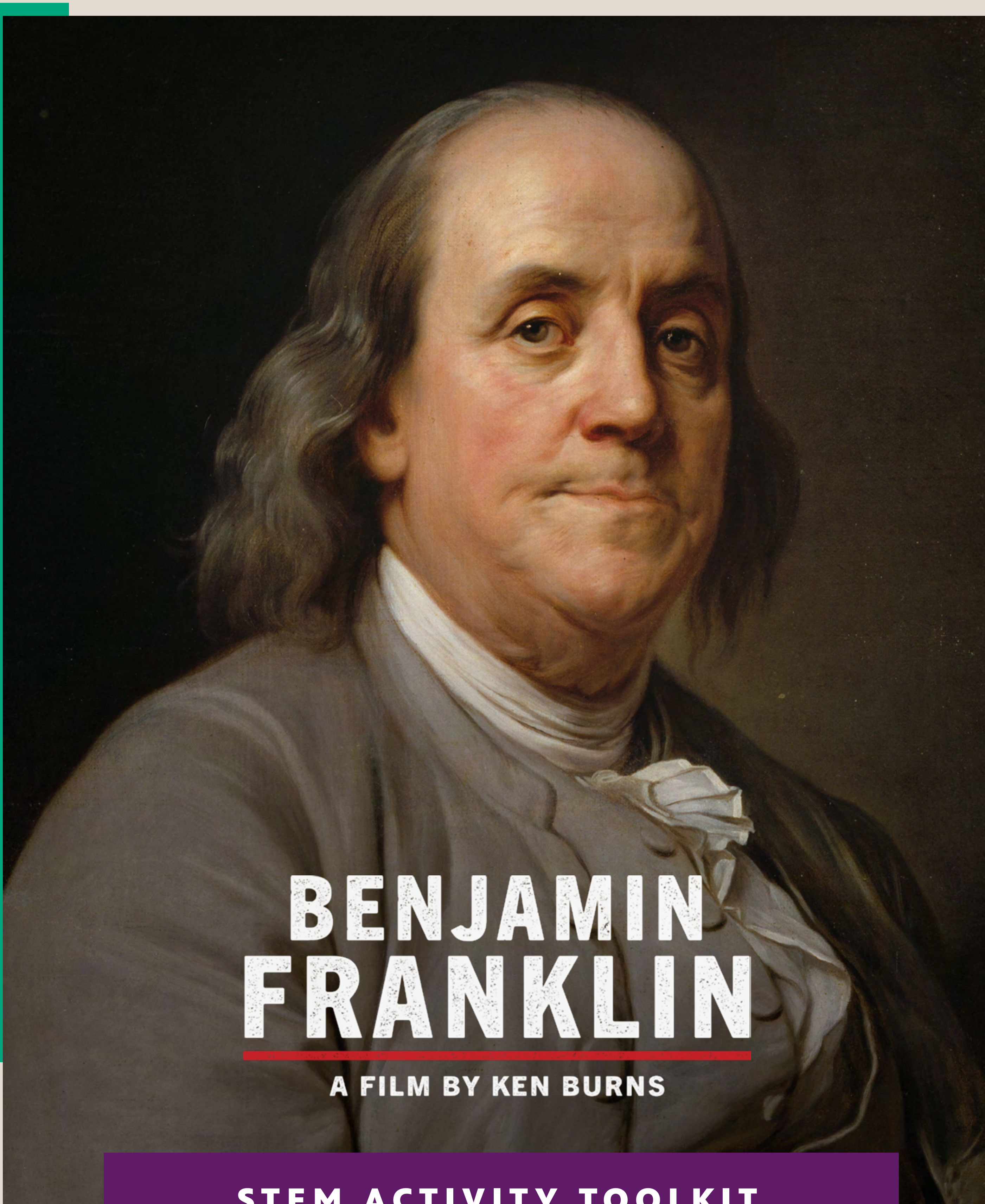

# BENJAMIN FRANKLIN

A FILM BY KEN BURNS

## STEM ACTIVITY TOOLKIT

WETA PBS

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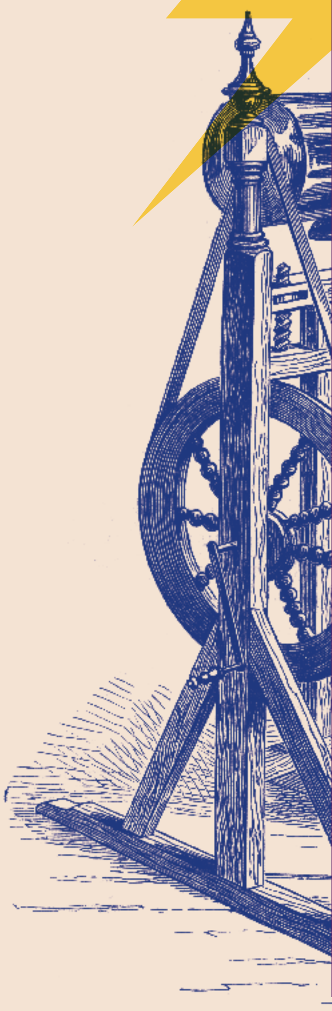



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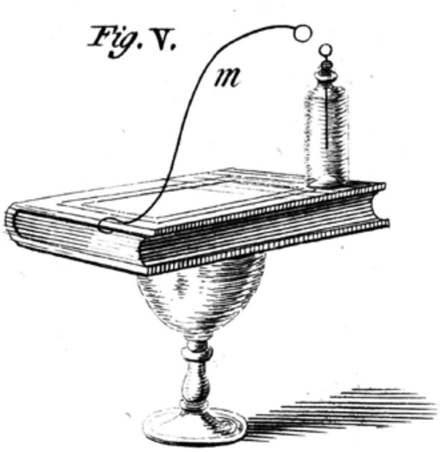
# 1. INTRODUCTION & OVERVIEW
## A. ABOUT THE FILM

**Ken Burns's four-hour documentary, BENJAMIN FRANKLIN, explores the revolutionary life of one of the 18th century's most consequential figures.**

**Visit www.pbs.org/benfranklin to learn more about the film or join the conversation using #BenFranklinPBS on social media.**

**Franklin, whose life has been celebrated as a quintessential American story, was anything but typical. His 84 years spanned nearly the entirety of the 18th century, an epoch of revolutionary change in science, technology, literature, politics and government—change that Franklin himself helped to advance. He launched the first public library in America, organized a volunteer fire company, and founded an academy that eventually became the University of Pennsylvania. His annual publication, "Poor Richard's Almanack," set a model for future humorists such as Mark Twain and contained maxims that are still part of our shared lexicon. And his famous experiments with electricity led to one of his most important inventions—the lightning rod.**

**BENJAMIN FRANKLIN** shows Franklin as a man fascinated by how the world works and an example of a person who boldly pursued his innate curiosity despite his lack of formal education. He participated in the scientific community of his time and grounded his inquiries in a desire to provide tangible solutions to everyday problems. As students, educators, citizens, and scientists, we can learn a great deal about the importance and relevance of understanding the world through the scientific endeavor from Franklin's example.



