Lesson 4: Investigating Atmospheres

Challenge Guiding Question: *How can we use experiments, models, and NASA data to help us better understand both Earth and Venus and to plan a successful mission to Venus?*

Unit Level Question: *How can models and investigations help us understand and compare Earth and Venus?*

Lesson Level Question: *Why are Earth and Venus so different now and what happened in the past to cause these differences?*

Lesson Summary: *Students will begin by considering temperatures that they are most comfortable in, and compare these temperatures to surface temperatures on the 4 innermost planets (Mercury, Venus, Earth, Mars). Then, they will plan and carry out investigations to produce data and use that data as evidence for a claim about temperature. Finally, they will use what they learned in this lesson and the previous lesson to make a claim about why Earth and Venus are so different now and support it with evidence.*

Tips for Expediting This Lesson:

Standards Links: *Click here for information about Elementary (click here), Middle (click here), and High School (click here) Standards associated with this lesson.*

Materials Needed

Lesson Links	Materials Available from NESSP	Materials Provided by the Teacher
TEACHER TIPS Scaffolding Investigations	None	**At a minimum, you will need:** ● Thermometers or temperature probes ● Large (1-2 liter) plastic bottles or other seal-able clear glass or plastic containers (2 per team) ● Light source (such as a grow bulb or sunlight outdoors) **Some additional materials will depend on the testable question that your students choose, but may include:** ● Baking soda and white vinegar (to generate CO2) ● Carbonation system (for carbonated beverages, such as SodaStream) ● Plain and carbonated water ● Plants ● Soil ● Different colored paper ● Timers ● Ways to measure or compare CO2 (such as pH paper, pH

		indicator solution, CO2 meters, or CO2 probes) **A note about materials:** The materials that you need will depend on the kinds of investigations that are designed by your students. In most cases, it is a good idea to gather as many of the materials listed as you can reasonably gather, and make these available to students as they design their experiments. See details in the lesson plan for additional supports as students design their own investigations.

Before The Lesson

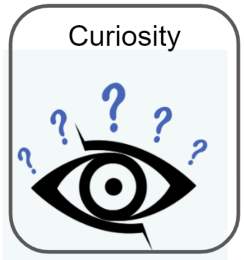
- Read MO-4. This will help you understand the goals of this lesson.
- **Engage**:
  - Use https://www.ncei.noaa.gov/access/us-climate-normals/ or https://drought.unl.edu/climographs.aspx or some other local source to find a graph of seasonal temperatures in your area. Copy this graph and paste it onto Slide 4 of the L4 Engage Slides
- **Explore**:
  - Review the TEACHER TIPS for supporting students as they plan and carry out their own investigations. Prepare to provide students with the LOWEST amount of support that you think they might need, and slowly add more supports if they struggle.
  - Gather materials
  - Review the Claim Examples (listed in Explain) to help you understand the purpose of these experiments.
- **Explain**:
- **Elaborate**:
- **Evaluate**:
- **Extend (optional)**:

Lesson Plan

Phase	Middle School	Materials/Prep
Engage (30 Min)	***Students will identify and share the temperatures that they are most comfortable in, and use this as the basis to examine and discuss surface temperatures on other planets.*** Use https://www.ncei.noaa.gov/access/us-climate-normals/ or https://drought.unl.edu/climographs.aspx or some other local source to find a graph of seasonal temperatures in your area. Copy this graph and paste it onto Slide 4 of the L4 Engage Slides ASK: What is the “best” temperature or weather for you? Why? Ask students to discuss this with a partner before getting ideas from the class.	L4, Engage

Students might know what season or type of weather they like best, but have difficulty correctly identifying the kinds of temperatures that season represents. In that case, display the local climograph that you found and placed on the L4 Engage slides (lined in side bar). Orient students on how to read the climograph (with temperature on one vertical axis and precipitation on the other. Be clear about whether it is displaying Celsius or Fahrenheit degrees. Ask students to connect the season they mentioned with the correct temperature before moving on. Collect responses on a class chart or whiteboard before moving on.

