Session 6: Nature of Science and the Greenhouse Effect

Overview

In this session, participants gain insight into the nature and practices of science in the best way possible—by **doing** and **reflecting** on science. They take a critical look at what is and is not an accurate view of science by attempting to define it. Participants experiment with a "mystery tube" in an investigative activity designed to provide an explicit sense of the practices of science: what scientists do and how science works. They then use models and engage in discussions to gain an understanding of Earth's changing atmospheric CO_2 concentration and its relationship to the greenhouse effect. They then revisit the question of how science works as they compare the greenhouse effect activity experience to a flow chart about how science works and participate in a research discussion. They come to appreciate the public's perceptions of science and why clarifying their own understanding of the nature and practices of science affects—and is in fact critical to—their own practice.

Session Goals

Theme	**Goals**
Climate Science Ideas	Engage in an activity that demonstrates that: ● heat-trapping gases in the atmosphere trap the sun's heat energy; ● there is a relationship between Earth's atmosphere and temperatures. Understand that: ● Climate change is a change in weather patterns over time – spanning years, decades, centuries, and even longer. ● Earth's atmosphere contains heat-trapping gases, such as CO_2 and methane. ● As CO_2 levels increase in the atmosphere, Earth's temperature rises. ● Scientific evidence suggests that the main cause of rising CO_2 levels in the atmosphere over the last 200 years has been people burning fossil fuels.

Using Data	Build on skills covered in previous sessions, especially those related to models.
Teaching & Learning	Review how the Five Foundational Ideas and the Learning Cycle instructional model can be used to design effective activities to achieve deeper conceptual understanding.
Framework /NGSS	Engage in a discussion and explore ideas about the nature and practices of science.

Materials Needed

For the class:

- PowerPoint presentation
- Digital/data projector
- Whiteboard or flip chart paper and pens
- Masking tape
- Access to the Internet and UCMP Understanding Science website: http://undsci.berkeley.edu/

For each participant:

- Climate Science Ideas Chart (from Session 2)
- Learning Cycle (from Session 3)
- ‘How Science Works’ flowchart–complex
- Five Facets of Science Research Discussion

For each small group of 3 participants, for Mystery Tubes, How Science Works

- Mystery Tube (See Preparation of Materials #4.)
- Blank sheet of paper and pencil
- 1 enlarged copy (11” x 17”) of ‘How Science Works’ flowchart–complex; see

Preparation of Materials #5.)

- 1 sticky-note pad or dry-erase pen (See Preparation of Materials #5.)

For Instructor, for Greenhouse Effect Demo

- 2, 1 liter clear plastic soda bottles with top of bottle cut off
- 2 thermometers
- 2 drinking straws
- 4 Alka Seltzer tablets
- 2 cottage cheese-type containers with lids
- Water, enough to fill cottage cheese-type container to about half full
- 2 small containers to use to elevate the cottage cheese-type container
- Dirt (fairly dry), enough to fill the bottom of the soda bottles to ~2 fingers depth
- To attach thermometer to bottle:
    - 2 push pins
    - 2 rubber bands
- 1 microwave
- 1 scissors

For Greenhouse Effect Computer Simulation
For groups of 3-4 participants:

- A computer
- Greenhouse Effect simulation from PhET Interactive Simulations (http://phet.colorado.edu/en/simulation/greenhouse)
- Greenhouse Effect Images (1 set):
    - A: atmosphere from space
    - B: where CO_2 comes from
    - C: plants/seaweed and photosynthesis
    - D: absorbed, reflected, transmitted diagrams
    - E: portions of sunlight absorbed, re-radiated etc. by different factors on Earth
    - F: Electromagnetic spectrum

- G: Keeling Curve
- Greenhouse Effect Image Captions (handout)

[**Note to Instructor:** *Great if small groups or pairs of participants have access to a computer so that they can manipulate the simulation for themselves rather than watch it as a demo. This is important for participant engagement and motivation*].

Preparation of Materials

1. **Duplicate handouts:**
    - Greenhouse Effect Image Captions (1 per small group)
    - Greenhouse Effect Images (1 set of 7 images per small group)
    - Five Facets of Science Research Discussion (1 copy per participant)
    - 'How Science Works' flowchart–complex; downloaded from the web: http://undsci.berkeley.edu/lessons/pdfs/complex_flow_handout.pdf
        - 8.5" x 11" (1 copy per participant)
        - 11" x 17" (1 copy per small group)
    - A few extra copies in case participants don't have access to their original copy:
        - Climate Science Ideas Chart (from Session 2)
        - Learning Cycle (from Session 3)
        - How Learning Happens-Five Foundational Ideas (from Session 3)

2. **Set up the greenhouse effect materials for the demo as shown below.** The description below includes making 2 identical set-ups. One set serves as the control and the second as the experimental bottle. The only difference between the two set-ups is that Alka Seltzer won't be used in the control.
    a. Slice the top part off 2 soda bottles so that they will fit in the microwave. Leave a part of the lip higher so that it can be folded over; this will act as the support for the thermometer. One of these bottles will serve as the control.
    b. Put dirt in the soda bottles, about 2 fingers deep
    c. Set up the thermometer so that it can be placed just above the dirt, and away from the

sides. Use the folded lip for support. A pushpin can be helpful here, and a rubber band to attach the thermometer to the pushpin.

d. Punch a small hole in the soda bottles ~3 fingers width above the soil line, with the pair of scissors. This is where the straw will be inserted

e. Punch a small hole in the cottage cheese containers near the top.

f. Fill the cottage cheese containers about half full of water.

g. In both bottles, insert the straw into the hole in the container on one end, and into the soda bottle on the other end. (Remove the thermometer and straw before heating the bottles and soil in the next step.)