## B. HOW TO USE THIS STEM ACTIVITY TOOLKIT

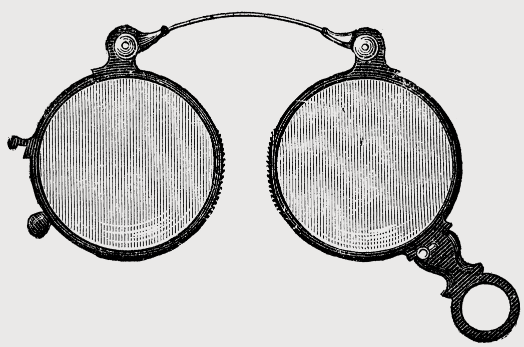
This toolkit was created to support all viewers of Ben Franklin, including young people, parents, caregivers, educators, and community organizations to engage in discussion and activities about the Science Technology Engineering and Math (STEM) concepts explored in the film series.

**The toolkit has four sections:**

**1. Introduction** frames the context of the film series, and provides guidance for educators and community leaders for engaging viewers in discussions and activities.

**2. Viewing the Series** provides pre- and post-viewing discussion guides.

**3. Explore the world like Benjamin Franklin** includes step-by-step guides for science investigations at home and in your community. These activities provide opportunities to use household items and online tools for collaborative STEM learning!



**4. Additional Resources** for finding information about Franklin's achievements, understanding the process of science, and how to support lifelong learning.

**For a deeper introduction to this guide, please watch our overview webinar that offers tips and best practices to use:** https://bit.ly/BFSTEMActivityToolkit

START WEBINAR NOW

## C. GUIDANCE FOR USERS

Exploring the life and work of Benjamin Franklin helps us to understand the process and history of science, and to reflect on the ways we learn and use scientific knowledge in our daily lives. Franklin studied observable parts of everyday life, including weather patterns and electricity. He did not just accept existing explanations for weather or lightning, but looked for evidence to test his ideas by making observations, reading, corresponding with other scientists, and sharing his findings with public audiences.

Franklin also knew that science is useful for improving people's lives and solving problems, as it is today. For many of our biggest challenges, from pandemics to climate change and environmental degradation, we need to turn to scientists for solutions and guidance, and use scientific knowledge to inform our everyday lives. Franklin's story helps us to understand how the process of science works and encourages us to think scientifically about the interesting, exciting, and important challenges we face today.

Be curious! Everyone should explore and experiment as Franklin did throughout his life, and connect science to your personal experiences. Just as Benjamin Franklin strived for self-improvement through daily practice, we can take steps to learn and support young learners to be confident as we explore and work to understand the world around us. The discussion questions in this toolkit challenge users to think about how Benjamin Franklin incorporated scientific thinking into everyday life, and how everyone can work and think scientifically.

**CITIZEN SCIENCE is one way people of any age can engage in the scientific process. People from every background can participate in the collection and interpretation of data, which can lead to making discoveries and solving problems that can help us understand and protect ecosystems, including human communities. To learn about the relationship between science and public life during Franklin's time, visit Dr. Franklin, Citizen Scientist. https://www.amphilsoc.org/museum/exhibitions/dr-franklin-citizen-scientist**

**FOR MORE INFORMATION ABOUT ENGAGING IN SCIENCE, PLEASE VISIT:**

SciStarter https://scistarter.org/citizen-science

FieldScope http://www.fieldscope.org/

Understanding Science, UC Berkeley Museum of Paleontology, https://undsci.berkeley.edu/

National Academies of Sciences, Engineering, and Medicine. (2018). How People Learn II: Learners, Contexts, and Cultures. Washington, DC: The National Academies Press. https://doi.org/10.17226/24783

National Research Council. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: National Academies Press. https://doi.org/10.17226/13165

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press. https://doi.org/10.17226/18290

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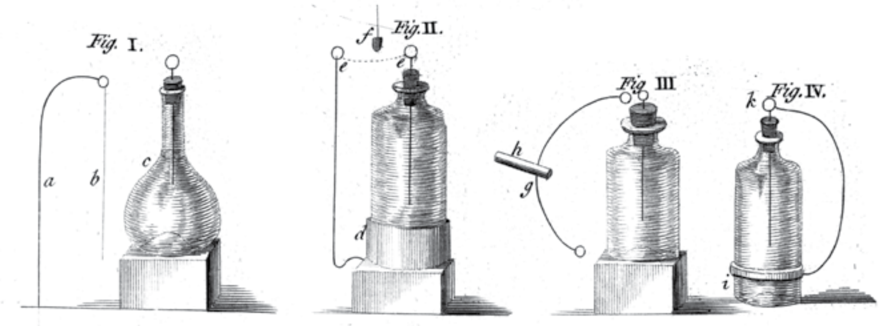
# VIEWING THE SERIES WITH A SCIENTIFIC EYE

## A. PRE-VIEWING DISCUSSION QUESTIONS




**Use these questions to start thinking about the science and engineering themes and concepts that appear in the Benjamin Franklin series.**

1. What do you think you already know about Benjamin Franklin?
2. What is science? What is a scientist?
3. How do you like to learn?
4. How and with whom do you share your ideas? These could be ideas about anything of interest to you.
5. If you had to pick one problem that you face in your community, what problem would you want to solve using science? Why?

## B. POST-VIEWING DISCUSSION QUESTIONS

**Use these questions to reflect on the science and engineering themes and concepts explored in the Benjamin Franklin series, and how they are connected to your own life and experiences. Note that these questions could be used after viewing Part 1 and/or Part 2.**

USE WORDS, DIAGRAMS, OR OTHER CREATIVE WAYS TO EXPRESS YOUR IDEAS.

