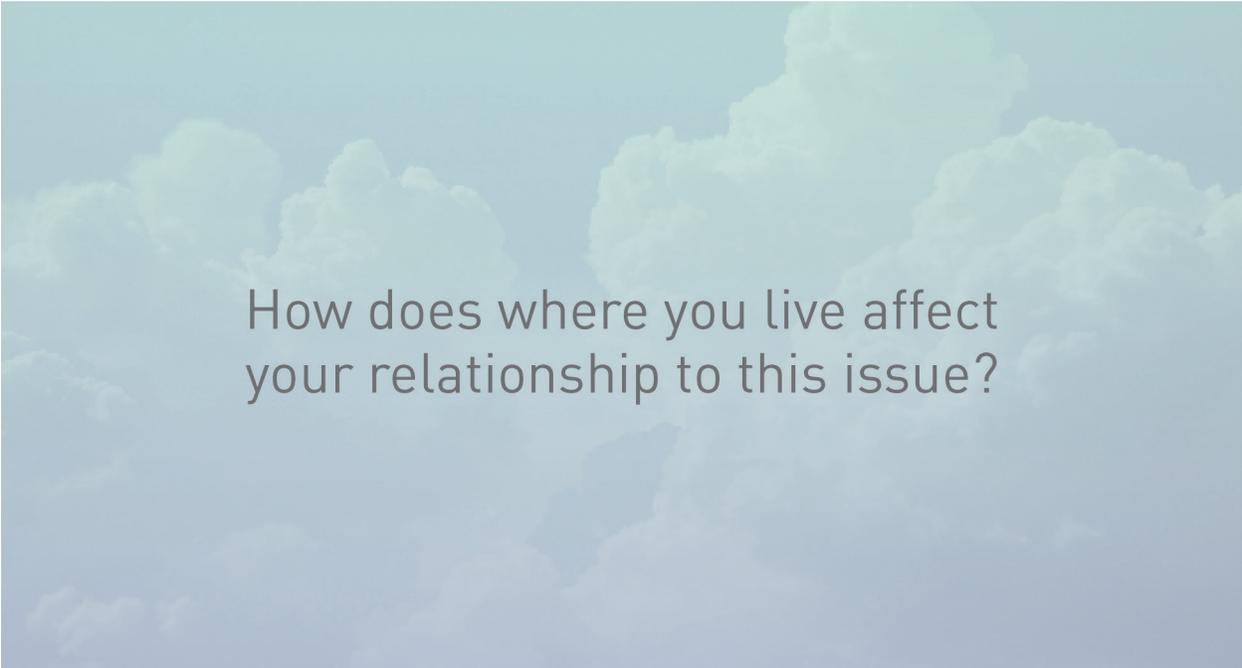


How does your company, school, or home support equality around this issue? How could it do so more?

## 50/50 QUESTION CARDS PRINT OUT

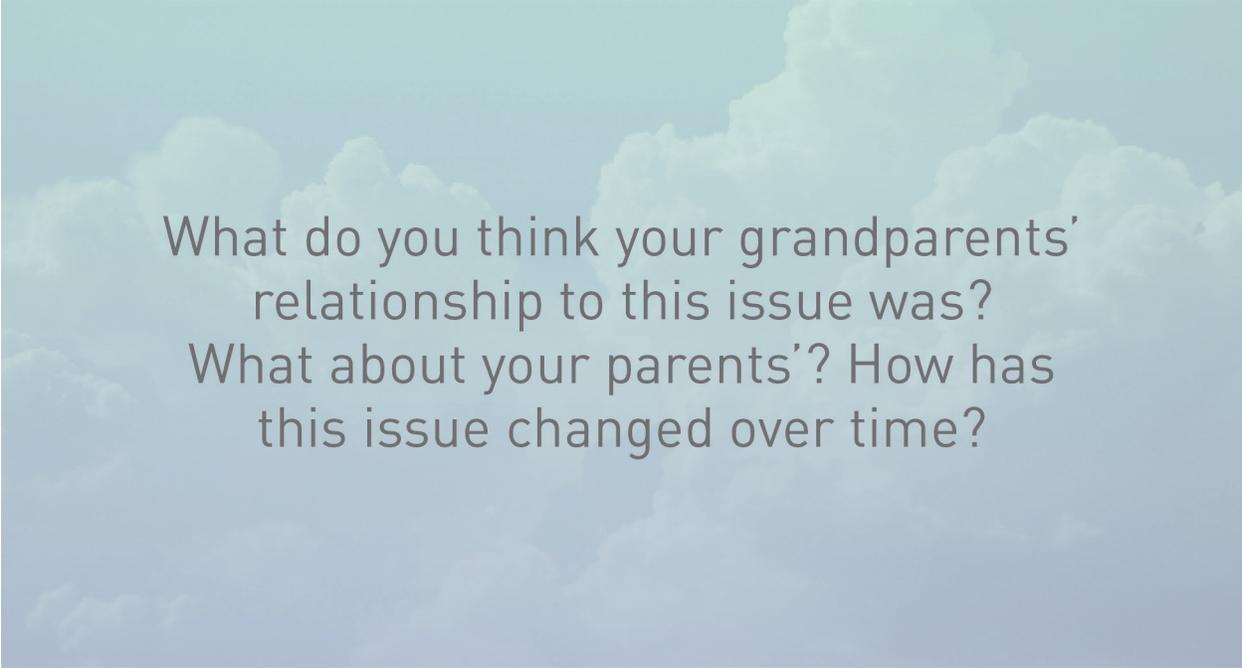


How does your city, state, and/or country support equality around this issue? How could they do so more?

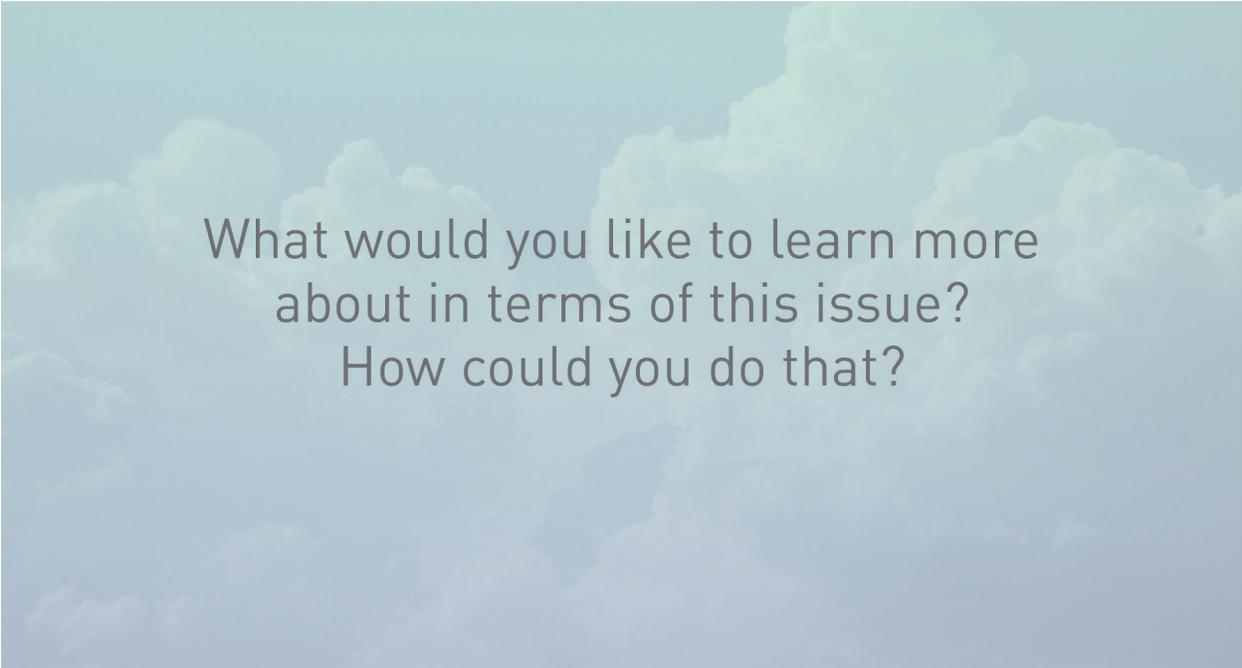


How does where you live affect your relationship to this issue?

