Session 8: *Designing Learning Experiences and Global Carbon Cycling*

Overview

In this session, participants continue to explore the carbon cycle through multiple experiences and discuss how the structuring and sequencing of activities about the carbon cycle can promote deeper understanding. Participants consider carbon flows between land, ocean and atmosphere reservoirs, including flows caused by human activities. They construct a model of the carbon cycle with information gathered from simulations, readings and investigations. Next, participants engage in a series of activities to deepen their conceptual understanding of the carbon cycle and discuss how the focus and design of each activity, as well as the sequence of their rotation through the activities affected what they learned. The Learning Cycle (introduced in Session 3) is reviewed and applied to the carbon cycle activities as a model to guide participants' thinking as they start to develop their own activity. Participants then consider how the crosscutting concepts of Systems & System Models and Scale, Proportion & Quantity can frame and support understanding of this complex cycle. Participants are presented with the requirements and a guideline (based on the learning cycle model) for the final project in which they will work over the next sessions to choose a specific testable question that can be addressed using professionally-collected data, from online data sources.

Session Goals

Theme	Goals
Climate Science Ideas	Understand that: • the ocean is a large carbon reservoir (OSS 2.5). • carbon flows on land, the ocean and atmosphere in processes of decomposition, formation of fossil fuels and limestone, and combustion of fossil fuels, as part of the carbon cycle (OSS 2.5 - 2.7).
Using Data	Build on skills covered in previous sessions, especially with regards to models and proxies.

Teaching & Learning	• Examine the advantages and limitations for learning in the design of different activities and consider how a sequence of activities may take advantage of their affordances • Review the Learning Cycle instructional model • Review that effective teaching employs a sequence of different teaching approaches and student experiences to achieve greater learning.
Framework/ NGSS	Learn about how the Big Ideas of Systems and System Models and Scale, Proportion and Quantity are described in the *Framework for K–12 Science Education and NGSS,* and discuss how they support conceptual understanding.

Materials Needed

For the class

- Powerpoint presentation
- Digital Projector
- Whiteboard or flipchart and markers
- Interactive Carbon Cycle Diagram
- Distilled or tested water* (see below)
- 2 bottles bromothymol blue (BTB)
- (optional) a few seashells (Note: we urge you to only use shells from existing shell collections rather than purchasing shells from shops or the Internet, as many times these are obtained at great cost to the organisms and their habitats.)
- Chart paper
- 1 3-6 oz jar with screw-top lid (baby food jars work well)
- 2 copies of Sample Student Investigation Questions

For groups of 3-4 participants

- 1 cafeteria-style tray
- 4 3-6 oz jars with screw-top lids (baby food jars work well)
- 1 drinking straw
- 1 set of Carbon Cycle Cards

For every participant (1 copy of each of the following)

- Defining the Carbon Cycle handout

- Carbon Cycle Diagram (used in Session 7)
- Image of Sydney Harbor (or locally-relevant image; used in Session 7))
- The Learning Cycle (provided in Session 3)
- Final Project Guidelines handout
- Topic Area Questions for Final Project handout
- Science Topic Area Paper Instructions handout
- Characteristics of Testable Questions handout
- *Framework for K–12 Science Education,* pp. 89-94
- NGSS - Scale, Proportion and Quantity and Systems and System Models (see pdf or access url at http://www.nextgenscience.org/sites/default/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf)
- NGSS - Systems and System Models (see pdf or access url at http://www.nextgenscience.org/sites/default/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf)

For the Carbon Cycle Activity Stations

(The materials here are for up to approximately 15 participants with one set-up of each of the three stations with up to 4-5 participants per station.) Note to Instructor: We recommend that with more than 15 participants, you will want to provide two set-ups of each station, so participants can rotate through them in the time allowed and have the opportunity to experience each station. Should you have more participants, you will need to increase stations and materials accordingly.