Control (no Alka Seltzer)

Experimental (includes Alka Seltzer)

3. **Demo or small group?** Decide if you will do the Greenhouse Effect computer simulation as a whole group demo or in small groups.

4. **Make Mystery Tubes.** Construct a Mystery Tube for each small group of 3 participants according to the instructions at http://undsci.berkeley.edu/lessons/mystery_tubes.html

5. **Enlarge and duplicate 1 copy of ‘How Science Works’ flowchart for each small group of 2–3 participants.** Copies should be at least 11" x 17" and very preferably in color. Consider laminating the enlarged copies so that they can be reused. (Laminating permits fine tipped dry-erase pens to be used instead of sticky notes with the How Science Works activity.)

6. **Read the background information for the instructor.** A science background reading is provided at the end of this session write-up.

7. **Test out the materials.**
    - **Time in microwave.** Test out the bottles in the microwave you plan to use. Depending on the strength of the microwave, you may have to modify the amount of time the bottles are heated. If the microwave is very high power, 17 seconds may be too long and may result in melting the plastic bottle. If too weak, then 15-17 seconds may not be long enough to heat the soil sufficiently.
    - **Soil moisture.** Make sure that the soil has enough moisture so that the microwave can actually heat the soil at least a few degrees centigrade. If the soil is bone dry - it won't heat. If too wet, too much water vapor is produced, which makes it difficult to read the thermometer through the side of the bottle and also interferes with the experimental results. Water vapor is a greenhouse gas and if a lot of water vapor is produced, then adding extra CO_2 in the form of Alka Seltzer can't increase the temperature beyond what the water vapor has already done.
    - **PhET simulation.** Download and test the Greenhouse Effect simulation to make sure it works on the computer from which you will be presenting (or used in small groups). The simulation is made in Java, and browser settings might need to be adjusted to allow the simulation to play since it is made by an independent developer (University of Colorado, Boulder). Give yourself sufficient time to enlist help of your institution's technology support staff. Also, mess around with the simulation so you are familiar with the features and functions.

Session at a Glance

Task	Description	Time (minutes)
A. Quick Write & Session goals	Participants respond to a quick write that prompts them to connect climate change with the reading they did for homework on the crosscutting concept of energy and matter. Session goals are introduced.	10
B. Think-Pair-Share	Participants discuss, "What is science? What is NOT science?"	10
C. Activity: *Mystery Tubes*	Participants collaborate in small groups to work out the interior construction of a mystery tube—without looking inside. This activity sets up a discussion about what scientists do and how science works.	30
D. Activity: *Greenhouse Effect*	An investigation using a demo and a computer simulation of the greenhouse effect engages participants in a learning experience designed to deepen their understanding of climate change, while modeling the learning cycle. This investigation is used as a common reference for analyzing the nature and practices of science.	55
E. Activity: *'How science works' Flowchart*	Participants review 'How science works' flowchart and relate it to the Greenhouse Effect activity they just completed. They trace their steps on the chart, which portrays how science works as a dynamic process.	15
F. Research Discussion: *Five Facets of science*	Participants read ideas from the research literature on the nature and practices of science. They discuss ideas of interest to them. Then based on the 'How science works' flowchart and the research discussion, they add to/revise the list they made earlier in the session regarding "what is and what is NOT science."	25
G. Reflection: *Looking back on*	Participants engage in the Three Interviews routine to reflect back on the Five Foundational Ideas and the Learning Cycle and how these were	20

what we've done so far	used in the design of the Greenhouse Effect activity.	
H. Homework	Explore UCMP Understanding Science website and read pages 78-82 of *A Framework for K-12 Science Education*. Use both resources to respond to reflection prompts.	5
	TOTAL: 2 hours 50 min	**170**

Session Details

A. Quick Write & Session Goals

1. **Participants do a Quick Write.** Participants write for 3 minutes to the following prompt based on the homework reading on the Crosscutting Concept: Energy and Matter:
   - Based on what you know now, what role(s) do you think that this crosscutting concept might play in understanding climate change?

2. **Turn and Talk.** Ask participants to turn to a partner and discuss their ideas about the prompt.

3. **Introduce session.** Tell participants that the rest of the session will focus on how science works and consider that in the context of the greenhouse effect and energy and matter.

Share session goals

1. **Display session goals slide.** Display the goals and briefly introduce each with a description of how they are connected and flow from one to another.
   - **Climate science Ideas:** Engage in an activity and use a model to explore the greenhouse effect.
   - **Using Data:** Build on skills covered in previous sessions, especially those related to models.

- **Teaching and Learning:** Review how the Five Foundational Ideas and Learning Cycle instructional model can be used to design effective activities to achieve deeper conceptual understanding.
- **Framework/NGSS:** Examine how the Crosscutting Concept of Energy and Matter can support evidence-based connections about climate change. Engage in discussions and explore ideas about the nature and practices of science.

B. Think-Pair-Share: *What is and is Not Science?*

1. **Introduce the activity rationale.** Introduce the question, What is and is not science? Explain that by closely examining what science is and how it works, we gain an understanding of its strengths and limitations. Share the following.
    - Taking a critical look at <u>what are and are not accurate views of science</u> can help hone our own understanding of science.
    - In teaching about science, it's vital to spend time thinking about the <u>nature of science</u> and <u>how it can be communicated</u>.
    - If learners don't have a good understanding of what science is, they'll have a difficult time determining which <u>questions science can and can't answer</u>.
    - Understanding *what science is* and *what it is not* helps us become <u>critical consumers of information, better able to engage in decision-making as knowledgeable citizens</u>.