## 50/50 QUESTION CARDS PRINT OUT



What do you think your grandparents' relationship to this issue was?  
What about your parents'? How has this issue changed over time?



What would you like to learn more about in terms of this issue?  
How could you do that?

# AIRFOIL LIFT



**GRADE: 3, 8**  
**SUBJECT: SCIENCE**

## STANDARDS

3<sup>rd</sup>: 3.1.a, 3.2.a, 3.2.c, 4.1.a, 4.2.c  
8<sup>th</sup>: 8.2.2

## Disciplinary core:

Life Science, Physical Science,  
Engineering

## Overview:

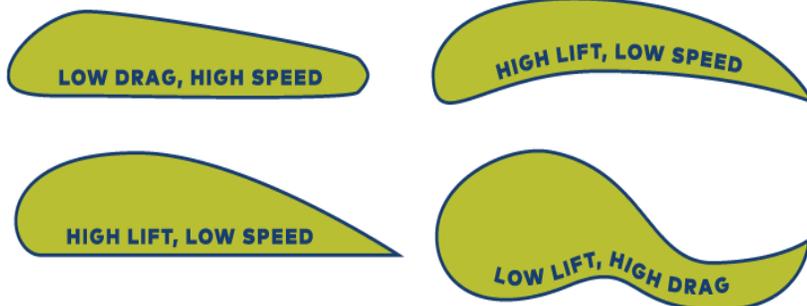
This lesson will explore the pushing/pulling force of lift through airfoil design. Students will explore Bernoulli's principle through hands on experiments. Activity 1 will introduce the concept of lift and allow the instructor to gauge student's previous knowledge. Activity 2 will focus on design and testing of airfoils. Experiments allow for measurable data and comparative analysis. Content will be tied to NASA resources and The Leonardo **FLIGHT** exhibit.

## MATERIALS

- 1.5 Drinking straws per student
- 1 Scissors per student
- 3' length of string per student
- Small desk fans or hair dryers
- Copy paper
- masking tape

## Objectives: Student will be able to:

- Investigate how an airfoil creates lift
- Design an airfoil
- Construct a model of an airfoil from materials provided
- Observe how their airfoil operates
- Explain and demonstrate Bernoulli's Principle
- Explore the action of lift as a force in flight



## Vocabulary:

**Airfoil:** a structure with curved surfaces designed to give the most lift; used as the basic form of the wings, and stabilizers of most aircraft.

**Lift:** force of the air acting on an airfoil, usually upwards and at a right angle to the direction of flight

**Drag:** force of the air acting on an airfoil; usually slowing the airfoil's speed and caused by disruption of airflow by the wing and other protruding objects

## Cross Cutting Science Concepts:

- Patterns
- Scale and proportion
- Cause and Effect
- Systems and system models

## Science & Engineering Practices:

- Asking questions
- Planning and carrying out investigations
- Constructing explanations
- Obtaining, evaluating, and communicating information



# 5E Lesson Plan

## ENGAGE: Access Prior Learning / Stimulate Interest / Generate Questions

1. Ask students: “How do planes fly?”, “How do birds fly?”, “What is similar about the way planes and birds fly?”, “What is different?”
2. Guide students to understand that both planes and birds achieve flight through the use of wings.
3. Tell students that they will be exploring the special properties of wings.

## EXPLORE: Students Experiment / Develop Own Understanding

### Demonstrate and introduce Bernoulli’s Principle.

1. Instruct students cut the strip of paper from their sheet and to tape a drinking straw to it.
2. Ask students what will happen when they blow in to the straw. Will the paper move towards the straw or away from it?
3. Ask students to blow into the straw. (The paper should respond by moving **toward** the stream of moving air.)
4. Ask students to explain why the paper moves as they observe.
5. If students struggle to explain this phenomenon, offer additional examples: Think about a windy summer day. You are sitting in a house and the wind pushed the curtains away from the window. When the wind rushes out of the room the curtains are pulled into the screen and the air leaves the room.

## EXPLAIN: Concepts Explained / Vocabulary Defined

1. When air moves over under and around an object, the air can push or pull the object in different directions.
2. When the student blows into the straw he/she creates an area of faster moving air. The slower-moving air under the paper now has higher pressure, pushing the paper up, towards the area of lower pressure.
3. Describe an airfoil to students. An airfoil is an aerodynamic surface shaped used for testing the reaction from the air through which it moves.
4. Bernoulli’s principle says that high pressure on one side of an object pushes the object away, into the area of lower pressure. For example, if air were to move faster above an object, high pressure below would push the object upward. And high pressure on top of an object moves the object downward Bernoulli’s principle explains how the pressure of gas (or a liquid) decreases as the velocity increases. High velocity then creates low pressure.

## ELABORATE: Applications and Extensions

### Build and Test an Airfoil

1. Instruct students to make an airfoil. Cut out the airfoil template. Cut or punch a hole as indicated. Bend on line and tape both edges together. Line up the holes and thread straw through the holes, then thread string through the straw. Look at airfoils of other students. Do all of the airfoils look alike? Depending on the neatness of the folding and taping, students will have some diversity in airfoil shape, allowing for more testing.
2. Ask students to complete the “Hypothesis” section of the Student Activity Sheet.
3. Model test process of students. Hold airfoil by the end of the strings so that the airfoil is horizontal. Test airfoil by walking fast or running, the airfoil should lift and travel up the string.
4. Extension: The lesson can be extended by marking measurements on string and including a timed race to observe level of lift. Student may record their observations and draw a diagram of the experiment.

## EVALUATE

Formative Assessment: Observe student process and use prompting questions to check for understanding.

Summative Assessment: Instruction students to complete the “Conclusion” section of the Student Activity Sheet.

NAME: \_\_\_\_\_



**HYPOTHESIS**

What do you think will happen when air moves over your airfoil?

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**CONCLUSION**

What did you observe during the experiment?

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-----  
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-----

Why did this happen?