<u>For Station A, Open-Ended Exploration: Interactive Carbon Cycle Diagram</u>

– Computer

– Access to Simulation: Interactive Carbon Cycle Diagram

  - go to the following url: http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview/oss68-resources/unit2
  - Scroll down to Session 2.7: Investigating Combustion and the Carbon Cycle; then click on Simulation: Interactive Carbon Cycle Diagram.

– 1 copy of the Station A sign and Instructions

<u>For Station B, Structured Activity: Paper Clip Carbon Cycle Model</u>

– 1-2 copies of the Station B Instructions and Worksheet

– 1 copy of the Station B sign

– 1 each of two different game boards labeled: “Paper Clip Carbon Cycle Model #1”, and “Paper Clip Carbon Cycle Model #2”

– 20 paper clips in each of five different colors

– 2 dice

For Station C, Guided Discovery: Tabletop Carbon Cycle Diagram

– 2 copies of the Station C: Instructions and Worksheet

– 1 copy of the Station C sign

– 1 set of 32 Carbon Cycle Cards

– 1 set of 3 labels (Ocean, Atmosphere, Land)

– 20 paper arrows

Preparation of Materials

For Activity B. Investigating Carbon Flow: Air to water

1. ***Test tap water.** Before you purchase distilled water, test your tap water to see if it will be neutral in affecting the expected BTB color change by adding some drops of BTB to a water sample. The water should be a strong blue. If it turns at all greenish, then use a different water source. Some bottled and tap water sources cause the BTB to change color, so distilled water is the recommended option to eliminate variables.
2. **Fill jars:** Prepare four jars for each group, plus one additional jar for the class:
    a. Fill jars about ⅓ full of distilled or tested water. Add about 30 drops of BTB until water turns a strong blue color. Cover jars with lids.
    b. Shake the additional jar for the class to make sure the BTB is well mixed. Then unscrew the top and blow 5 deep breaths directly into the jar. Quickly replace the lid. Do not shake. Set the jar aside for use during the session.
3. **Prepare trays.** Set out a tray for each group and place the following items on each tray:
    - 4 filled jars with lid
    - 1 wrapped straw

For Activity C. Carbon Cycle Diagram & Defining the Parts

1. Make 1 copy for each participant of *Defining the Parts of the Carbon Cycle* handout.
2. Have additional copies of the *Carbon Cycle Diagram* to distribute in case participants displaced their copy provided in Session 7.

For Activity D. Carbon Cycle Activity Stations

1. **Copy station instructions and worksheet**. Make enough to have one-two for each station you are setting up.
2. **Set up the stations.** Set up the three stations by putting the materials (described under "What You Need" above) on a tray, with the instructions for that station. You'll need to set up duplicate sets of these stations if you have more than 20 participants. The three stations are: Open-Ended Exploration; Structured Activity; and Guided Discovery.
3. **Access two computer simulations** (one to use in carbon cycle stations and one for the discussion about the learning cycle which follows).
    - http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview/oss68-resources/unit2
        - 2.7 Simulation: Interactive Carbon Cycle Diagram
    - http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview/oss68-resources/unit3
        - 3.10 Simulation: Change the Flow

Final Project & Testable Question Activity

1. Make one copy for each participant:
    – Final Project Guidelines
    – Topic Area Questions for Final Project
    – Science Topic Area Paper Instructions
    – Characteristics of Testable Questions
2. **Sample Student Investigation Questions.** Make two copies of this sheet. Cut each sheet into strips so that each strip has one question. During the activity, two sets of partners will work on one of the questions so that later in the activity, they can compare answers. Distribute a different question to each matching set of partners.
3. **Become familiar with the Ocean Literacy Framework** composed of the Ocean Literacy Principles and the Ocean Literacy Scope & Sequence available at oceanliteracy.net. There are seven Ocean Literacy principles, and the complementary Scope and Sequence is comprised of 28 conceptual flow diagrams that provide grade-band appropriate concepts. Learn about the Principles and the Scope and Sequence at http://oceanliteracy.wp2.coexploration.org/ocean-literacy-framework/principles-and-concepts/
4. Optional: become familiar with the **Climate Literacy Principles** at