Next, display slide 5 from the L4 Engage Slides. Once again ask students to discuss the prompts on Slide 5 with a partner before taking ideas from the class.

	Slides 5 and 6/7 represent an opportunity to generate surprise and curiosity in students. It is important to let students make their own predictions and explain why they made the prediction on Slide 5 BEFORE moving on to Slide 6/7. Most students will likely make the wrong predictions, which is OK!

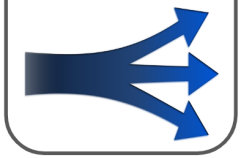
Choose if you will display Slide 6 (Celsius degrees) or Slide 7 (Fahrenheit degrees). Ask students to consider this data and compare it to the predictions they made on Slide 5. Were there predictions correct, incorrect, or partially correct? They should also consider their most comfortable temperatures from the start of Engage. Which planets include their “most comfortable” temperature?

Teacher Guidance: Students will likely predict that the hottest planet is Mercury and the coldest is Mars, but that is not what the data shows! While Mars DOES have the coldest average temperature, Mercury has the coldest minimum. Venus is the hottest on average and the hottest maximum temperature--and the temperature hardly changes at all. Why is this the case? Something else must be going on! Guide students through these noticings and wonderings until they get to this contradictory realization; the planets’ temperatures don’t seem to make sense when you consider how close or how far away they are from the Sun. DO NOT move on to Slide 8 until students have noticed these ideas in the temperature.

Display Slide 8. Guide students to understand what the chart is showing. For younger students or those without much prior knowledge of the atmosphere, you can talk about the atmosphere like a blanket. The Earth has 1 blanket; Venus has 92 blankets. Mercury and Mars have very, very thin blankets. Does this give students any new ideas about the temperature chart?

Go back and forth between the temperature chart you are using (Slide 6 or 7) and the atmosphere chart (Slide 8), and see what students say. Once they come to the idea that the atmosphere might be one reason why the temperatures are not what they originally expected, you can be ready to move on.

SAY: In this lesson, we are going to plan and carry out investigations about temperature and the atmosphere to see

	if we can find and explain a connection between the two variables. NOTE: It is up to you to decide if you would like students to ONLY test different amounts of CO2 in an atmosphere OR if you would like them to test other possible variables that they came up with earlier in the lesson. It is also up to you to decide if you want to allow each group to do a different experiment, or if you want to design a single type of experiment for the whole class to try. For example, students may want to test: ● Proximity to the "sun" (Two identical bottles, one very close to the "sun" and one far away ● The color of the ground (White/light ground inside the bottle vs dark/black ground) ● Plants VS no plants ● Cloud cover (part of one bottle is covered or painted; the other bottle is totally clear. ● Humid air VS dry air (spray mist of water into one bottle, keep the other bottle dry). In each case, the dependent variable (what students observe or measure to see if it is impacted) is the temperature inside each bottle. This might be a one-time temperature measurement after temperatures become stable OR graphs of the temperature in each bottle over time.	
Explore (150 Min)	***Students will plan and carry out an investigation to understand at least one variable that impacts surface temperature on planets.*** Grade Level Adaptation  The goal of all of these investigations is the same--students should plan an investigation to produce evidence how a variable that they can control (amount and type of gas in the atmosphere) impacts a variable that they can measure (temperature). However, this part of the lesson will look very different depending on if you take a directive, collaborative, or supportive stance as students plan the investigation. Your stance should be based on your students' prior experiences with planning and carrying out their own investigations. Review the "*SCAFFOLDING TIPS*" document linked in the sidebar. Some ways to structure this portion include: ● **<u>Directive Stance (MOST SUPPORT):</u>** You choose a testable question and the materials, all groups investigate the same testable question. You give the students a lot more specific directions, explaining why those directions are important or make sense. However, at a minimum, students should be able to explain why the testable question was chosen, how the materials and equipment work, and the data they are collecting. ● **<u>Collaborative Stance</u>**: Between "Directive" and "Supportive" stances. You may provide more support in some areas (like what materials are available and examples of testable questions) and less support in other areas. Circulate as students plan and ask probing questions if students are off track or need more support. ● **<u>Supportive Stance (LEAST SUPPORT):</u>** You give students little support ahead of time, but circulate as they plan and ask probing questions from the Scaffolding Tips table. If you notice groups of students struggling with a particular idea or step, you may hold a short meeting where you bring them	TEACHER TIPS Scaffol… Planning and Carrying Out Investigations Template **Materials needed for the experiment will vary based on the level of sophistication. At a minimum, you will need:** ● Thermometers or temperature probes ● Large (1-2 liter) plastic bottles or other seal-able clear glass or plastic containers (2 per team) ● Light source (such as a grow bulb or sunlight outdoors) **Some additional materials will depend on the testable question that your students choose, but may include:** ● Baking soda and white vinegar (to