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-----  
-----  
-----

Tape Straw Here

NAME: \_\_\_\_\_



TOP



NAME: \_\_\_\_\_

BEND AIRFOIL HERE DO NOT FOLD



BOTTOM



# EXHIBIT: ALGAE

## ACTIVITY: Bubble Bomb

*How is photosynthesis related to baking soda and vinegar?*



### DISCOVER

A chemical reaction can propel a film canister high into the air or pop a zip lock bag with a bang! Like gasoline and biofuels, baking soda and vinegar were partially formed through photosynthesis. Be an engineer and see what other objects you can move with this reaction.

### MATERIALS

For each Film Canister Rocket:

- Film canisters with tight-fitting lids (get them for free at locations that still develop film: Walgreens, Costco, Wal-Mart)
- ½ tsp. baking soda
- 2 tsp. vinegar (white or apple cider)

For each Sandwich Bag Bomb:

- 1 zip lock sandwich bag
- 4-inch square of paper towel
- 1 ½ Tbsp. baking soda
- ½ c. vinegar (white or apple cider)
- ¼ c. warm water

Optional materials:

- Measuring spoons
- Eye dropper

### PONDER

- How do the baking soda and vinegar change after they are mixed?
- Is this a physical or chemical reaction? How do you know?
- What would happen if you changed any of the variables?
- Could this chemical reaction be a useful fuel for transportation? List the pros and cons.
- Where do vinegar and baking soda come from? What organisms are involved in their creation?

Grades: 5th-12th

Group Size: 2-4 people per group

Time: 5-20 minutes

Utah Core Curriculum:

- 5th Science 1.3 a, b, c, e
- 8th Science 1.2 b, c; 1.3 a, e; 1.4 a, b; 2.1 a

Process Skills & Higher Level Thinking Skills:

- Observing
- Questioning
- Investigating
- Comparing
- Predicting
- Hypothesizing

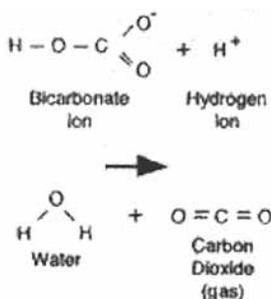
Related Activities/Exhibits:

- Innovation Cloud
- Forces & Motion

### WHAT'S GOING ON?

Carbon dioxide and water are produced when baking soda (sodium bicarbonate) and vinegar (acetic acid) react. The buildup of pressure from this gas causes the canister to fly and the bag to pop.

In other words: Sodium bicarbonate + acetic acid  $\Rightarrow$  water + carbon dioxide. In chemical form the reaction looks like this (the hydrogen ion is from the acetic acid):



Sodium bicarbonate is made from salt (sodium chloride) and limestone (calcium carbonate). Most limestone is made primarily from the skeletons of marine organisms.

Acetic acid is a product of fermentation. In this process, microorganisms digest the sugars from plants (like apples, in the case of apple cider vinegar). After the microorganisms get the energy they need from the sugars, vinegar is left over.

When a plant undergoes photosynthesis, it is creating sugars from carbon dioxide, water, and sunlight.

Look at the equation above to determine whether the  $\text{CO}_2$  in the vinegar and baking soda reaction is from the baking soda or from the vinegar.

### EXPERIMENT

Warning: These reactions can fly in all directions. Do the experiments outside and wear safety goggles.

To launch a Film Canister Rocket:

1. Remove the lid of a film canister and pack the center of the lid tightly with  $\frac{1}{2}$  teaspoon of baking soda.
2. Pour about 2 teaspoons of vinegar into the empty film canister.
3. Snap the lid firmly onto the canister.
4. Tip the canister over and set it down so that the lid is on the ground.
5. Stand back! (If the canister doesn't shoot up into the air within a few seconds, try another canister with a tighter-fitting lid.)

To make a Sandwich Bag Bomb:

1. Scoop  $1 \frac{1}{2}$  tablespoons of baking soda into the center of a 4-inch square of paper towel. Fold in the paper towel so the powder stays inside.
2. Pour  $\frac{1}{2}$  cup of vinegar and  $\frac{1}{4}$  cup of warm water into the zip lock sandwich bag.
3. Carefully keep the paper towel package dry while zipping it inside the sandwich bag. Do this by holding the paper towel through the sides of the plastic bag. After the bag is fully zipped, let the paper towel drop into the vinegar.
4. Stand back and watch the bag expand and pop with a bang!

### EXPAND

**Experiment:** Experiment to see how changes to the canisters or zip lock bags alter the results. Can you alter the canister to make it fly higher, or in a particular direction?

**Extend:** Can the same chemicals be used to move other types of objects? What if you strap the canister onto a match box car?

**Discuss:** Is this reaction more similar to photosynthesis or respiration? In photosynthesis,  $\text{CO}_2$ , water, and light combine to make sugars. In respiration, sugars are broken down into  $\text{CO}_2$ , water, and energy.

**Exhibit:** You can apply your newly-acquired knowledge of this type of reaction to The Leonardo's algae exhibit.

# EXHIBIT: MATERIAL SCIENCE

## ACTIVITY: What's in Our Water?

*How do contaminants affect our drinking water?*



### DISCOVER

You will create a small farmland and coastline, and students will observe how contaminants travel through the groundwater. Students will then create a well and observe the purity of its drinking water.

### MATERIALS

Each station needs:

- Plastic or glass container approx. 16" wide x 12" deep x at least 6" high
- 4-5 cups of gravel
- Food coloring (any color)
- Water
- 1 squirt bottle with removable top

- 1 straw
- 1-2 paper towels

Optional materials:

- 2 cups sand
- Fake turf
- Hot cocoa powder

Grades: 8th-12th

Group Size: 5 students per station or one demonstration in front of 30 students

Time: 15-30 minutes

Utah Core Curriculum:

- 8th Science 1.1 b, c
- 9th Earth Science 4.1 a, b, c, d, e
- ILO 5 a

Process Skills & Higher Level Thinking Skills:

- Observing
- Questioning
- Investigating
- Comparing
- Applying
- Analyzing

### PREPARE

Before class begins, follow these instructions to prepare the "farmland" and "coastline" for each group.

1. Tape a straw to the inside wall of the container.
2. Pile gravel on one side of the container (the same side as the straw), creating a coastline. If desired, pile sand on top of the gravel and place fake turf on top of the sand.
3. Add water until the water is about half as high as the gravel.

# EXHIBIT: MATERIAL SCIENCE

## What's in Our Water?

### WHAT'S GOING ON?

This demonstrates how easily a contamination can travel through a permeable layer. The spaces in between the gravel and sand allow for the contamination to get sucked up the well. In the real world, this process takes much longer because of the larger space that needs to be traveled and the tighter packing of the soil.

For more information and ideas, visit

- <http://geology.com/water>
- <http://education.usgs.gov/common/secondary.htm>
- <http://www.groundwater.org/gi/sourcesofgwcontam.html>

*Below are some sources of potential water contaminants. Encourage your students to think of others.*



*Drilling practices, including fracking*



*Runoff from factories and industrial processes*



*Pesticides on farms*

4. Place the “straw” of the squirt bottle top into the straw that you have taped to the container (so when you pump the squirt bottle, it draws water from the bottom of the container).

### PONDER

- What processes or materials can contaminate our water?
- What processes are or could be used to clean up water contamination?
- How long does it take to contaminate and decontaminate groundwater?
- How is the demonstration in this activity similar to and different from real life?
- What real-life contaminants could the cocoa powder and food coloring in this activity represent?