2. **Define the nature of science.** <u>The nature of science</u> refers to the *characteristics of science and the knowledge that science produces*. It can also be thought of as *what a scientist does* that signifies that he or she is engaging in science.

3. **Display the Think-Pair-Share prompts.** Display the prompts. Give participants a minute to think about them and consider what a scientist would be doing to signify that he/she was "doing science".
    - What is science? What is it not?

4. **Pair and Share.** Give participants a few minutes to talk to a partner.

5. **Broaden the discussion to a Whole-Group Share.** Create two columns on the board or chart paper: one titled Science IS, the other, Science IS NOT. Invite participants to share their thinking. Organize and record their ideas on the board as you facilitate and summarize the discussion. Remember to listen to participants' responses; ask for evidence, explanation, or clarification; and encourage them to share agreements, disagreements, and alternative ideas or opinions. Participants may share some or all of ideas listed below. (If needed, revisit the definition of empirical evidence: evidence obtained by direct observation or experimentation.)

*[***Note to Instructor:** *If it comes up, you might specify why science is defined as the study of the natural, not the supernatural world. Science does not weigh in on the subject of the supernatural one way or the other, because the supernatural is not based on empirical evidence. It can neither be proven nor disproven using science]*.

Science is	Science is not/does not
● Study of the natural world ● Observations and measures of phenomena ● Based on empirical evidence ● Replicable / Reproducible ● Falsifiable ● Peer reviewed ● Durable (robust, resilient), but open to change	● Study of the supernatural world ● Pseudoscience ● Stagnant ● Oblivious to evidence that counters other evidence ● Make moral judgements

Let participants know that they will spend more time thinking and talking about these two prompts in the next activities.

6. **Ask for impressions of how the public thinks of science.** Ask participants to think about what images of a scientist doing science the public might think about if they were asked "What is science?" and "What is not science?". Take a few responses.

7. **Display slide "What is a scientist" and participants respond to prompts.** Show the slide and explain that the images came from an internet search of the question "What is a scientist?". Pose the following prompts, and take only a few responses, as participants will come back to their ideas about 'what is science' later in the session.
   - How does your image of scientists and what they do compare with what these images portray to the public? Are they similar or different, and in what ways?
   - Why do you think that is?

C. Activity: *Mystery Tubes*

1. **Introduce the Activity.** Display the Mystery Tube slides and tell participants that they will work in groups of twos or threes to share ideas and <u>propose a hypothesis</u>. They'll be asked what they think the interior structure of a "Mystery Tube" looks like, and how they might test their ideas—**without looking inside the tube!** Explain that this activity sets up a discussion about what scientists do and how science works.

2. **Distribute a Mystery Tube to each group.** Remind participants that their goal is to figure out the interior structure of the tube without opening the tube to look inside. Give them about 10 minutes to work with and investigate the tubes.

3. **Have participants draw their ideas of the internal structure.** Distribute a sheet of paper to each group and have them draw a diagram of the internal structure of the tube as they think it looks. Ask them to label what they think is going on inside it. Explain that these diagrams are models that can be used to explain their understanding about the internal structure of the tube.

Circulate and ask the groups some of the following prompts:

- **a.** How might you test your ideas and the accuracy of your model without looking inside or destroying the tube?
- **b.** What evidence have you gathered to support your model?
- **c.** How confident are you in your model?
- **d.** What observations make you wonder whether or not your model is an accurate representation of the internal workings?

4. **Pair up groups for sharing.** Have each group share with another group: (a) their model (diagram), and (b) what they would say if they were going to publish their findings about the mystery tubes right now**.** Encourage them to comment and ask questions about one another's models.

5. **Provide an opportunity to revise.** After they've shared and discussed their models, give each group a few minutes to revise their diagrams if they wish. Tell them that revision based on new evidence is part of the practices of science.

6. **Begin Whole-group Share.** Ask each group to draw its model on the board for everyone to see. Use some or all of the prompts below to encourage groups to comment on each others' models. Remember to listen to participants' responses; ask for evidence, explanation, or clarification; and encourage them to share agreements, disagreements, and alternative models. Let them know that vigorous discussion among scientists is also part of how science is done. Question prompts:
    - **a.** Did something you heard from sharing with another small group lead you to change your model?
    - **b.** How confident are you about your hypothesis?
    - **c.** What fits your observations and what doesn't?
    - **d.** Which models are plausible? [Likely most, or all]
    - **e.** Is there a way to decide which model most closely fits all the available evidence we have right now? [*Possible answers may include: arguing, voting, revisiting our evidence/observations, choosing the most complicated/least complicated*]

f. What additional evidence would we need to decide between the models? How could we be more confident? [*Obtain more evidence; cut the tube open; develop a three-dimensional model to test your ideas and compare to your observations of the mystery tube....*]

7. **Collect the tubes.**

[*Note to instructor*: *Although this activity is about "solving" a mystery, do not reveal the answer during the activity itself. But be prepared: Being denied the "right answer" may distract and frustrate some participants. If that happens, it can be helpful to ask follow-up questions, such as, How certain can scientists be of getting the "right answer" in their investigations? What do scientists do in their investigations to be more certain? What can you do to be more certain of your model? At the end of the activity, you can decide if and when you want to divulge the "answer" to the inner workings of the mystery tube—either in this session or a future one. If you decide to share the answer, it's best to just give participants the key search word (mystery tube), so that those who are interested and motivated can pursue the answer online].*

8. **Debrief Hands-on: Mystery Tube.** Facilitate a discussion to debrief participants' experience in the activity. Ask the following questions and record on the board as they share their ideas about "What scientists do." Challenge participants to provide explanations, evidence, or clarifications to elaborate on their thinking. Encourage them to provide alternative opinions or ideas, and to react and respond to the ideas shared.
   - **a.** Were you "doing science"?
   - **b.** What were you doing that is similar to what scientists do?