	together for support on that specific topic. In all cases, the goal is for you to provide the **minimum amount of support** that will allow your students to succeed and to **allow students to make as many decisions and choices as possible.**

SAY: There are many factors that determine the surface temperature of a planet, including the density of the atmosphere, what it is made of, what the surface is like, and how close the planet is to the Sun. We are going to plan and carry out careful investigations to help us understand how these factors affect the temperature inside a closed bottle of gas. We will use clear, closed containers, create two different conditions, and see how temperature is different.

Show students the materials and equipment that you have available for the experiment, and make sure they understand what each is or does. You can do this by showing a material list or image on a slide, writing a list on the board, or by showing them the actual materials and equipment.

Initially, the students might have general ideas like "I want to understand compare atmospheres" but after an initial discussion or brainstorming sentence to guide them with the following sentence structure to come up with a testing question they can design an experiment to investigate. In this case, the dependent variable will always be temperature (or temperature over time), but the independent variable could be many different things.

- How does _____(IV)_____ affect temperature?
- What is the effect of _____(IV)_____ on temperature ?
- What effect does _____(IV)_____ have on temperature ?

Once students have chosen an independent variable, emphasize the importance of only changing ONE THING and keeping everything else the same between the two experimental bottles.

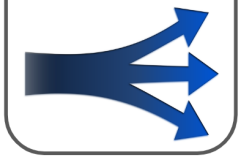
Next, give students access to the "Planning and Carrying Out Investigations" template. Direct them to fill out parts 1-5 of the template as they plan their investigations. In addition to what is in the Planning and Carrying Out Investigations template, you may also wish to ask students to create a plan for how long the experiment will take and the frequency that they will collect observations.

Before proceeding, be sure that (1) the students have identified a testable question that they can address with the materials and time provided, (2) the defined frequency of observation is compatible with the time available, and (3) they are taking appropriate measurements to make a claim about their testable question.

Students should then construct their experiments and carefully collect data for their investigations. We have provided the following support videos to help you use NESSP supported equipment.

generate CO2)
- Carbonation system (for carbonated beverages, such as SodaStream)
- Plain and carbonated water
- Plants
- Soil
- Different colored paper
- Timers
- Ways to measure or compare CO2 (such as pH paper, pH indicator solution, CO2 meters, or CO2 probes)