### EXPERIMENT

This activity shows how contaminants can travel from their sources to other locations, even into your drinking water.

1. Divide the students into groups of about five students each and give each group a prepared container.
2. Have the students add several drops of food coloring to the water and dirt or turf in their container. They can also sprinkle some cocoa on the turf and then spray the turf with water to simulate rain. The food coloring represents a contamination such as oil and fracking fluid and the cocoa represents pesticides from a farm.
3. After adding the contaminants, students should pump the “well” using the spray bottle top. Have them spray the well contents onto a paper towel until they begin to see the contaminants staining the towel with water from the well. It may take a few minutes.
4. Ask students to suggest ways to prevent contamination, ideas to decontaminate the system, and discuss any questions they have.

### EXPAND

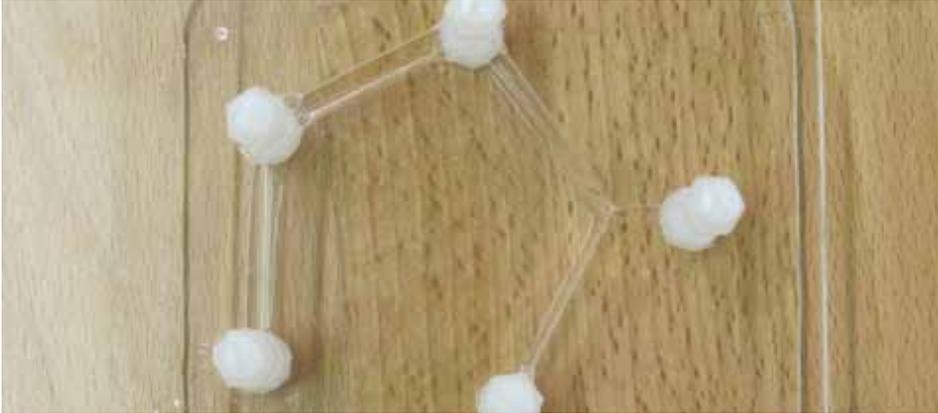
**Experiment:** Try adding a non-porous layer (such as clay) and compare how the contaminants travel through different materials.

**Discuss:** Discuss current events related to water contamination. Have students walk around the school or their neighborhood looking for possible contaminants (oil leaking from cars, pesticides on lawns, local factories, etc.)

## EXHIBIT:

# ACTIVITY: Bubble Paths

*Why are bubbles spherical? What other shapes can they make?*



## DISCOVER

Students will experiment with various geometrical configurations of soap film and bubbles while discovering how light behaves when it passes through the distinct media of soap and water.

Grades: 8th-12th

Group Size: 1-3 students per bubble block

Time: 30 minutes for construction; 10 minutes for discovery

Utah Core Curriculum:

- 6th Science 6.2 a, b, c, d, e
- 8th Science 4.1 b, c
- Geometry
- Chemistry 3.3 c

Process Skills & Higher Level Thinking Skills:

- Observing
- Questioning

Related Activities/  
Exhibits:

- Hylozoic Veil
- Holotype

## MATERIALS

For a durable bubble block, you will need:

- 2 4-inch squares of 1/8" or 1/16" acrylic sheets (available at hardware stores)
- 3-6 nylon bolts (you can use metal screws, but they will eventually rust) (available at Radio Shack or Home Depot)

You can also build a cheaper version using:

- 1 plastic CD case
- 1-2 drinking straws, cut into 3-6 pieces about 1/4" long
- Hot glue or other water-resistant glue

You can use a store-bought bubble solution or make your by mixing:

- 2/3 cup Joy dishwashing soap
- 1 gallon water
- 2-3 Tbl of glycerin (find it at your local pharmacy)

You will also need:

- A drill with a bit that matches the size of the bolts, screws, or straws
- A razor or utility knife (to score the acrylic sheets or CD case)
- A container to hold the bubble solution, with an opening wide enough to dip the blocks in and out.
- Paper towels

## WHAT'S GOING ON?

Light is refracted and reflected when it passes through the bubble. We see so many colors because the soap film causes some of the light waves to reflect off the outer surface of the bubble. Other light waves enter the thin film and then reflect off the inner surface of the film. Both of those emerging reflected waves will interact with each other. The resulting interference will produce different wavelengths of light, or different colors. Varying thicknesses of bubble film produce different colors, because light takes longer to travel through a thicker film, so the resulting light wave interference changes. If the film gets thinner than the wavelength of visible light, it appears black. To put a bubble's width in perspective, a bubble can be up to 500 times thinner than a human hair!

You can view a video exploring the idea of the shortest distance between points at [http://www.snibbeinteractive.com/platforms/socialfloor/products/boundary\\_functions](http://www.snibbeinteractive.com/platforms/socialfloor/products/boundary_functions)

## PREPARE

If you use acrylic sheets, you'll need to drill the holes. Experiment with the number and location. If you glue the posts to the squares, allow time for the glue to dry. Have some towels handy so you can wipe up any spilled bubble solution.

## PONDER

- What's the shortest distance between 2 points? 3 points? 4 points?
- How are the rainbows in nature formed?
- Why is a bubble covered in so many colors, when just white light is shining on it?

## EXPERIMENT

1. Submerge the bubble blocks in the bubble solution and remove. Watch how the path of the soap film configures itself.
2. Gently blow the soap film to change its path, and observe how it re-configures itself back to equilibrium. The soap film will follow the shortest path between points, because this provides the most stable bonding between water and soap molecules.
3. Document your findings.
4. Use a block as a "bubble wand" to blow a bubble. Coat another block or your hand with soap to catch the bubbles. Observe the patterns of light on the surface of the bubble.

# EXHIBIT: VISUALIZING SOUND

## ACTIVITY: Exploring Sound

*How does sound travel? How can we “see” sound?*



### DISCOVER

Students will explore three stations, each of which demonstrates different properties of sound. The “big ideas” of each station are: 1) force affects sound waves; 2) sound waves have certain characteristics; 3) sound travels differently in liquids, solids, and gases.

### MATERIALS

- 1 metal or plastic container (any shape or size)
- Plastic wrap (enough to cover the top of the tin or container)
- 2-3 teaspoons of sand
- 1 plastic lid (any size)
- 1 plastic spoon
- 1 rubber band (big enough to fit around the edge of the tin or container)
- 1 Slinky
- 1 meter stick or tape measure
- Music box (or cell phone with a musical ringtone or anything that makes noise)
- 2 sandwich zip lock bags
- Towel (optional, just in case)
- 2 pan lids or other pieces of metal
- 1 metal spoon
- Student worksheets (attached)
- Worksheet answer key (attached)

### PREPARE

1. Make copies of the student worksheet (attached) or create your own.
2. Prepare station 1: Force & volume
  - a. Cover the container with the plastic wrap and secure it with a rubber band.
  - b. Put the sand on top of the plastic wrap.

Grades: 2nd-9th

Group Size: 10-30 students in 3 groups of 3-10 students each.