1. What was one surprising or interesting thing you learned about Benjamin Franklin's scientific achievements? Why did you find that surprising or interesting?
2. How did Benjamin Franklin make scientific discoveries? What did he do with this knowledge?
3. How did Benjamin Franklin like to learn? How is that similar or different from how you like to learn?
4. How and with whom did Benjamin Franklin share his scientific ideas? Why was sharing ideas important to Franklin?
5. Describe at least one problem Benjamin Franklin solved or attempted to solve using science. Why was that problem important in his family or community?

| BEFORE you watch the film... | AFTER you watch the film... |
|---|---|
| What do you already know about Benjamin Franklin as a scientist? | What was one surprising or interesting thing you learned about Benjamin Franklin? Why did you find that surprising or interesting? |
| What is science? What is a scientist? | How did Benjamin Franklin make scientific discoveries? What did he do with this knowledge? |
| How do you like to learn? | How did Benjamin Franklin like to learn? How is that similar or different from how you like to learn? |
| How and with whom do you share your ideas? These could be ideas about anything of interest to you. | How and with whom did Benjamin Franklin share his scientific ideas? Why was sharing ideas important to Franklin? |
| If you had to pick one problem that you face in your community, what problem would you want to solve using science? Why? | Describe at least one problem Benjamin Franklin solved or attempted to solve using science. Why was that problem important in his family or community? |

# 3 EXPLORE THE WORLD LIKE BENJAMIN FRANKLIN: INVESTIGATIONS AT HOME AND IN YOUR COMMUNITY

## A. ACTIVITY 1: WHAT'S THE CLIMATE?

This activity is ideal for families and friends **(children 7+)**, and can even involve people living in different places.

In the **classroom**, this activity is appropriate for grades 2 and up, and could be done over a couple of days, allowing students to gather observations and report back about their findings.

## OVERVIEW

In this activity, you will work and think like Benjamin Franklin, by gathering observational data about weather and climate and comparing your ideas.

## TIMING

This activity will take approximately 45 minutes, but could happen over two days to give learners more time to record observations about weather and climate.

## OBJECTIVES

**Learners of all ages will...**

- Explore the difference between weather and climate.
- Examine and discuss observations and data about climate change.

## MATERIALS

- Pencil
- A copy of the Understanding Global Change Earth Scene (black & white or color) for each person recording climate observations: https://ugc.berkeley.edu/teaching-download/earth-scene/
- Access to Show Your Stripes: https://showyour-stripes.info/l/globe
- Access to the Project Drawdown Solutions: https://drawdown.org/solutions/table-of-solutions

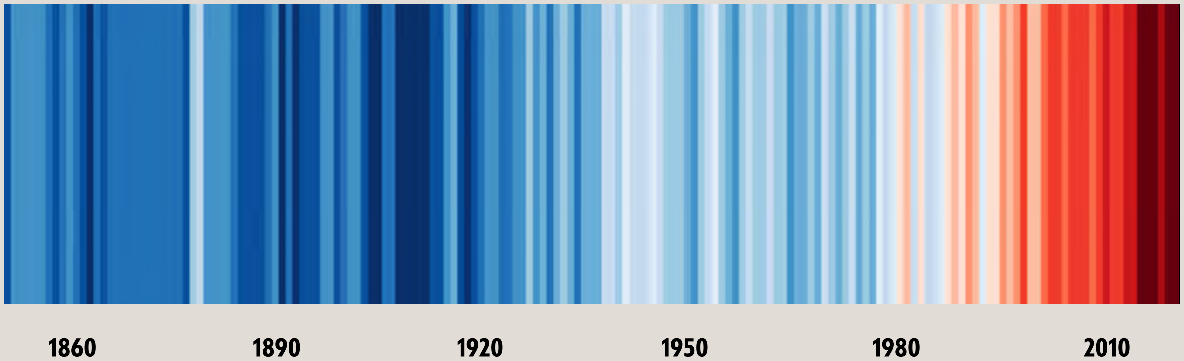
**1.** Based on our lived experiences, weather conditions can change day-to-day. **Weather** describes the **short term variation** (over hours, days, or weeks) in temperature, precipitation, wind, and clouds. We observe and measure weather at specific points in time. We can take lots of weather measurements over long periods of time to understand the climate in a region. **Climate** is defined by the average weather, including seasonal variation in temperature, precipitation, wind, and clouds, **over long periods of time** (over decades, centuries, or millennia). Let's make some observations to help us think more about the difference between weather and climate.

We already know that a puddle on the ground can be evidence of a recent rainstorm (the weather). But now, take a look around your house, school, or place of work, and outside and identify what things you can see that are evidence of the climate where you live. Be creative and think about all your personal items, such as clothes, the plants and animals outside, the way your home was constructed, etc. It might also help to think about the experiences of a family member who lives in a different place, for example Washington D.C. vs. Florida. Both you and your cousin in Florida might own a raincoat, but only one of you might have a wool coat! Record your observations on a copy of the Earth Scene. (10-15 min)

**2.** Scientists are collecting data all over the world to study how the climate is changing due to human activities, especially the burning of fossil fuels and agricultural activities that release greenhouse gases. This increase in greenhouse gases causes more heat to be trapped in our atmosphere, increasing average global temperatures. The rate of warming and the amount of warming won't be the same everywhere because of how air masses and the ocean move and distribute heat over the surface of the Earth, but overall, the average temperature of the Earth is increasing. Because there is more heat in the Earth system, this heat can cause extreme weather events such as hurricanes, to be even more severe.

To visualize how the climate in your state is changing, visit the Show Your Stripes website, developed by Dr. Ed Hawkins at the University of Reading. These striped graphics are visual representations of the change in temperature as measured over the past 100+ years. Red stripes indicate warmer temperatures and blue and white stripes indicate cooler temperatures. You can look at the global change (as seen below) or search for your location. Each stripe represents the temperature in that country or state averaged over a year. For most countries and states, the stripes start in the late 1800s and finish in 2020. (10-15 min)

## GLOBAL TEMPERATURE CHANGE (1950-2020)




The Show Your Stripes graphics were developed by Professor Ed Hawkins at the University of Reading, https://showyourstripes.info/

## AS YOU LOOK AT THESE GRAPHICS, DISCUSS THE FOLLOWING QUESTIONS:

- What do you notice?
- What does this graphic make you wonder?
- What else do you want to know about how and why climate change is happening?

**3.** Benjamin Franklin understood that the various parts of the Earth are interconnected, and that changes in one part of the Earth could affect the climate and extreme weather over time in another place. In the 1780's when a thick "fog" prevented the sun's rays from warming the earth during the summer and led to a brutally cold winter in North America and Europe, Franklin proposed that it may have been caused by a volcanic eruption in Iceland, thousands of miles away.

Today, we face major challenges in both adapting to human-caused climate change and reducing the impact of human activities on the planet.

We already have the knowledge to reduce the amount of greenhouse gases in our atmosphere. We know that we can use technology, policy, business models, and behavior to address the climate crisis and help sustain ecosystems and human populations around the globe.

In groups or as a family, explore this list of Project Drawdown solutions and try to identify which ones reduce the most carbon dioxide in our atmosphere and why they would be good options for addressing climate change. (10-15 min)

Photo credit: www.noaa.gov

Note that carbon dioxide is measured in gigatons. For help understanding what that means visit https://gml.noaa.gov/outreach/behind_the_scenes/gases.html

**AS YOU LOOK AT THE PROJECT DRAWDOWN SOLUTIONS, DISCUSS THE FOLLOWING QUESTIONS:**

- How might these solutions improve your everyday life?
- How could these solutions be implemented at different scales (in your home, in your community, in your state, in your country)?
- Why is changing our sources of electricity such an important part of solving the climate crisis? How is electricity produced?