	 Depending on your students' prior knowledge, grade level, and equipment available, they may wish to experiment by generating CO2 and comparing how the concentrations of CO2 impacts temperature. However, students might not be clear on how to make the CO2 concentration higher or how to measure those levels. Here are some ideas for you to guide them through: **Ways to Produce CO2** ● **Carbonated beverages are produced by adding CO2 to water.** You could buy carbonated water (or make it using a SodaStream or other carbonation machine). Fill two identical bottles part way; one with plain water and one with carbonated water. Tightly cap and shake to release the CO2 into the airspace in the bottle. ● **Adding baking soda and vinegar produces CO2.** If you mix baking soda and vinegar, do so in a well-ventilated area and start with small amounts. To capture the CO2 that is produced, put the baking soda into a plastic bottle with a small mouth using a funnel. Then, pour in a small amount of vinegar and quickly cover the opening of the bottle with a balloon. The balloon will fill with CO2. Twist the balloon before removing it in order to capture the CO2. You can then introduce this captured CO2 into one of your two bottles for experimentation. ● **You breathe out more CO2 than you take in.** Can you capture your own breath and compare it to the atmosphere? What else might be different about the air you exhale versus the air that you inhaled? For example, is the air you exhale warmer or colder than the air you inhaled? Is it more or less humid? Account for these variables if you decide to use YOURSELF as CO2 machine! **Ways to Measure CO2** ● CO2 meters or probes ● pH paper or indicators. CO2 dissolved in water lowers the pH because it is acidic. Make sure that students carefully document their experimental design by taking images of their experimental set-up, as well as documenting how they designed and carried out the experiment in writing. Students should then keep track of any data collected in a table as well as making note of any additional factors that might affect the results of their experiment.	
Explain (30 Min)	***Students will analyze the data from their experiments in order to make a claim about how the variable they chose for their experiment impacts the temperature on planets.*** If all students did the same investigations, different groups likely still got slightly different data. Have all groups share their data in a manner that allows everyone to access it. What is similar and different about the results? If students did several trials, they may need to average their data and, depending on their grade level and prior math	Claim Examples (TEACHER GUIDANCE ONLY) Claims and Evidence Template (Explain)

	experiences, do other statistical analyses. If different groups of students did different kinds of experiments, have them share their experimental procedures and results in pairs or small groups. **Grade Level Adaptation**  **Middle and High School Students Only** Due to the time and materials necessary to do hands-on experiments in the classroom, computer simulations can use another useful tool to quickly understand how variables interact. Consider allowing students to gather additional evidence using one or more of these simulations. ● Phet Simulations: ○ https://phet.colorado.edu/en/simulations/greenhouse-effect ○ https://phet.colorado.edu/en/simulations/molecules-and-light ● Related Phet lessons: ○ https://docs.google.com/document/d/1g8zSsa9zjrSrQC-Bdwmh4GYQgmN4WXhGwpVDks5pocl/edit?tab=t.0 ○ https://phet.colorado.edu/services/download-servlet?filename=/activities/4705/phet-contribution-4705-8273.pdf ○ https://phet.colorado.edu/en/activities/7149 ● LASP w/simulations where students "build planets": Planet Designer: What's Trending Hot? (see links in table here).* *Note: NESSP has had mixed results getting this software running on different operating systems. We recommend that you test the simulation early and carefully on the devices that students will be using. Next, each student or group will produce a claim with evidence from their own experiment. (If older students engaged in the simulations above, they can use evidence from the simulations as well. However, their own experimental evidence must also be included.) In order to help guide your students to a claim, review the Teacher Guidance claim examples (linked in the side bar). Have students review each others' claims and evaluate whether the claims are convincing or not. Does the data support the claim?	
Elaborate (60 Min)	***Students will use any evidence they have gathered from Lesson 3 or this lesson to make claims about what happened in the past to make Earth and Venus so different now.*** Watch this video: https://www.youtube.com/watch?v=z8HB8jlWai8 SAY: Scientists know that Earth and Venus used to be a lot more similar than they are now. What they aren't as	Claim / Evidence Template (Elaborate)

<table>
<tr>
<td></td>
<td>sure about is WHY they are so different now. Why are they so different now? What do you think happened (or didn't happen) to make them so different? You will use any sources of evidence from the previous lesson or this lesson to make a claim.

Present students with the table below. They will also need access to the resources and their work from Lesson 3 and earlier parts of this lesson.

<table>
<tr><th>Claim</th><th>Sources of Evidence</th></tr>
<tr>
<td>While it is important to note HOW Earth and Venus are different now, what we are looking for here is your claim about WHY they are different. What happened (or didn't happen) on one planet in the past to make them so different now? Your claim should take the form like this:

The main thing that happened to make Earth and Venus so different now even though they used to be more alike was: _____.