Time: 45 minutes (10 minutes at each station, plus a short introduction and concluding discussion)

Utah Core Curriculum:

- 6th Science 6.3 a, c
- 8th Science 4.1 a, b, c
- Physics 4; 5.1 a, f

Process Skills & Higher Level Thinking Skills:

- Hypothesizing
- Investigating
- Communicating
- Observing
- Questioning

Related Activities/ Exhibits:

- The Leo on Wheels Voice Print & Whisper Dishes
- Digital Commons Sound Booth
- Materials Science

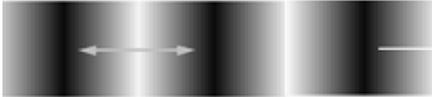
# EXHIBIT: VISUALIZING SOUND

## Exploring Sound

### WHAT'S GOING ON?

#### Wave Types

There are two main types of waves: longitudinal and transverse. Sound waves are longitudinal waves, as illustrated by the Slinky. Another example of longitudinal waves is seismic primary waves (P-waves).



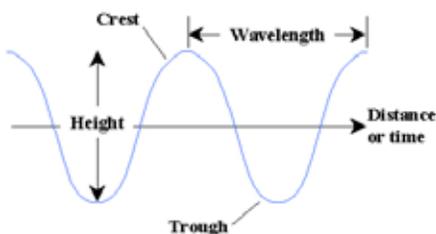
Sound moves through longitudinal or compression waves, with the vibration in the same direction as the travel.

Examples of transverse waves (up and down movement perpendicular to the direction of energy) are electromagnetic waves (light) and seismic secondary waves (S-waves). Moving a rope up and down creates transverse waves.



Light moves through transverse waves; the oscillations are perpendicular to the direction of travel.

#### Wave Characteristics



- The **crest** of the wave is where the particles are crowded, or compressed.
- The **trough** of the wave is where the particles are less crowded.
- **Amplitude** is the distance the wave oscillates (the size of the wave).

- c. Place the metal spoon, one of the metal lids, the plastic spoon, and the plastic lid next to the tin or container.
3. Prepare station 2: Wave characteristics
  - a. No preparation needed. You will be using the Slinky and meter stick or measuring tape.
4. Prepare station 3: Transfer of sound through various objects
  - a. Fill the zip lock bag water water. (you may want to double-bag it so it doesn't leak). Have a towel close by in case it leaks.
  - b. Set out the music box, metal lid, and drinking glass.
  - c. Print the sound speed chart or prepare it to display on a projector.

### PONDER

- How does sound travel?
- What professions need to know how sound travels through various materials?
- Is there sound in outer space? Why or why not?
- Do animals hear sound the same as humans?

### EXPERIMENT

Divide the students into three groups and assign them each a station to begin with. Each group should spend about 10 minutes at each station.

#### Station 1: Force & volume

1. Beat the metal lid with the metal spoon very softly close to the tin. Notice the sound and enter your observations on the worksheet.
2. Beat the metal lid with the metal spoon very hard close to the tin. Notice the sound and enter your observations on the worksheet.
3. Do the same with the plastic lid and spoon. Record what you notice on the worksheet.

#### Station 2: Wave characteristics

1. Two students should extend the Slinky 120 cm (~48"). While one student holds one end still, the other should push their end at 2-second intervals. Record what you notice.
2. Two students should extend the Slinky 30 cm (12") While one student holds one end still, the other should push their end at 2-second intervals. Record what you notice.

# EXHIBIT: VISUALIZING SOUND

## Exploring Sound

- **Frequency** is the number of waves in a certain time period.
- **Period** is the time of one cycle, or wavelength.
- A **wavelength** is the distance between a point on the first wave and the same point on the second.

### Station 1: Force & volume

Sound waves are caused by matter's vibration. The greater the force, the greater the wave amplitude, the more the object vibrates, and the louder the sound. Volume is the amount of sound energy reaching your ears.

### Station 2: Wave characteristics

The shorter the space, the more the waves were compressed. The waves also moved out from the vibration source - your hand. See the definitions and diagram above and on the previous page for more information on specific wave characteristics.

### Station 3: Transfer of sound through various objects

Sound travels through moving particles. If there are no particles, there is no sound, so there is no sound in outer space. In hard, solid materials, sound waves can move very fast because the particles in solids are close together and bump into each other often. In liquid, sound waves don't move as fast as in solids, because the particles are farther apart and don't bump into each other as much. In gas (air), sound waves move even more slowly because the particles in gas are farther apart and don't bump into each other very often.

### Station 3: Transfer of sound through objects

1. Play the music box in the air, about 3" from your ear.
2. Put the plastic bag of water next to your ear. Have a friend place the music box against the other side of the plastic bag and play the music.
3. Put the metal lid next to your ear. Have a friend place the music box against the other side of the metal and play the music.
4. Record the differences in sound on your worksheet.
5. Look at the sound speed chart. Through which medium does sound travel the fastest? The slowest?

### Reflection

Have the students discuss what they have learned about sound. Encourage them to share ideas of how these principles might be applied to other subjects (music, architecture, etc.) and share questions they have about how sound travels. This discussion can take place in small groups, with the whole class, or as a writing assignment.

## EXPAND

Newton's Laws: The characteristics of sound waves can be related to Newton's laws of motion. The principles that govern forces and movement also govern the behavior of sound.

Acoustics: When designing rooms and buildings, architects and engineers take into account the principles of sound and use materials that will create the desired effects. For example, a concert hall is designed specifically to amplify sound while a library or classroom may be designed to muffle sound.

Animals: Different animals perceive sound in different ways. You may want to discuss these differences with your students.

Communicating: Discuss how technology enhances our hearing. Talk about how different communication methods work (cell phones, satellites, etc.) as well as how hearing aids, speakers, and ear plugs can help us.

# EXHIBIT: INNOVATION CLOUD

## ACTIVITY: Hot Air Balloon

*How can you overcome the pull of gravity to create flight?*



### DISCOVER

Students will investigate the effects of different variables on flight as they search for solutions to create a working hot air balloon using simple objects. The finished product should reflect correct principles of both physics and design—it should successfully fly and look good.

### MATERIALS

For each balloon you will need:

- A lightweight(6-10 microns) plastic trash bag (We used 10-gallon, 8.6 micron Kirkland brand bags from Costco, but you can experiment with different sizes & styles)
- 4 birthday candles
- Matches or a lighter
- Balsa wood - 1 piece of 1/8" x 1/8" at least 10" long and 2 pieces of 1/4" x 1/4" at least 13" long each (You can also use straws or other lightweight material)

- 4-6 feet of thread
- Aluminum foil - about 4" square
- Scotch tape

Optional supplies:

- Cardboard or other material to protect the floor from dripping wax
- A pitcher or bucket of water nearby (just in case)
- Markers, paint, and other decorations

### PONDER

- Gravity affects all objects on the earth. How can you overcome the effects of gravity to create flight?

Grades: 6th-12th

Group Size: 3-7 people per group

Time: 1-2 hours

Utah Core Curriculum:

- 6th Science 6.1 e
- 7th Science 1.3 a, b, c
- 8th Science 1.3 b
- Physics 2.3 c

Process Skills & Higher Level Thinking Skills:

- Observing
- Investigating
- Problem solving
- Applying concepts
- Evaluating
- Creating

# EXHIBIT: INNOVATION CLOUD

## Hot Air Balloon

### WHAT'S GOING ON?

Hot air balloons rise because of buoyancy. There is more air pressure at sea level (about 14.7 psi) than at higher altitudes because the air is supporting the weight of all the air above it. Because air pressure is generally greater below an object than above, air pushes up more than it pushes down. But this buoyant force is weak compared to the force of gravity. For buoyancy to lift an object, the object has to be lighter than an equal volume of the air around it.