**4.** Optional extensions: Explore the following resources for more information and explorations about weather and climate change!

- PBS LearningMedia, NOVA, Decoding the Weather Machine: https://www.pbslearningmedia.org/collection/nova-decoding-the-weather-machine/
- NASA, Vital Signs of the Planet: https://climate.nasa.gov/
- Understanding Global Change: https://ugc.berkeley.edu/
- How Global Warming Works “in under 5 minutes” video: https://www.howglobalwarmingworks.org/in-under-5-minutes-ba.html
- Climate Literacy and Energy Awareness Network: http://cleanet.org/
- NOAA Weather & Climate: https://oceanservice.noaa.gov/facts/weather_climate.html

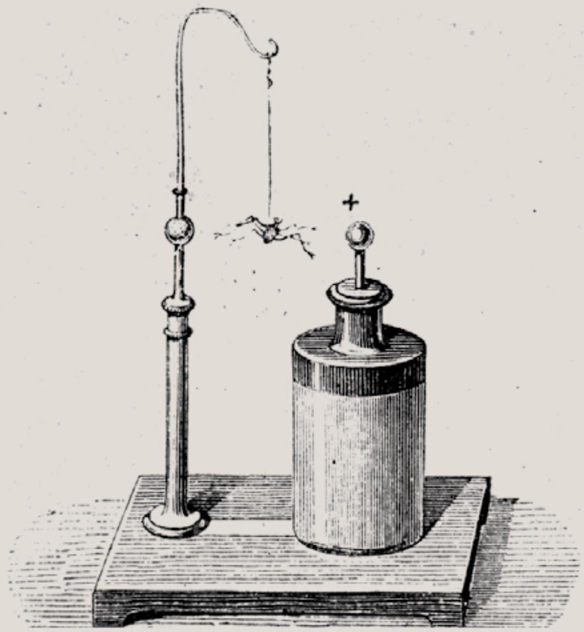

Earth Scene from Understanding Global Change, UC Berkeley, Museum of Paleontology, ugc.berkeley.edu

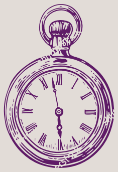
# B. ACTIVITY 2: HOST AN ELECTRICITY PARTY!

## OVERVIEW

> **"I never was before engaged in any study that so totally engrossed my attention and my time."**
>
> \- Benjamin Franklin

Benjamin Franklin was fascinated by electricity, and enjoyed sharing his discoveries with friends and colleagues. In this activity, you will host a party, as Franklin did, where you will make some observations about static electricity and figure out how to impress your friends and family with different experimental designs. Franklin would do tricks with electricity, such as making bells ring or fake spiders jump. It was from these experiments and observations that he was able to further his understanding of electricity and lightning. This activity invites participants to tinker with static electricity.





## TIMING
2 HOURS

## OBJECTIVES
**Learners of all ages will...**

- Learn to make observations about electricity.
- Modify an experimental design to help answer questions.
- Draw models and construct explanations about processes and phenomena that cannot be easily seen.

This activity is ideal for community events and classrooms (children 7+). You will need time to collect and organize all the materials in advance of the event, especially if you are working with younger audiences. Ensure that you have a set of the materials for each group of 3-4 participants. We recommend having at least one adult in each group of young learners, if possible. For younger learners, you might need to provide more support for the more open ended explorations.

In the classroom, this activity is appropriate for grades 2 and up, and could be used at the beginning of a unit about electricity. Make sure you leave enough time to gather and organize the materials for your students. This activity is a great launching point for learners of all ages to explore static electricity and how it behaves. Your group will likely generate a lot of questions, but this will lead to more learning and exploration!

## MATERIALS

- Pencil
- Blank paper
- Model template provided in toolkit
- 1 ft of PVC pipe (vinyl pipe you can get at a hardware store). You could also look for other items made of vinyl in your home, such as window blinds and old records. Alternatively, or additionally, you could use a balloon, but the PVC pipe will be reusable for future experiments.
- 1 piece of wool clothing (could be a sock, hat, glove, scarf, or you could **buy a piece of wool cloth**). Alternatively, you could use your hair, but only if you are comfortable rubbing the PVC or the balloon on your head.
- 1 clear glass jar, or cup between 8- 12 oz
- 1 large paperclip
- 1 piece of cardboard, wide enough to cover the mouth of the jar
- Tape
- Scissors
- A sheet of aluminum foil at least 6x6 inches
- Additional items for more experimentation:
  - 3-4 inch pieces of thin twine or rope
  - Plastic wrap
  - Tiny pieces of Styrofoam
  - Other rods or pipes made out of metal or glass
  - Salt or pepper

- Access to PBS LearningMedia videos about static electricity:

  - **Testing for Static Electricity:** https://www.pbslearningmedia.org/resource/phy03.sci.phys.mfe.zele/testing-for-static-electricity/

  - **Static Electricity: Snap, Crackle, Jump** https://pbslearningmedia.org/resource/phy03.sci.phys.mfe.zsnap/static-electricity-snap-crackle-jump/

  - **Static Electricity: DIY Science Time** https://pbslearningmedia.org/resource/b27c3297-ecc7-4254-bdeb-8e0cf208c8fc/static-electricity-diy-science-time/

## PROCEDURE

### PART 1: SETTING UP THE EXPERIMENT (10 MIN)

**1.** Cut out a cardboard lid for the jar or cup (this could be done in advance).

**2.** Cut out two strips of aluminum foil measuring ¼ inch x 3 inches.

**3.** Straighten outside of the paperclip and poke the end through the middle of the cardboard lid. Then, tape this side of the paperclip to secure it to the cardboard.

**4.** Shape the other end of the paperclip into a “J” and use the end to poke holes through the two strips of aluminum foil. When you hold the cardboard with the “J” of the paperclip down, the foil strips should hang next to each other.

**5.** Place the lid on the jar with the aluminum foil strips hanging down. The foil strips should not touch the bottom of the jar. If they do, you can trim them with the scissors or adjust the position of the paperclip.

Experimental setup showing how the cardboard, paperclip, and aluminum foil strips should be arranged and placed on the jar.

## PART 2: ELECTRIFYING OBSERVATIONS! (20 MIN)

**1.** Before touching the materials, discuss as a group what you think would happen if we: 1) Rub the PVC pipe with the wool cloth, and then, 2) move the pipe close to the end of the paperclip poking out of the jar without touching the paperclip. After you talk, draw some of your ideas.