D. Activity: *Greenhouse Effect*

1. **Display images.** Show images that capture how various places around the world are being affected by climate change. Tell participants the location of each and briefly describe the contrasting images. (Left to right: California; Sub-Saharan Africa; off the coast of Florida)

2. **Quick Write - what do you already know about climate change?** Have participants spend a couple of minutes individually writing some notes addressing the following prompts:
    a. What do you notice across the images?
    b. What do you think is causing the phenomena shown in the images to happen?
    c. What do you know about the cause(s) of climate change?

3. **Share with a partner or two.** After about 2 minutes, have participants spend 2-3 minutes sharing their ideas with 1-2 people next to them. Wander the room to eavesdrop on their conversations.

4. **Facilitate whole group share.** Ask participants to share some of the ideas that emerged from their partner discussions. Depending on what they share, add some of the following information about the images shown to lay the groundwork for them to engage in the upcoming tasks.
    - The average sea level has been rising steadily since the late 19th century; some places are experiencing even greater sea level rise than the average.
    - The 10 warmest years in the last almost 150 years all have occurred since 2000, with the exception of 1998. The year 2016 ranks as the warmest on record. (Source: NASA/GISS).
    - Climate change is a change in weather patterns over time – spanning years, decades, centuries, and even longer.
    - Scientists agree that the climate is changing and it is human-caused due to the release of vast amounts of CO_2 from human activities.

5. **Display these points.**
    a. The greenhouse effect is a natural process that keeps Earth at a habitable temperature. It causes Earth to be an average temperature of 15 degrees C, rather than -15 degrees C.
    b. However, the enhanced greenhouse effect caused by increased CO_2 levels in the atmosphere is what is causing Earth's temperature to rise alarmingly, leading to rising sea level, shrinking glaciers, warming ocean and atmosphere - and the resultant effects on ecosystems and organisms (including people).

6. **Sketch the greenhouse effect based on current understanding.** Tell participants that the greenhouse effect is a key concept to understanding climate change, and this activity will give them a chance to think about and build on what they know. Ask them to sketch a diagram that depicts their current understanding of the greenhouse effect. In their sketch, they should make sure to do the following:
    a. Label their diagram.
    b. Include CO_2 in their diagrams however they think it makes sense.
    c. Record any questions they have about the greenhouse effect on the side of their diagram.

    Remind them that the purpose of this sketch is to capture and record their evolving thinking. At various times throughout the hands-on activity, they will be prompted to add details and additional questions to the sketch.

Describe the Greenhouse Effect Demo model and make predictions

1. **Describe the model.** Describe the model used to represent the natural process of the greenhouse effect as follows:
    - Soil in the bottom of the bottle represents land.
    - The top of the bottle is open so that the air in the bottle is atmospheric air.
    - A thermometer hangs from the top of the bottle into the air of the bottle to measure the air temperature (emphasize that the thermometer is not placed in the dirt).
    - The bottle with soil will be placed into the microwave for 15-17 seconds to represent solar radiation from the sun (the microwave) being absorbed by Earth's surface (the soil).
        - Describe that microwaves don't heat the air, and thus only the soil will be absorbing heat from the microwave. It may be helpful to note that this activity could be done outside in the actual sun, but it's a lot faster to do it inside with the microwave serving as the heat energy to the system. Note: See description in Science Background at the end of the session regarding using a microwave in the model.

2. **Describe adding increased level of CO_2 to model current atmosphere (enhanced greenhouse effect).** Tell participants that after you've created the natural process of the greenhouse effect by placing the model in the microwave, you will then add an additional variable (increased CO_2 concentrations into the atmosphere) to model the state of the current enhanced greenhouse effect.
    - CO_2 will be produced in the plastic container by dissolving Alka Seltzer tablets in the water. The bubbles released by the Alka Seltzer tablets and water are CO_2 bubbles. CO_2 is a greenhouse, or heat-trapping, gas.
    - The straw connecting the plastic container to the bottle will bring CO_2 generated in the container into the atmosphere over the soil in the bottle.
    - The second bottle is set up in the same way, and will serve as the control. No Alka Seltzer will be added to the control set-up, and hence no additional CO_2.

3. **Make predictions, then share with partner.** Have participants think about what will happen to the temperature of the "atmosphere" in each of the bottles after the soil in the bottle is heated by the "sun" (microwave)? Tell them to make a prediction for each bottle, *including their reasoning* for their predictions, and then discuss their predictions and reasonings with a partner. Display the discussion questions:
    - What do you think will happen to the temperature of the "atmosphere" after the soil in the bottle is heated by the "sun" (microwave)?
    - What will happen when additional heat-trapping gas (CO_2 from Alka Seltzer) is added to the atmosphere in the experimental bottle? (Remind them that the Alka Seltzer is used in the model to represent increasing CO_2 entering the atmosphere).
    - What do you think we will find out about climate change/which of your questions about climate change do you think this demonstration will answer?

    Circulate around the room, taking mental notes about what participants are talking about with each other and engaging them in one-on-one and small group discussions about their reasoning where appropriate.