Hot air balloons rise because warm air is less dense than cool air, so the mass per volume is less. One cubic foot of air weighs approximately 28 grams. If you heat that air by 100 degrees F, it weighs about 7 grams less. Therefore, each cubic foot of air contained in a hot air balloon can lift about 7 grams. That's not much, which is why it is important that the balloon have as much volume and as little mass as possible.

Archimedes figured out this principle of buoyancy more than 2,000 years ago, but nobody built a successful hot air balloon until 1783.



*Step 4: The aluminum foil catches dripping wax and protects the wood frame from catching on fire.*

- The first successful hot air balloons were made in 1783. The same basic designs are still being used today. What physics principles do you need to know to create a hot air balloon?
- You've probably heard that hot air rises. Why is that?
- What are volume, density, mass, and air pressure? How do they affect flight?

### EXPERIMENT

There are several ways to create a hot air balloon. Listed below are the steps of one way to make a small balloon that will fly in your classroom. For older students, rather than giving them the step-by-step directions below, talk about the various factors that affect lift and give them a variety of materials to design their own hot air balloon.

You may be tempted to do this activity outside, but if there is any wind at all, the balloon will not fly and there is a greater likelihood that the flame will spread. The best location is an open room without fire hazards that is relatively cold (a science classroom or gym work great).

**Safety Note:** This is a very fun activity. However, it can also be dangerous, as you will be using open flame. Be sure your students can handle the responsibility. You may want to have the students design and create the balloon (steps 1-6) then light the candles and handle the balloon while it is flying yourself (steps 7-8).

1. If the plastic bag you are using is gathered at the bottom, cut off the bottom just below the seam. Lay the bag flat and tape the end shut. (This is to increase the volume of the bag).
2. Cut the 1/8" balsa wood into two 13" segments and the 1/4" wood into one 10" segment. Tape these pieces to form an "H" with the longer segments on the side and the shorter one forming the horizontal bar.
3. Wrap a small piece of aluminum foil around the middle of the horizontal bar of the "H" so that it covers about 4" of the wood and has sides that come up 1/4" - 1/2" (to catch the melting wax from the candles).
4. Cut 3 or 4 candles in half. Trim the cut ends so that each of the half candles has a wick showing. Using the match, melt the bottom of each candle and stick it inside of the aluminum foil "boat" on the wood frame.
5. Decorate your hot air balloon (optional).
6. Tape the edges of the "H" to the open edge of the bag.

## EXHIBIT: INNOVATION CLOUD

# Hot Air Balloon



Step 9: Set the lit balloon carefully on the floor.



Step 10: Flight! Watch the balloon carefully as it flies and extinguish the fire before it reaches the wood frame.

7. Tie the thread to the wood frame to keep it from flying away from you.
8. Put a piece of cardboard or other cover on the floor to protect from dripping wax. Carefully light the candles while having someone else hold the top of the bag so that the sides don't touch the lighted candles.
9. Set the lit balloon on the cardboard on the floor, holding the sides away from the flame as it fills with hot air.
10. After a minute or two, the balloon will fill up with heated air and rise. Hold on to the string so you can keep it away from anything flammable in the room. The wax from the candles may drip a little. Watch the balloon carefully.
11. Use the string to bring the balloon down and blow out the candles before they melt all the way down. If you let the candles burn all the way down, the wooden frame may catch on fire.
12. If you have time, change the variables (size & weight of the bag, number of candles, shape of the frame, different materials, etc.) to investigate how changes affect the lift.

### EXPAND

**Experiment:** How can the principle of buoyancy be applied to objects other than hot air balloons? (For example, boats, things that float or sink in water or other fluids.)

**Extend:** This activity can be used in conjunction with other activities to teach about density, air pressure, or inventions.

**Discuss:** What hot air balloons are being used for exploration? For information on current NASA projects, see [www.nsbfnasa.gov](http://www.nsbfnasa.gov).

**Exhibit:** The Leonardo's Innovation Cloud highlights local inventions and innovations. How is the process to develop a hot air balloon similar to the process these innovators used?

# ACTIVITY: Hunting for Algae

How often do you interact with algae and not realize it?



## DISCOVER

How often do you interact with algae? Believe or not, you use products made from algae every day! In this activity, students will analyze the ingredient of foods and beauty products to discover which products contain algae.

## MATERIALS

This activity focuses on finding materials that contain algae. These products are available wherever packaged foods and manufactured goods can be found. Good places to start include a kitchen, bathroom, or grocery store.

## PREPARE

**In the classroom:** The day before you do this activity, assign students to search their cupboards and refrigerators at home for products that contain algae. Have them bring in the product, packaging, or a picture or list of items that contain algae.

**In the home:** If you are already at home, just head to the kitchen!

## PONDER

- How many food and household products use algae?
- Why would algae be used in so many common products?
- How does an algal cell produce the chemical compounds used in these common products?

Grades: 5th—12th

Group Size: 1–30 students

Time: 10 minutes if supplies are already gathered. 30—60 minutes if searching cabinets or refrigerators for items.

Utah Core Curriculum:

- 5th Science 1.3 c
- 7th Science 1.3 b, c, d
- 8th Science 1.4 b, c; 2.1 a, b
- Chemistry 4.1 f
- Science Intended Learning Outcome 5.a (7th, 8th, Chemistry, & Biology)

Process Skills & Higher Level Thinking Skills:

- Investigating

Related Activities/ Exhibits:

- Photosynthesis

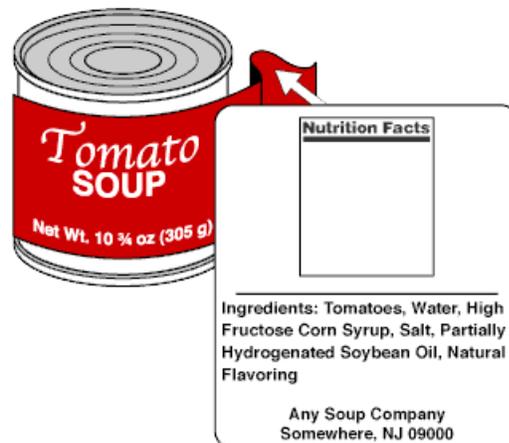
### WHAT'S GOING ON?

Through the process of photosynthesis, algal cells convert carbon dioxide into sugars. These sugars form a thick, gel-like substance that gives shape to algae cell walls. Once extracted from the cell walls, these sugars can be used in products that need a creamy, gummy, or plastic-like texture. In the food industry, alginate (usually extracted from seaweed) is used as a thickening agent and a foam stabilizer to maintain the creamy texture of dairy products. Carrageenan is another form of algae used in this same way. Propylene glycol alginate thickens acid foods like soda pop, salad dressing, and the foam in beer. Calcium alginate is thick like jell-o and can be used in science laboratories to trap and study proteins, to grow bacteria or fungi in petri dishes, to encapsulate drugs in a pill form, or to create a type of bandage for wounds. Sodium Alginate and Sargassum are used as emulsifiers in the food and textile industry, which means they can hold fat and water together so things don't split into two layers. They can also create fibers durable enough for a firefighter's fire-proof clothing. Sargassum is also used as a fertilizer, an additive in soy sauce, a treatment for goiters, and a common vegetable in Japan.