**2.** Now, we will test your ideas! Rub the PVC pipe (or balloon) with the wool cloth (or your hair) for at least 5 seconds. Some students might start talking about static electricity, or notice little snaps and shocks that come off the PVC pipe.

**3.** Make sure the whole group is watching the jar and place the PVC pipe near the end of the paperclip poking out of the jar, but don't touch it! What happened?! Record your observations on your paper.

**4.** Now move the PVC pipe away from the jar. What happened?! Discuss with your group members!

**5.** Now work in pairs and draw a model of what happened during the experiment. A template for modeling is provided in the toolkit. Think about what you can see and what you cannot see with your eyes. Show what you think was happening when the PVC pipe was rubbed against the wool, and what happened as the PVC pipe was moved toward and away from the jar. Write down any questions in the box at the bottom of the handout.

## PART 3: CONTINUE EXPLORING AND ANSWERING QUESTIONS (40-60 MIN)

**1.** Now it's time for you to share ideas with the whole group or class (10 min). Ask participants:

- What did you include in your model?
- How can you explain what happened in the jar?
- How could you test your ideas?
- How would you change your model based on the ideas that have been shared?

Remind learners of all ages that in Benjamin Franklin's time, scientists didn't have perfect explanations for how electricity behaves, and many of the early experiments looked a lot like this one! As you work to figure out what is going on, you are following in the footsteps of these scientists, and exploring in this way will give you a better understanding of what is happening!

**2.** After all the groups have shared, ask the groups to experiment more with the materials provided. Some experiments could include:

- Touching the PVC pipe to the paperclip on the jar.
- Rubbing the PVC pipe for different amounts of time or on different materials.
- Touching the PVC pipe directly to a piece of aluminum foil.
- Placing other objects in the jar, such as a piece of rope, Styrofoam, or salt to see what happens.
- Touching the paperclip with your hand when the PVC pipe is close to the jar.
- Touching the paperclip with other household objects (remind young learners to be courteous and ask if they can use something if they are not in their own home).
- Rubbing other materials (metal, plastic, glass, etc.) and then touching the paperclip.
- Replacing the aluminum foil strips with smaller or larger strips, or with another material, such as paper.
- Test paper strips with and without shading one side with pencil.
- There are SO many possibilities!

Over time, you will start to figure out which conditions and materials used in the experiment will change the results and which ones do not. Remember to write down or make sketches of your experimental setups and observations. (20 min)

**3.** Come back together at the end of the class or event to discuss what materials were used by the different groups. Write ideas on the board to document what the group figured out. Then watch one or more of the PBS LearningMedia resources linked below that are appropriate for your audience or classroom to further everyone's understanding of the experiment(s). Ask students how the experiments in these videos are similar or different from the ones they conducted. (10-40 min)

- **Testing for Static Electricity:** https://www.pbslearningmedia.org/resource/phy03.sci.phys.mfe.zele/testing-for-static-electricity/
- **Static Electricity: Snap, Crackle, Jump** https://www.pbslearningmedia.org/resource/phy03.sci.phys.mfe.zsnap/static-electricity-snap-crackle-jump/

- **Static Electricity: DIY Science Time** https://www.pbslearningmedia.org/resource/b27c3297-ecc7-4254-bdeb-8e0cf208c8fc/static-electricity-diy-science-time/

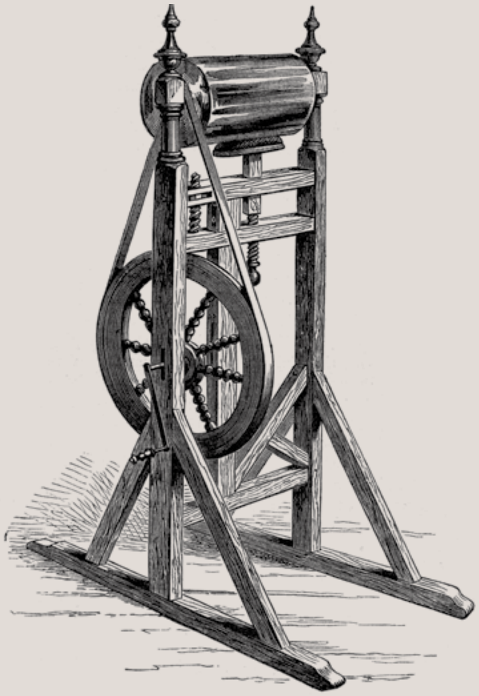
- **Additionally, here are some simulations works for teachers, community leaders, and adult learners to help visualize how this experiment and static electricity works:**

  - **SIMPOP Electroscope:** https://simpop.org/electroscope/electroscope.htm

  - **PhET Interactive Simulations, University of Colorado, Boulder:** https://phet.colorado.edu/en/simulations/balloons-and-static-electricity

  - **Balloon Charging Lab (simulation)** https://www.pbslearningmedia.org/resource/arct15-sci-ballooncharginglab/balloonchargingl-lab/

**4.** Finally, have everyone work in pairs to revise their models and apply what they have learned to explaining what happened in the experiment. Everyone still might have more questions, and that's OK! There is a lot more to learn about electricity and how it works!



Benjamin Franklin´s First Electrical Machine

**Draw a model of what you think is happening during the experiment in the space below! Think about what you can see and what you cannot see at different points in the experiment. What changes?**

**Explain using words and diagrams what happened when...**

| The PVC pipe was rubbed with the wool... | The PVC pipe was moved near the paperclip in the jar.... | The PVC pipe was moved away from the paperclip in the jar. |
|---|---|---|
| | | |