4. **Participants record ideas.** Give participants about 2 minutes to write down their thoughts from their discussion. Encourage them to include their reasoning, and remind them they will have

opportunities to add to/revise their thinking.

5. **Share participants' ideas.** Report out the predictions and reasoning you heard from participants as you circulated around the room.

Do the Greenhouse Effect Demo

1. **Start with the natural greenhouse effect.**
    a. Measure the temperature of the "atmosphere" in both bottles (experimental and control) before placing them in the microwave. Record the temperature on the board.
    b. Remove the thermometer. Heat the soda bottles and soil in the microwave for about 15-17 seconds or so—long enough that it is hot, but not so long that it melts the bottle.
    c. Re-attach the thermometer to each of the soda bottles. Make sure the thermometer does not touch the dirt directly.
    d. The thermometer reading will rise as the heat from the soil emanates into the "atmosphere" of the bottles. Keep watching the temperature until it stabilizes (wait ~30s) and record the temperature.
    e. While waiting for the temperature to stabilize, reconnect the straw between each bottle and its corresponding small container of water.

2. **Add CO_2 into the model for one bottle to simulate enhanced greenhouse.**
    a. Quickly put 4 Alka Seltzer tablets into **one** of the plastic containers with water, and close the lid. This is the experimental set-up. CO_2 will be generated and piped into the experimental soda bottle. Don't add any Alka Seltzer tablets to the control bottle.
    b. Note the temperature again in both bottles. Is there a change? Wait until the temperature stabilizes, and take another reading.
    c. Compare the reading before and after the Alka Seltzer was introduced. (The temperature will go up after Alka Seltzer is added). Compare the reading between the experimental and the control bottles.
    d. Keep observing and recording the temperature. Observe how long it takes before the temperature starts dropping in each of the bottles.

3. **Small Groups Discuss to Make Sense of Results.** Display the following questions and have participants discuss in small groups:
    - How might you explain the temperature change? [*CO_2 'somehow' keeps the heat in*]
    - What does this model demonstrate about the relationship between increasing CO_2 in the atmosphere and the temperature on Earth? [*as more CO_2 is added to the atmosphere, temperatures will increase*]
    - Why does the temperature change with the influx of CO_2? [*we can't tell from this model; maybe the CO_2 traps it*]
    - What do you think this temperature change resulting from CO_2 has to do with climate change? [*increasing amounts of CO_2 from human industry or other processes are contributing to climate change*]
    - In what ways is this model an accurate representation of the phenomenon and what are its limitations? [*Accurate: the bottle is open, so actual atmospheric gases are in the model's atmosphere; the sun heats the land, and the land releases heat to the atmosphere; more CO_2 is being released into Earth's atmosphere. Limitations: the Earth's surface is covered in more than just soil, including large amounts of water; the change in CO_2 on Earth isn't occurring at the same rate as in the bottle experiment; the temperature of the model starts to drop because the CO_2 generation stops.*]

4. **Add to/Revise drawing.** Have participants add to or revise their individual greenhouse effect diagrams to reflect how they are thinking about the greenhouse effect now, with new information gained from the Greenhouse Effect Demo. Have them also record any additional questions they have about the greenhouse effect, and cross out questions that have been addressed.

5. **Small groups share results with other small groups.**
    a. Have each small group share with another small group: their predictions, diagrams, questions, and
    b. What they would say if they were going to "publish their findings" about the greenhouse effect right now – how would they explain their findings?

Encourage them to comment and ask questions about each other's diagrams and explanations and what additional information they think they need to know about the relevant concepts. As they discuss, walk around and take note of what kinds of explanations and questions are emerging.

6. **Report out summary of what you overheard.** Re-capitulate ideas of which you became aware during the small-group discussions. Share that is sounds like they are in need of some additional information. Tell them the following simulation may help them to have a better understanding of the greenhouse effect in terms of WHY greenhouse gases cause the temperature to rise.

Heat-trapping Gases computer simulation model

1. **Introduce simulation.** Acknowledge that at this point most groups are probably clear that increasing atmospheric CO_2 causes temperatures to rise. However, some may be unsure of WHY that happens and WHAT exactly is going on with heat-trapping gases that cause them to react this way. Tell them that at this point they will try to relate what they observe in a simulation model to what is happening in the atmosphere. The participants' challenge is to use the simulation and images you'll provide to figure out WHY atmospheric temperatures rise when greenhouse gases (heat trapping gases) are present in the atmosphere.

2. **Distribute Greenhouse Effect Images to small groups.** Have them explore the Greenhouse Effect Images handouts for a few minutes, without the Greenhouse Effect Image Captions handout (additional information handout) and discuss their observations with their small group. Display the following prompts:
   - What are the images displaying or representing?
   - Which of these images are you finding helpful to understand the greenhouse effect?
   - What did you discuss about each of the images? What questions arise for you as you look through the images?
   - What do you want and need more information about?

3. **Facilitate whole group discussion.** Lead a discussion focused on the small-group conversations about the images. Encourage participants to share ideas, questions, what

additional info they would like, and what images they found helpful and why.

*[**Note to Instructor**: Don't give a lot of additional information. It is Exploration time. Learners use the objects to explore the concept and get information, and think about what additional information they want/need. It is not yet time for Concept Invention].*

4. **Distribute Greenhouse Effect Image Captions handout to small groups.** Distribute the Greenhouse Effect Image Captions handout and give small groups a couple of minutes to review and discuss the additional information.