In addition to sugars, algae cells produce oils. Fossilized algae contribute to the petroleum we mine from the earth. So, in essence, algae contributes to any petroleum-based products: from the gas that moves your car, to the plastics in your cell phone, to the Vaseline in your chapstick.

### EXPERIMENT

1. Search your cupboards for products that may contain algae. Below is a list of products that commonly contain algae, but feel free to find your own to add to this list.
  - sushi seaweed sheets
  - pastries
  - jelly
  - ice cream
  - processed cheese (cream cheese, cheese whiz, mac 'n'cheese, American cheese)
  - candy
  - yogurt
  - sour cream
  - mayonnaise
  - margarine
  - frozen dairy desserts
  - canned frosting
  - whipped cream
  - imitation orange pulp
  - soda pop
  - salad dressing
  - gravy
  - hot chocolate mix
  - brownie mix
  - toothpaste
  - fish food
  - dog/cat food
  - medicine
  - lotion
  - paint
  - gasoline
  - anything made with a petroleum bi-product (vaseline, motor oil, asphalt, propane, wax, lubricating oils, etc)
  - oxygen (algae produces a large portion of the oxygen we breathe)
  - dental molds
  - agar plates
  - bandages
  - ink
  - firefighter's fireproof clothing
  - fertilizer
2. Find the ingredients list. All packaged foods, cleaning supplies, medicines, and beauty products have a list of ingredients on the side. It's usually fine print, so pull out a magnifying glass if needed!



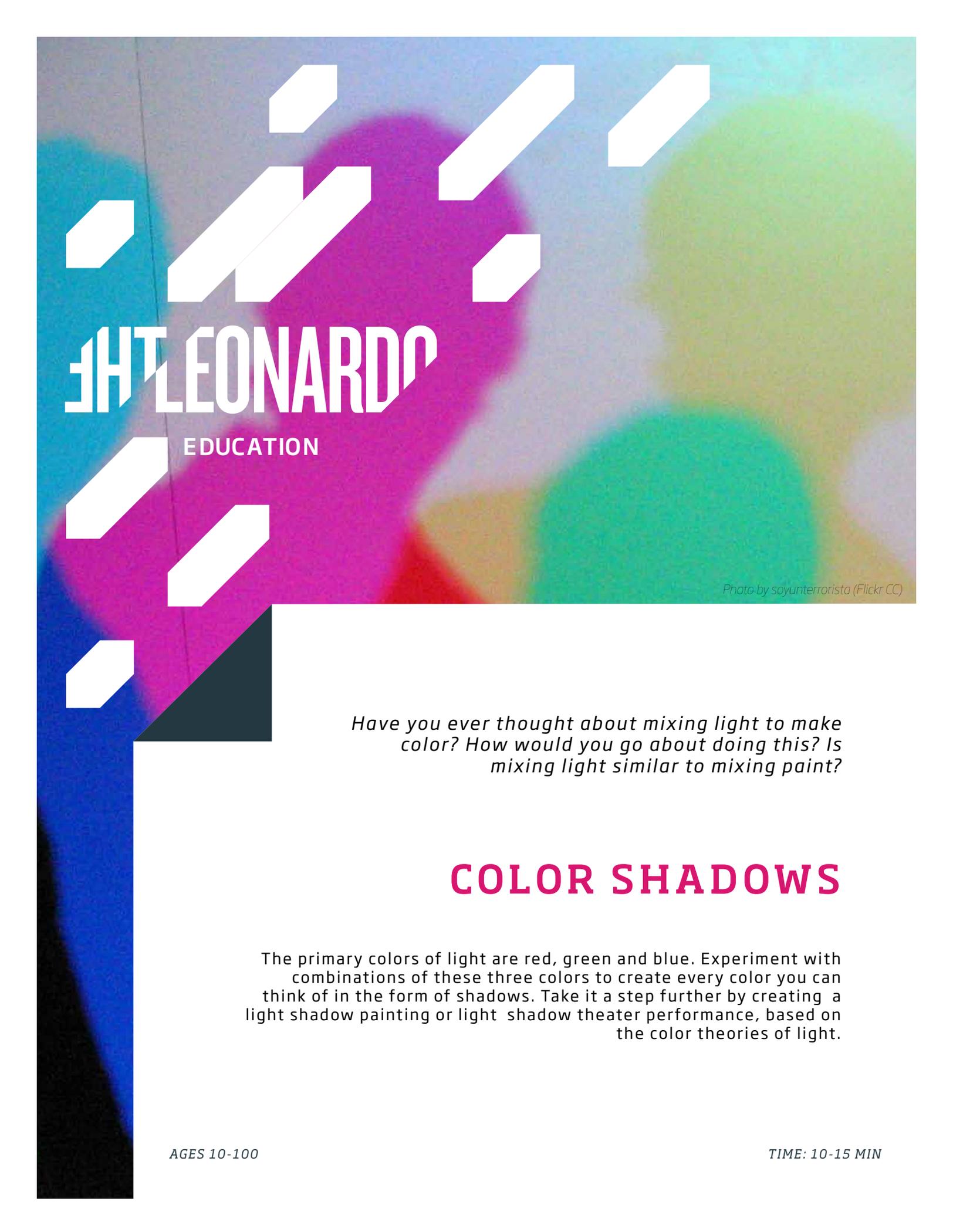
How does algae contribute to the air you breathe? Through the process of photosynthesis, algae produces oxygen. Scientists estimate that algae (primarily in the oceans) produce 73%-87% of the oxygen for the planet.

(Possible Fix For Global Warming? Environmental Engineers Use Algae To Capture Carbon Dioxide, Science Daily, April 1, 2007. [http://www.sciencedaily.com/videos/2007/0407-possible\\_fix\\_for\\_global\\_warming.htm](http://www.sciencedaily.com/videos/2007/0407-possible_fix_for_global_warming.htm))

3. Identify the algae. Algae comes in many forms and its products are identified by names such as: alginate, calcium alginate, alginic acid, sodium alginate, propylene glycol alginate (PGA), carrageenan, beta carotene, agar, sargassum, guluronic acid, and mannuronic acid. Look for these terms in the lists of ingredients on the products you selected.

### EXPAND

These large chains of sugar can create polymers. A polymer is a huge molecule with many repeating smaller parts. The most common algae-based polymer is calcium alginate, which is a gooey, plastic-like substance made up of many six-carbon sugar rings all bound together in large chains. See the attached diagram for a molecular structure of calcium alginate. Our world is full of polymers, including plastics, polyester, and even DNA!



# THE LEONARDO

EDUCATION

*Photo by soyunterrista (Flickr CC)*

*Have you ever thought about mixing light to make color? How would you go about doing this? Is mixing light similar to mixing paint?*

## COLOR SHADOWS

The primary colors of light are red, green and blue. Experiment with combinations of these three colors to create every color you can think of in the form of shadows. Take it a step further by creating a light shadow painting or light shadow theater performance, based on the color theories of light.