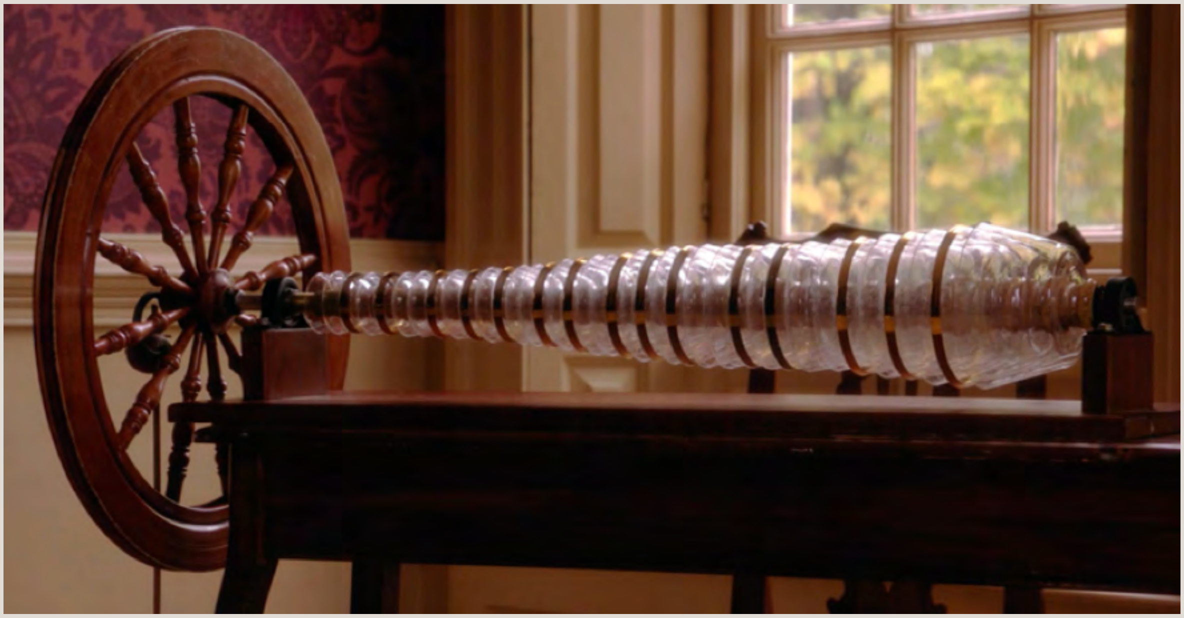
**Questions I have...**

## C. ACTIVITY 3: MAKING MUSIC - HOW LOUD IS YOUR INSTRUMENT?

This activity is ideal for **community events and classrooms (children 5+).** You will need to prepare the materials in advance and ensure that you have a set of the materials for each group of 3-4 participants. We recommend having at least one adult in each group of young learners, if possible.

In the **classroom,** this activity is appropriate for grades kindergarten and up, and could be used at the beginning of a unit about sound.

This activity is a great launching point for learners of all ages to explore sound, how it's made, and how it behaves. Your group will likely generate a lot of questions, but this will lead to more learning and exploration!



Glass Armonica

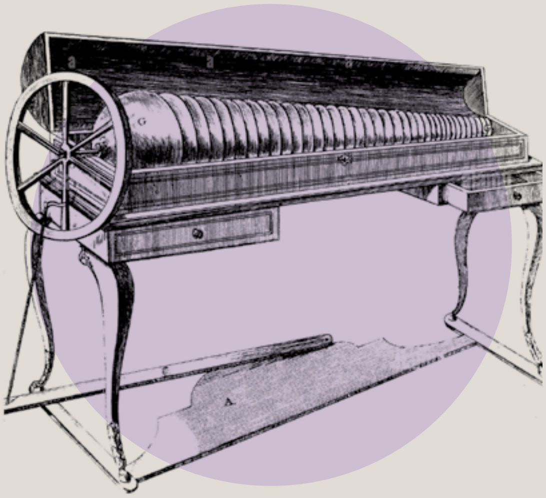
## TIMING
1 HOUR

## OBJECTIVES
**Learners of all ages will...**

- Observe sound vibrations.
- Create an instrument.
- Determine which instrument makes the loudest sound.

## OVERVIEW

Benjamin Franklin was an accomplished amateur musician who also invented an instrument using his expert understanding of how to make different sounds. This instrument, the glass armonica, is a more efficient way to play musical glasses by rotating a set of different sized crystal bowls and moving wet hands over them. Famous musicians of his time like Mozart and Beethoven wrote music for Franklin's instrument! In this activity, participants will experiment with household objects to understand how sound is made and moves, and challenge each other to make the loudest and softest sounds.



## MATERIALS

- Pencil
- Blank paper
- A jar
- Platic wrap (enough to cover the jar)
- Salt, pepper, or rice
- Baking sheet
- Materials for making instruments, depending on what is available! Here are some suggestions:
  - Rubber bands
  - Boxes
  - Metal spoon
  - Empty plastic bottles
  - Cans (look out for sharp edges)
  - Rice
  - Straws
  - Scissors
  - Tape
  - Plastic wrap
  - Aluminum foil
  - Wax paper
  - Combs
  - Other materials you have!
- **Access to PBS LearningMedia video The Science of Sound** www.pbslearningmedia.org/resource/ba1c1421-6d54-4044-98b7-496f325cccb7/sound/

## PROCEDURE

### PART 1: WHAT IS SOUND?
### INITIAL OBSERVATIONS (10 MIN)

**1.** Stretch the plastic wrap over the glass jar and place some salt on the top. Spread the salt out enough so that individual grains are visible.

**2.** Tell participants to make a sketch on a blank piece of paper of what they see (the jar, plastic wrap, and the salt). Everyone can work in pairs, and adults can help younger learners.

**3.** Now place the pan very close near the top of the glass jar (but not touching it!) and make sure everyone can see the salt on the plastic wrap.

**4.** Hit the pan hard a number of times and observe what happens! Then make a sketch and try to explain WHY you saw what you did. What does this observation tell you about how sound is made?

**5.** Now watch just the first 48 seconds of the PBS LearningMedia video The Science of Sound https://www.pbslearningmedia.org/resource/ba1c1421-6d54-4044-98b7-496f325cccb7/sound/

**6.** Based on what was learned while watching the salt on the jar and the video, ask participants to add more ideas to their sketches.

### PART 2: MAKE YOUR INSTRUMENT! (40 MIN)

**1.** Using the items selected, or items around your home, construct a musical instrument! Think about the following questions as everyone figures out their own design:

- Sound is made by vibrations (pushes and pulls in the air), so what's vibrating on your instrument?
- Can you modify the design of your instrument to make it louder or softer?
- How many different sounds can you make with your instrument? Or does it always sound the same? What do you have to do to the instrument to make different sounds?
- Does your instrument sound like anything else you have heard before? Another instrument, animal, or machine?
- How does the sound change in different places, such as in your room vs. outside?

**2.** As participants finish their designs, have them swap instruments and teach each other how to "play" them. Compare and contrast how sounds are made. Do any of the instruments sound the same? Why or why not?

## PART 3: HOW LOUD IS YOUR INSTRUMENT? (10 MIN)

**1.** Ask everyone to demonstrate their instrument for the group. As everyone listens, try to determine which instrument is the loudest and which is the softest.

**2.** Have everyone play their instrument near the jar with the saran wrap and salt. Can anyone make the salt move on top of the saran wrap with your instrument? Who can make it move the most? Note: instruments that involve air movement might disturb the salt, but these are not the sound vibrations. Try to have participants position themselves so they do not blow on the salt. This can be challenging.

**3.** Now watch the rest of the PBS LearningMedia video The Science of Sound to learn more about how sound is measured. www.pbslearningmedia.org/resource/ba1c1421-6d54-4044-98b7-496f325c-ccb7/sound/

**4.** Optional extension. Download a decibel meter to a smartphone, such as Sound Meter or Decibel to measure how loud your instruments are to discover if you were correct in estimating which one was the loudest and which one was the softest.