5. **Explain different parts of the simulation.** Tell participants that they will now work in pairs (or small groups if there are not enough devices) to engage with a computer simulation that may help to answer some of their remaining questions.
   a. Click on the Greenhouse Effect tab. Note the temperature as you change the "Greenhouse Gas Concentration" by using the slider (none to lots).
   b. Click on the Photon Absorption tab.
      i. Tell participants they can use the photon gun to make sense of what is happening in the Greenhouse Effect tab (which shows a similar result as the Greenhouse Effect Demo).
      ii. Show them how to make the visible (light) and infrared (heat) photons shoot out of the gun by sliding the tab on the gun to the right.
   c. Demonstrate different behaviors of the gases.
      i. Tell participants there are three things that photons can do when they come in contact with a molecule—be absorbed, be reflected, or be transmitted (absorption looks like wiggling).
      ii. Show them one example of each (transmission: fire a visible photon through any molecule; reflection and absorption: fire an infrared photon through a methane molecule--some will bounce off immediately (reflection) and some will make the molecule wiggle (absorption).
      iii. Have participants look for the relevant images among the Greenhouse Effect Images.

    d. Let participants know they can flip back and forth between the Photon Absorption tab and the Greenhouse Effect and Glass Panes tabs to make sense of how greenhouse gases impact temperature.

6. **Have participants spend about 5 minutes exploring the simulation.**

7. **Pairs or small groups join with another pair or small group to discuss.** After about 5 minutes, display the following prompts and have participant pairs/groups talk with another pair/group of participants to describe their current understanding of greenhouse effect and heat-trapping gases:
    a. Which gases might be greenhouse gases? What is the evidence for this? [CH_4, CO_2, H_2O *all wobble when the infrared photons are fired at them, meaning they are absorbing heat energy.*]
    b. Why do greenhouse gases cause temperature to rise? Use evidence from the simulation to support your explanations. [*They absorb heat energy; in the simulation, we saw them wobble when infrared photons hit them, while non-greenhouse gases did not do this*]
    c. In what ways is the simulation an accurate representation of the Earth's atmosphere and greenhouse gasses, and in what ways is it inaccurate? [*Accurate: heat energy is trapped by the gases; many of Earth's heat-trapping gases are represented. Inaccurate: not all of Earth's heat-trapping gases are represented; it only shows a small part of Earth; there are far fewer photons represented than there are in the actual atmosphere*].

8. **Facilitate brief whole-group discussion about the above discussion prompts.** Provide additional information or clarifying comments where appropriate.

9. **Add to/Revise drawing and writing.** Give participants about 4 minutes to add to or revise their diagram and writing for the prediction and reasoning to capture their evolving thinking. Encourage them to incorporate new information from the computer simulation and the various discussions. Display the following prompts as suggestions for what to include in their revised writing:

a. Explain the greenhouse effect in your own words.
b. Record additional questions you still have about the greenhouse effect, the model and the simulation.
c. How far off was your original idea of the greenhouse effect from what you know now?

10. **Synthesize ideas and display the following key take-aways**:
    - There is a relationship between Earth's atmosphere and temperatures on Earth.
    - Earth's atmosphere contains heat-trapping gases, such as CO_2 and methane.
    - Heat-trapping gases in the atmosphere trap the sun's heat energy.
    - As CO_2 levels increase in the atmosphere, Earth's temperature rises.
    - Heat-trapping gases (CO_2, CH_4, nitrous oxide, and water vapor) comprise less than 1 percent of Earth's atmosphere, but they make a large contribution to our planet's climate.
    - Scientific evidence suggests that the main cause of rising CO_2 levels in the atmosphere over the last 200 years has been people burning fossil fuels.
    - Earth's CO_2 level has increased and decreased quite a bit throughout Earth's history, but no known changes in the past 750,000 years have happened as quickly as this recent change.

*[***Note to Instructor***: Suggest that if your participants want more information on heat-trapping gases, they might be interested in watching the youtube video How do Greenhouse Gases Actually Work? https://www.youtube.com/watch?v=sTvqIijqvTg or the 4 minute long video, Climate Change 101 with Bill Nye from the National Geographic Society. https://www.youtube.com/watch?v=EtW2rrLHs08].*

11. **Add climate science ideas to the Climate Sciences Ideas chart.** Elicit ideas from participants about how to organize the ideas on the class Climate Science Ideas chart regarding where to record them (i.e. which row and column) and whether the ideas are related to climate science concepts presented earlier in the course. Encourage participants to record their ideas on their individual Climate Science Ideas charts.

12. **Turn and Talk - Relating greenhouse effect to our everyday lives.** Have participants turn to someone near them and discuss the following prompts for 3 minutes:

- What's one thing I might do or change to address the role that humans play in climate change?
- In what ways did my ideas change about the greenhouse effect?
- What helped me to change my ideas and to learn the concept?

E. Activity: *'How Science Works' Flowchart*

1. **Introduce How Science Works flowchart.** Distribute a copy of the enlarged (11" x 17") 'How Science Works*'* flowchart and a sticky note pad (or dry-erase marker) to each table group. Tell them that this diagram shows another way to illustrate how science works. Give them a minute to review individually before asking them to share briefly with others in their group their reactions and what they find interesting and relevant in the flowchart.

2. **Have them correlate their own process to the flowchart.**
   a. Ask participants to think about the steps they went through when they engaged in the Greenhouse Effect activity and tried to make sense of the concept. What are all the things they did that are represented on the chart?
   b. Have them write a #1 on a sticky note to represent the first step they took, and then place that note on the flowchart to show where they took their first step.
   c. Have participants proceed, in their small groups, to number all the steps they took and place those numbers on the flowchart poster where appropriate.