OR

There are many reasons why Earth and Venus are so different now, despite being more similar in the past, but the three most important things that happened were:_____.</td>
<td>The most important part of this task is your evidence and how you explain that evidence as supporting your claim.

You will need multiple pieces of evidence to support your claim. Some sources of evidence that you could consider using include:
● Carbon Cycle Game (Lesson 3 Explore)
● Fructose Model (Lesson 3 Explore)
● Readings and Videos (Lesson 3 Elaborate)
● Venus Carbon Cycle Game and Explanations created by students (Lesson 3 Elaborate)
● Investigation (Lesson 4 Explore/Explain)
● Simulations (Lesson 4 Explain)
● Resources in "Getting Up to Speed" with Venus
● Students' own research (if allowed by teacher) from trusted sources</td>
</tr>
</table>

You may wish to use the Claims/Evidence Template for the Elaborate section. Note that it is different than the template in the Explain section. While the "claim" is listed first on the template, it is likely that students will need to revisit the evidence first before finalizing their claims.

Students can make individual claims or work in a pair or small group. At least once before their claims are final, students should have an opportunity to share their draft work with a peer or small group to compare ideas and get feedback.

When all students are finished, consider completing a gallery walk where students can clearly see and compare claims, evidence, and explanations.</td>
<td></td>
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<tr>
<td>Evaluate
(30 Min)</td>
<td>Students will document their work and learning for this lesson by meeting the deliverables outlined in MO-4.

The Mission Development Log requirements for this lesson are outlined in MO-4. Students are likely to have a lot</td>
<td>MO-4</td>
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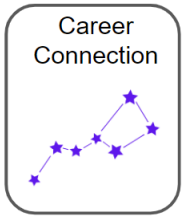
	of additional documentation in their Science and Engineering Notebooks, but the MDL should be a summary of their work.	
Extend (Optional)	***Students will explore NASA careers related to the work of this lesson.***  There are several NASA careers related to this lesson featured in the Career Connection Catalog, explore them all to learn about the people at NASA that could achieve this Mission Objective! After reviewing the featured jobs, ask students to pick out key words or phrases that are related to this job or things that interest them about this job. Create a word cloud or keep this list somewhere to refer back to in Lesson 7.	

Planning & Carrying Out Investigations Template

1. Materials. What do you need for your investigation? Resources, tools, and equipment:

Do you think you need other tools or materials? Develop a Materials List in consultation with your teacher.

2. Testable Question. What do you hope your experiment will reveal? Science question we will try to answer:

3. How will your investigation work? Experimental Set-up (Label equipment and materials used)

4. Experimental Steps (What we will do, listed in the order in which we will do it, and what we will measure or observe)

5. Expected Outcome (What we predict will happen)

Stop here, and check in with your teacher before proceeding!

6. Data & Observations:

7. What did your investigation reveal? What did you learn?

8. What new questions did this bring up?

Claim Examples (TEACHER GUIDANCE ONLY)

These examples are provided to guide the teacher NOT THE STUDENTS. Use these examples to help guide students to their investigation plan as well as their agricultural plan.

Claim:

- Example, basic claim: Dark colored planets are hotter than light colored planets.
- Example, mid-level claim: As the amount of CO2 in an atmosphere rises, the temperature also goes up.
- Example, advanced claim: For every ### mm/L increase in CO2 concentration in an atmosphere, the temperature increase by # degrees C.

Evidence: Provide raw data with charts or tables, as well as explanations.

- Example: We tracked the temperature every 5 minutes in the bottle with the black paper floor and the bottle with the white paper floor. The temperature in the black jar went up faster and it was always warmer than the white jar.
- Example: In our experiment, the bottle we put the extra CO2 in was 8 degrees F hotter than the other jar after 2 hours under the lamp.

Claims and Evidence Template (Explain)

Claim(s):
Evidence:
Data and Calculations:
Assumptions:

Claims and Evidence Template (Elaborate)

Claim(s):		
Evidence	**Source of this Evidence**	**How this Evidence Supports the Claim**