# 4 ADDITIONAL RESOURCES

## A.FRANKLIN'S DISCOVERIES AND INVENTIONS

**There are many excellent resources online and in print to further investigate Benjamin Franklin's scientific achievements. Below is a list of some of his significant scientific discoveries and inventions with supporting resources which can be referenced and explored.**

**Experiments and Observations on Electricity, a book of Franklin's letters:** https://library.si.edu/digital-library/book/experimentsobser00fran

**Experiments with Electrification of the Atmosphere, Science Friday:** https://www.sciencefriday.com/segments/archive-benjamin-franklin-scientist/

**The Lightning Rod, Franklin Institute:** https://www.fi.edu/history-resources/franklins-lightning-rod

**The Glass Armonica, Demonstration by composer William Zeitler:** https://www.youtube.com/watch?v=eEKlRUvk9zc

**First Chart of the Gulf Stream, Library of Congress:** https://www.loc.gov/resource/g9112g.ct000136?r=-0.489,-0.129,1.884,0.69,0

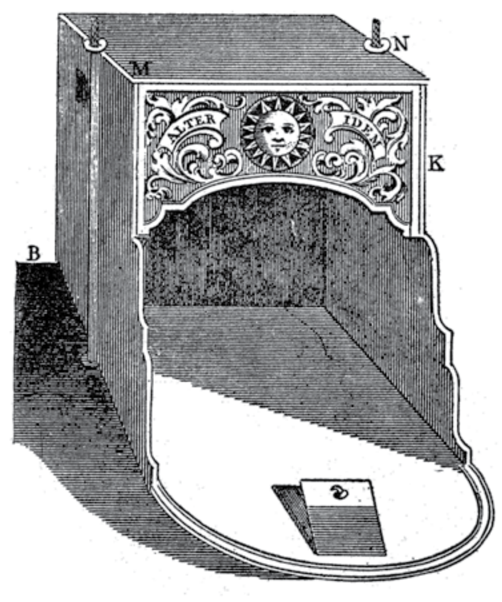
**Bifocals, US Library of Medicine:** https://infocus.nlm.nih.gov/2009/06/01/focusing_on_ben_franklin/

**The Franklin Stove, Franklin Institute:** https://www.fi.edu/benjamin-franklin/inventions

**Benjamin Franklin's Science, I. Bernard Cohen, Harvard University Press:** https://www.hup.harvard.edu/catalog.php?isbn=9780674066595

**Stealing God's Thunder, Philip Dray, Penguin Random House:** https://www.penguinrandomhouse.com/books/42829/stealing-gods-thunder-by-philip-dray/

**The Autobiography of Benjamin Franklin:** https://standardebooks.org/ebooks/benjamin-franklin/the-autobiography-of-benjamin-franklin

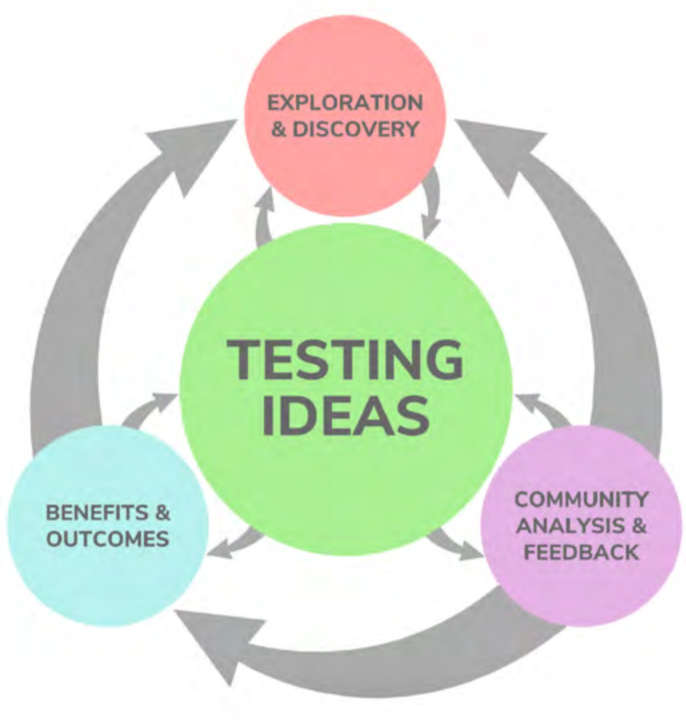



Benjamin Franklin´s Stove.

## B. THE PROCESS OF SCIENCE

**The film series, BENJAMIN FRANKLIN can be used to initiate discussion about the nature and process of science, and illuminate misconceptions about how science works.**

Science is often explained as a series of ordered steps, called "The Scientific Method," which does not accurately describe the complex, non-linear, iterative nature of the process of science. As demonstrated by the life of Benjamin Franklin, scientific investigations can be motivated by various reasons and personal experiences, working as a scientist involves repeated testing of ideas and data collection, engaging with the larger scientific community, and sharing findings with the public.




Understanding Science, UC Berkeley, Museum of Paleontology, undsci.berkeley.edu.

After watching the Ken Burns, BENJAMIN FRANKLIN series, viewers can reflect on Franklin's work as a scientist using the "How Science Works" flowchart from the Understanding Science Project at the University of California Museum of Paleontology at UC Berkeley. This flowchart is a more complete and accurate representation of the process of science that also reflects the Science and Engineering Practices of the Next Generation Science Standards.

### TIPS FOR USING THE FLOWCHART:

- Visit the Online Interactive developed with HHMI BioInteractive for an introduction to the "How Science Works" flowchart: https://www.biointeractive.org/classroom-resources/how-science-works. You can open the interactive by clicking "Launch Interactive" or download the macOS or Windows desktop app. The Interactive is also available in Spanish.

- There are two versions of the "How Science Works" flowchart in the Interactive: "Detailed" and "Basic." Please review the versions and determine which one is most appropriate for your students or audience. The "Detailed" flowchart is recommended for students in high school and college, while the "Basic" flowchart is recommended for students in middle school and community events. Note that the "Basic" model has fewer components and more accessible language, but the

"Detailed" model offers more components to describe the processes of science.

- First, introduce the "Simple" flowchart, as seen above, and then explore more detailed versions of the diagram.

- Various printable versions of the flowchart are also available on the Understanding Science website: https://undsci.berkeley.edu/teaching/teachingtools.php

- Thinking about science as an iterative, ongoing process is likely new to learners of all ages. Learners are less likely to include discussions with peers, presenting their ideas, or communicating science in their communities in the models they construct of the process of science than other parts of the process, such as asking questions, or collecting data. However, activities within the scientific community and increasing public understanding of science are important parts of what it means to do science. The film provides insight into how Franklin engaged both with the scientific community and the public to share his discoveries and find useful applications for his newfound knowledge.