3. **Pair up groups to compare flowcharts.** Have each small group share its completed flowchart with another group. Ask them to spend just a few minutes looking for similarities and differences, then choose a few groups with quite different flows represented on their charts and have them place their posters on the wall where everyone can see them.

*[***Note to insructor:** *An interactive 'How Science Works' flowchart can be accessed from the UCMP "Real process of science" page at http://undsci.berkeley.edu/article/howscienceworks_02. If you are using this version, hang the question prompts on chart paper for the group to refer to].*

4. **Expand the discussion to a Whole-group Share.**
    a. Ask participants to share their reactions to the 'How Science Works' flowchart. If time permits and you've decided to use the interactive online version of the flowchart (which allows you to focus the community on one aspect of the flowchart at a time), display that now.
    b. Use some or all of the following prompts to lead a discussion about how what they did in this session relates to how science works. Question prompts:
        - What do you notice about your pathway shown on the flowchart?
        - How does what you did in this activity differ from what you were taught about the science process in school?
        - Which part(s) of the science process and practices shown on the flowchart did we address in this session (including the Mystery Tubes and our discussions)?
        - Which part(s) did we not address?

5. **Distribute a 'How Science Works' flowchart handout to each participant**. Mention that they may want to hang on to this as a resource to refer to later.

F. Research discussion: *Five Facets of Science*

1. **Introduce Five Facets of Science Research Discussion.** Tell participants they will read and discuss more about the nature and practices of science as well as teaching about science to build on their understanding of how science works. Pass out the Five Facets of Science Research Discussion handout to each participant.

2. **Introduce active reading for the research discussion.** Tell participants that they will read this document using the active reading strategy. When they are finished they will share their ideas with a partner. As they read, they should be actively engaging with the text by doing the following:

a. Underline and star ideas that are interesting or surprising; make notes in the margin with your own thoughts.
b. Circle ideas that are confusing or you do not agree with; write your questions and comments in the margin.

3. **Participants share with a partner.** After a few minutes, as participants start to finish up their reading, have them turn to a partner to share their ideas. Give partners about 5-7 minutes to talk.

4. **Facilitate group discussion.** Remember to listen to participants' responses; ask for *evidence*, *explanation*, or *clarification*; and encourage them to share agreements, disagreements, and alternative ideas or opinions. As participants share their thinking, challenge them to elaborate and encourage them to consider multiple viewpoints. Ask if any ideas were particularly interesting, surprising, or if there were any ideas that they disagreed with. Lead the discussion using the Discussion Map format. Three of the Facets of Science will likely elicit more discussion and diverse ideas or disagreements than others:
   - *Nature of Science***.** Science educators commonly struggle with the idea that science is a way of looking at the world that may be distinct from other worldviews and ways of knowing. In large part this is due to lack of awareness about other knowledge systems. Recognizing that there are other worldviews helps educators understand why some learners struggle with understanding and engaging in science. It can be helpful to share the references in the sidebar with your participants. These sources introduce and elaborate on the similarities and differences between Western science and the traditional knowledge of non-Western cultures; on how the latter has contributed greatly to and continues to inform modern science; and on teaching science in the context of other worldviews.

     "*The foundations of modern science were laid long before [the Renaissance], and were particularly influenced by the Islamic civilization. The transfer of the knowledge of Islamic science to the West through various channels paved the way for the Renaissance, and for the scientific revolution in Europe. [T]he great Islamic scientists...are as important as any great European scientist.*" — Maurizio Iacarrino, (2003)

- *Culture of Science.* Educators often question whether science is a cultural enterprise. This struggle may be connected to the one above about recognizing Western science as a worldview, rather than as a static and universal concept. If educators view science strictly in terms of facts, laws, and theories to explain the natural world, then how can it be a culture? And if they view it as a culture, is that contrary to the concept of science as an objective enterprise?
  The quotes (below) are from M. Fenichel, H. A. Schweingruber, *Surrounded by science: Learning science in informal environments*. 21–22. (National Academies Press, Washington, D.C., 2009).
    - Science is a culture. "In fact, the scientific community has its own core values, habits of mind, knowledge, language, and tools. These values include common commitments to questions, research perspectives, and ideas about what a viable scientific stance involves. Making progress in science depends on scientists being open to revising their ideas if called for by the evidence. The complex exchange of information and ideas and eventual evolution in thinking occurs in a community in which scientists also have developed a shared language. This language is added to or modified by scientists from specific disciplines as they work toward their own shared goals."
    - Science is influenced by cultural values. Scientists make choices about what is worth investigating, what to pay attention to, and how to approach particular problems. The social, political, and economic environments in which scientists live and work are equally influential (e.g., in decisions regarding what research gets funded). "The recognition that science is a cultural enterprise implies that there is no cultureless or neutral perspective on science, nor on learning science—any more than a photograph or a painting can be without perspective."
    - "Recognition of both aspects of culture in science is critical for promoting science learning."

- *Students doing and reflecting on science*—specifically the statement that "**students…use**

practices that approximate what scientists do." Some science educators find the idea that students only "approximate" science extremely disagreeable. Invite such participants to elaborate on their thinking to understand the source of the disagreement.

Here are some thoughts to keep in mind as you facilitate the discussion:

- Does the stated position suggest that students are not capable of doing science?
- Does it contradict the emphasis on the practices of science?
- If students are not doing all of science as shown on the 'How Science Works' flowchart, does that mean they aren't doing science?