AGES 10-100

TIME: 10-15 MIN

# OBJECTIVES

Students will:

## 1 PONDER

2-5 minutes

Begin the exercise by asking students some of the following questions to encourage them to begin thinking about light and colors. Add other questions or adjust these based on the knowledge and interest of your students.

- What are the primary colors when mixing pigment? (red, blue, yellow)
- What are the primary colors when mixing light? (red, green, blue)
- Why do pigment and light have different primary colors?
- How could you make other colors of light?
- How many colors can be created independently when mixing light? How many colors can be created simultaneously?
- What careers need to know how to mix colors?
- How do you manipulate shadows and the color of light on a daily basis?

## 2 EXPLORE

10-15 minutes

### COLOR COMBINATIONS

1. Direct the students' attention to the screen and explain that today they will be exploring the colors of light and its shadows.
2. Ask students what they expect to see on the screen when all three lights are turned on and why.
3. Ask one of the students to turn on the power strip (which will turn on the light bulbs) to show them that the combination of the three lights creates white light.
4. Ask, "What color should we make next?"
5. Have students hypothesize what color of bulbs they will need to use to make that color.
6. Invite one or two students to test their hypothesis. They can block specific colors by placing black card stock or black tissue paper in front of that light bulb (not touching the bulb). If the first student's hypothesis turns out to be incorrect, invite another student to come forward and test their hypothesis until you have successfully created

# PREPARATION

## MATERIALS

- 3 incandescent light bulbs: 1 red, 1 green, and 1 blue
- 3 bulb sockets with 2 prong plug
- 1 power strip
- 1 extension cord
- A large white surface, (whiteboard, white wall, projection screen or a white bed-sheet.)
- Objects to cover light bulbs: 2 sheets of black card stock and 3 sheets of translucent black paper (black tissue paper works well)
- Digital camera (optional)
- Tripod for camera (optional)

## PREPARATION

- Prepare an area that can be dark or at least dimmed. If necessary, cover any windows with black paper or fabric.
- Set up a projection surface with an open area in front of it where students can experiment.
- Plug the three sockets into a power strip (evenly spaced). Screw the three light bulbs into the sockets. Connect the power strip to an extension cord and place it in front of the projection surface.

the right color.

- Repeat steps 4-6 with several colors.

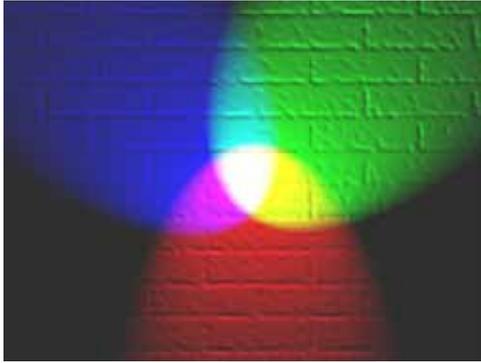


Image courtesy of Wikimedia Commons. Author: en:User:Bb3cxv

### SHADOW THEATER

Invite one student to hold the power strip with light bulbs and one or two students to control which bulbs are blocked. Encourage the rest of the group to create a shadow theater by creating a variety of colored shadows using their bodies or classroom objects. As they do, ask them questions to help them think about some of the concepts below (or others that you can think of).

- Have the students observe how their shadows interact.
- How does the distance of the lights and objects from the screen impact the colors created?
- What affects the intensity of the colors?
- Challenge the students to see how many different colors they can get display the screen at the same time.
- Challenge the students to get each color to cover the screen, one at a time.

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## EXPAND

Variable time

Take this exercise a step further by experimenting with video or photographic exposures in order to document your light and shadow art. Have students use a digital camera and long exposure times to experiment with creating a light shadow painting. How many color combinations can they represent in their scene? Encourage students to play with movement and exposure time. Encourage students to create a video script based on the color of light and the primary colors of RGB. Could you use this colored shadow technology for the lighting in your next theatrical performance?

### MORE FROM THE LEONARDO

- Look for more light-related lesson plans on [www.theleonardo.org/learning/resources](http://www.theleonardo.org/learning/resources), including activities using prisms and glow sticks.
- Visit The Leonardo and explore our Digital Corner and Materials Science station to learn how the concepts in this lesson are used in other applications.

## WHAT'S GOING ON?

### ADDITIVE VS. SUBTRACTIVE COLOR

Additive color refers to color emitted by a light source. Additive color systems start without light (black). Light sources of various wavelengths combine to make a color. The primary colors are red, blue and green.



A subtractive color model explains the mixing of paints, dyes, inks, and other pigments. Each color is caused by absorbing (subtracting) some wavelengths of light and reflecting the others. We see the reflected color(s). The primary colors in a subtractive color model are red, yellow, and green.



### ADDITIVE COLOR COMBINATIONS

At least 7 hues of light can be created using combinations of red, blue and green light. These hues include blue, red, green, white, cyan, magenta and yellow. Other hues can be created by changing the proportions of colored light combined.

Red + Green = Yellow  
Blue + Green = Cyan  
Red + Blue = Magenta

## WHAT'S GOING ON?

The human eye perceives the mixture of red light, green light and blue light as white light. When we look at a rainbow, we are seeing this process in reverse - rain water splits white light from the sun into a spectrum of different colors. When one of the colored lights in this exercise is blocked, the ones that are left combine to make a new color. The proportion of each color will affect how the color is expressed. This can be seen as students stand at different distances from the screen to alter the shadow colors.

### OUR EYES

The light receptors in the retinas of our eyes that perceive color are called cones. The three main types of cones perceive short, middle, and long wavelengths of light. The short wavelength cones perceive blue-ish light, the middle wavelength green-ish light, and the long wavelength red-ish light. A mixture of these receptors are used to see the full range of colors in the light spectrum. With these three types of cones we can see more than a million different shades of color.

### RGB IN TECHNOLOGY

Red, green and blue light combinations are detected or produced by many devices we use on a daily basis. Just a few examples include: TVs, video cameras, digital cameras, image scanners, plasma TVs, computer screens, cell phone displays, and video projectors. Because of differences in technology, R,G,B levels vary not only from manufacturer to manufacturer but also within the same device over time.

## UTAH CORE CURRICULUM

### 5th Grade

- Visual Arts 1.1; 1.3a,b,c,d; 4.3b,d

### 6th Grade

- Science 6.2a,e
- Visual Arts 1.1; 1.3a,b,c,d; 4.3b,d
- Theater 2.1b

### 8th Grade

- Science 4.1e

### 7th-12th Grade

- Foundations of Art I 1.1a,b,c; 4.2b
- Foundations of Art II 1.1a,b,c; 2.2a,b; 4.2b Theater II 3.1b
- Theater III 1.1a,b,c; 3.1; 3.2
- Theater IV 1.1a,b,c; 3.1; 3.2
- Film 1.1; 1.2; 3.3
- Art History and Criticism 1.1a,b,c
- Photography 1.1c; 4.2b

### PROCESS AND HIGHER-LEVEL THINKING SKILLS

- Observe
- Hypothesize
- Investigate
- Discover patterns
- Communicate and collaborate
- Play/tinker
- Connect diverse concepts

## ASSESSMENT

# THE ELECTROMAGNETIC SPECTRUM