- Franklin's work is in the realms of both science (generating knowledge and explaining how the world works) and engineering (developing new technology to solve problems), which are related and interdependent disciplines. To learn more about the similarities and differences between science and engineering, please check out this page on Understanding Science: https://undsci.berkeley.edu/article/technology_checklist.

Some viewers might recognize that Franklin also worked as an engineer, and you can discuss this as a group.

- You can use the flowchart to reflect on how you engaged in the process of science after you do the hands-on activities in this toolkit.

**DISCUSSION QUESTIONS:**

**Based on what you learned in the film, how did Franklin engage in the scientific process? Identify the relevant parts of the "How Science Works" flowchart.**

**What were some of the sources of inspiration for Franklin's scientific work?**

**What were some of the scientific questions that Franklin wanted to answer? What did he do to answer those questions?**

**Do you think Franklin ever felt that he had "finished" his scientific investigations? Why or why not?**

**What was one way that Franklin used his scientific knowledge to improve the lives of others?**

**How was Benjamin Franklin's scientific process similar or different from how you engage in science?**

## C. LIFELONG STEM LEARNING

> **“This library afforded me the means of improvement by constant study, for which I set apart an hour or two each day, and thus repair’d in some degree the loss of the learned education my father once intended for me.”**
>
> – Benjamin Franklin

Throughout his life, Franklin was constantly learning through reading and writing, debating ideas with friends and colleagues, and directly gathering data and making observations of the natural world. He encouraged the education of others through the establishment of the Library Company of Philadelphia and a college that became the University in Pennsylvania.

As evident in Franklin’s life, not all science learning happens in a classroom. Much of his work and contributions to science occurred through making careful observations and collecting data out in the world, then sharing this information through discussions and exchanging letters with his peers, the scientific community in the United States and Europe, and the public. Our lived experiences and personal interests can help us pursue knowledge and make contributions in our communities and, in turn, enrich our shared experiences in the classroom.

**For educators in the classroom: Benjamin Franklin was always seeking to explain how the world worked. He would use various experiences and observations to help explain how electricity, weather, or ocean currents function. Help students connect their out-of-school time experiences, observations, and prior knowledge to classroom learning. Ask students to share their ideas and thoughts using the following questions when exploring new STEM phenomena and concepts:**

- What do you notice?
- What do you wonder?
- What does this (image, video, dataset, etc.) remind you of? Explain why!
- Have you seen anything or experienced something like this in your home/neighborhood/community?
- How might this phenomenon affect your life?
- Why might it be important for you to understand this phenomenon/concept?
- How is this phenomenon/concept related to other topics we have explored in this class?
- What questions do you still have about this phenomenon/concept?

Students could first discuss these questions in small groups of 2-4 and then share answers with the entire class.

You can return to these questions throughout the school year to support students in taking ownership of their knowledge and connecting STEM learning to their lives.

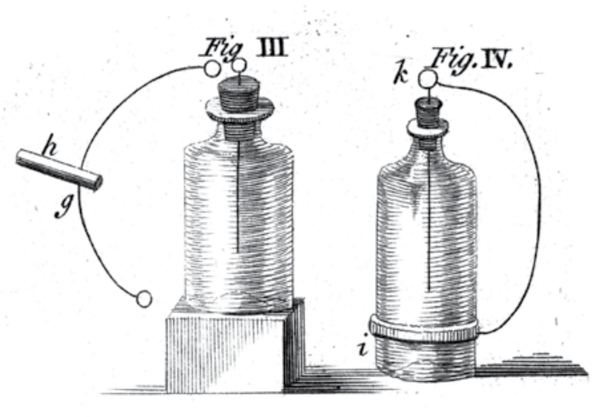
**For families and community leaders: Think about how you and your family might continue your own explorations in STEM using these and other opportunities:**

- Engage in citizen/community science. There are many opportunities to learn about your local ecosystems by participating in collecting and analyzing environmental data. You could track weather or air quality, monitor local creeks and rivers, or document the species in your own backyard! Here are some great programs to help you find a project that is of interest to you!

  - SciStarter (https://scistarter.org/) is an online platform to search for citizen and community science projects in your region.

  - FieldScope (http://www.fieldscope.org/) is an innovative map-based data collection and analysis platform that supports citizen and community science projects with tools to collect data from dispersed geographic locations and to analyze trends, patterns and change over time, including the impact of interventions.

  - iNaturalist (https://www.inaturalist.org/) allows users to upload photos to identify plants, animals, and fungi, share and discuss their findings with an online community of naturalists.




- Establish or join a book or podcast club. Find some buddies and discuss books and podcasts. Share ideas for topics and themes and make sure everyone gets an opportunity to explore topics that are of interest to them.

- Host a STEM exploration night for family and friends!

  - Have you ever wondered how birds evolved to fly? How GPS works? Why cakes rise (or don't) when you bake them in the oven?

  - Pick a question that fascinates you based on your own experiences and find some resources developed by educators or scientists (such as images, videos, podcasts, readings, or experiments with household items), that can help you understand how and why the different parts of the world work the way that they do!

  - Hint: The most interesting questions often begin with the words HOW or WHY. For example, Benjamin Franklin asked questions similar to, "How is lightning similar to a shock felt from my battery?" or "Why does it take longer to travel by ship from England to Philadelphia than traveling from Philadelphia to England?"

  - Here are some resources that can help you brainstorm ideas and begin to answer your questions:

PBS LearningMedia Science pbslearningmedia.org/subjects/science/
Science Friday https://www.sciencefriday.com/
Radiolab https://www.wnycstudios.org/podcasts/radiolab
Startalk https://www.startalkradio.net/

# CREDITS AND ACKNOWLEDGEMENTS

**For more info about BENJAMIN FRANKLIN and to download free educational materials visit:**
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## PRODUCTION CREDITS

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A production of Florentine Films & WETA Television
Executive Produced by Ken Burns

BENJAMIN FRANKLIN is a production of Florentine Films and WETA Washington, D.C. Directed by Ken Burns. Written by Dayton Duncan. Produced by Ken Burns and David Schmidt. Edited by Craig Mellish. Co-Producers Katy Haas and Craig Mellish. Associate Producer Emily Mosher. Cinematography by Buddy Squires. Narrated by Peter Coyote. Voice of Benjamin Franklin Mandy Patinkin. Assistant Editors J. Alex Cucchi and Cat Harris. Production Coordinator Vicky Lee. Apprentice Editor Nora Colgan. Executive Produced by Ken Burns. The executive in charge for WETA is John F. Wilson.

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