One point to share is that Jonathan Osborne (the author of the passage that includes the statement "classroom [science] can only ever be approximations of scientific practice") is also one of the lead authors of the *Framework for K–12 Science Education*, the document upon which Next Generation Science Standards (NGSS) are based. This may not appease the detractors in your community, but it does relate the concept back to nationally recognized reform documents such as the Framework and Standards, which may alleviate some of their concern.

5. **Review what is science and how science works from Think-Pair-Share.** Review the "what is and is NOT science" list participants made previously in the session, and have them revise it based on new ideas from the 'How Science Works' flowchart and the readings. Record participants' ideas in a new color on the same chart paper where their original ideas were recorded.

G. Reflection: *Looking back on what we've done so far*

1. **Review Learning Cycle and Five Foundational Ideas.** Instruct participants to pull out their Learning Cycle and Five Foundational Ideas handouts from a few sessions back (Session 3). Give them three minutes to think about how the different parts of the Greenhouse Effect activity they engaged in were designed to reflect the Learning Cycle instructional model and Five Foundational Ideas about how people learn. Refer them to the following prompts and remind

them to record their ideas:

   a. Which phases of the learning cycle were represented in the Greenhouse Effect activity? Be ready to support your answer with examples.
   b. Which of the Five Foundational Ideas were represented in the activity? What makes you think that?

2. **Introduce the Three Interview routine.** Tell participants that they will share their ideas with others in a routine called Three Interviews as follows:
   a. Stand up with their notes and handouts, and mingle silently around the room until you call stop. Then pair up with another person nearest them.
   b. Share ideas with each other and each record something they heard from their partner.
   c. When time is called, mingle again, stop when time is called, and pair up with a new partner to share ideas again. Record something new, such as additional evidence or examples, and share something that's new to your partner.
   d. Repeat with a third partner.

3. **Lead Whole-Group Sharing.** Call on volunteers to share examples of each of the phases of the learning cycle and the Five Foundational Ideas as represented in the Greenhouse Effect activity.

4. **Display slide of Greenhouse Effect activity and the Learning Cycle.** Share the slide of how the greenhouse activity matches up to the learning cycle phases to organize and synthesize the discussion. Remind participants that each of the activities they will encounter in the course was designed with the learning cycle in mind. Encourage them to look for the different phases as new activities are introduced. This review was to help them apply the learning cycle in the design of one of their own activities as part of this course.

H. Homework

1. **Explore the UCMP Understanding Science website.**Visit the UCMP Understanding Science website http://undsci.berkeley.edu, and explore, including the Misconceptions about Science page http://undsci.berkeley.edu/teaching/misconceptions.php.

2. **Read from the Framework for K–12 Science Education and respond to prompts.** Read the Framework for K–12 Science Education pp. 78-79 "Reflecting on the Practices". Respond to the reflection prompts:
   - What did you find interesting/surprising? What do you think would be interesting/surprising to middle school students or the general public?
   - In what ways has your understanding of the nature and practices of science deepened?
   - Describe why it is important to include the nature of sciences in science instruction.
   - What questions were raised for you or what do you wonder about based on reading the **Five Facets of Science** during class?

Background for the Instructor

How was the Greenhouse Effect demo similar to the actual greenhouse effect? How was it different? Some responses participants might share:

- The bottle is so small in comparison with our actual atmosphere. Does mass of an object have an effect on greenhouse effect? For example, the mass of the model? If you had a really large model and only added a little bit of CO_2, you wouldn't see anything. We amplified the amount of CO_2 we added and compressed the time scale. Real greenhouse effect happens over about 50 years. The model is not a perfect example of what's going on in the planet because the proportions are not accurate.
- The bottle is like the atmosphere because it's open. There's room for energy to go in and energy to go out.
- In the model there is no constant external source of heating like the sun. You put it in the

microwave. Then you also have the emission of infrared radiation that goes into space, or into the room in our model. For the model to be more like the planet, you'd need to have a steady amount of infrared leaving the soil because it was continuing to be warmed. In our model we only heated it once, and it just kept losing heat.

Why does a microwave serve as an effective model of the Sun in the greenhouse demo?
You might want to share with the participants why a microwave serves as an effective model of the 'Sun' in this greenhouse activity. This note also explains why a microwave more accurately models the greenhouse effect than does a heat lamp.

When solar radiation from the Sun enters the atmosphere, about half of it is absorbed by Earth's surface, converted to heat energy, and re-emitted back from Earth's surface to the atmosphere as infrared radiation. This latter part of the process is what we are interested in modeling here - what happens **after** Earth's surface absorbs the solar radiation and emits it back as infrared radiation (heat energy). That is when the greenhouse effect comes into play and why it is the infrared radiation emitted from the soil that is important to include in the model, rather than the incoming 'solar radiation'.
In this model, microwave radiation is used to heat "Earth's surface" (the soil in the bottle). Microwaves are absorbed by the water molecules in the soil (or food you are cooking) and then re-emitted as infrared radiation (heat energy). Microwaves don't heat the sides of the bottle or the air in the bottle (e.g. water vapor or other gases); microwave radiation is only absorbed by liquid (in this case, water in the soil). This models the greenhouse effect quite well since greenhouse gases absorb the re-emitted infrared radiation, rather than the incoming solar radiation.

A heat lamp does not model the greenhouse effect accurately because a heat lamp emits mostly infrared radiation which would heat up any water vapor and other greenhouse gases in the "atmosphere" of the bottle as it passes through the atmosphere on the way down to the soil. This is not how the greenhouse effect works.