Revisiting Big charts

Make one copy for each participant:

– *Framework for K–12 Science Education,* pp. 89-94
– NGSS - *Scale, Proportion and Quantity* handout
– NGSS - *Systems and Systems Models* handout

Session at a Glance

Task	Description	Time (minutes)
A. Session goals	Session goals are shared.	2
B. OSS Activity 2.5: *Tracking Carbon flows through the Ocean Reservoir*	Participants explore how carbon moves from the atmosphere into the ocean. Using jars with water and BTB, they develop their own investigations and consider how each investigation might help to answer the question. Using evidence from the results of their investigations, participants work together to make an explanation for how CO_2 gets from the atmosphere into the ocean.	15
C. Activity: *Carbon Cycle Diagram & Defining the parts of the Carbon Cycle (OSS 2.6 and 2.7)*	Participants share what they know about carbon flows after organisms die, and fossil fuels and limestone reservoirs. They track carbon flows on a diagram and define the processes included so far in their carbon cycle model.	8
D. Activity: *Carbon Cycle Investigation Stations*	Three activities focus on the carbon cycle to help participants come to a deeper conceptual understanding of the carbon cycle and explore how the sequence and design of experiences support learning.	45
E. Discussion: *Designing experiences to support learning*	Participants reflect on the carbon cycle investigation activities, and discuss what helped them to answer their own questions and come to a deeper understanding. They also discuss how the activities modeled the five foundational ideas of learning, and the learning cycle instructional model.	15
F. Discussion: *Framing the Carbon Cycle with Crosscutting*	Participants read and discuss the crosscutting concepts of Systems and System Models or Scale, Proportion & Quantity, described in the *Framework* and NGSS. They reflect on how each of the crosscutting concepts of Matter and Energy, Systems and System models, and,	15

Concepts (Update the Big Charts)	Scale, Proportion & Quantity affect their understanding of how carbon flows through the ocean, land and atmosphere in the Carbon Cycle, and record observations on the Big Charts.	
G. Applying the Learning Cycle: *Final Project showcasing a data activity*	Participants are presented with the requirements and a guideline (based on the learning cycle instructional model) for the final project.	10
H. Introduction to Topic Area Questions	Participants are provided with a list of broad, but investigable "Topic Area Questions" they can choose from to develop their own data activity to teach their middle school students a climate science concept.	10
I. Activity & Discussion: *Asking Testable Questions*	Participants practice refining investigation questions into testable questions as they use "SMART" questions (from Session 7) and a "Testable Question Checklist" to revise sample student questions.	40
J. Homework	Using the Topic Area and Topic Area Question from the "*Topic Area Questions for Final Project"* provided, participants do research about the science concept, write an overview and answer associated questions about the data they will need to get started on their final project.	10
	TOTAL: 2 hrs 50 min	**170**

Session Details

A. Share Session Goals

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:** Carbon flows between the land, the ocean and atmosphere through many different processes as part of the carbon cycle.

- **Using data:** Use data to make conclusions and relate it to a broader science concept. Discuss and use strategies to develop testable questions to explore using authentic data. Introduce the Final Project Guideline used to develop a data-based lesson plan to showcase what they've learned.
- **Teaching and learning:** Review the Learning Cycle instructional model and examine the possibilities and limitations for learning in the design of different activities.
- **Framework/NGSS:** Learn about the Big Ideas of Systems and System Models and Scale, Proportion and Quantity*,* and discuss how they support conceptual understanding.

B. OSS Activity 2.5: *Tracking Carbon flows through the Ocean Reservoir*

1. **Carbon in the ocean reservoir.** Remind participants that in the previous session they explored that photosynthetic organisms (including in the ocean) both use and produce CO_2 in the processes of photosynthesis and respiration, respectively. Add that many ocean organisms with hard shells also use carbon that came from CO_2 to make calcium carbonate ($CaCO_3$) shells, which help to protect their soft body parts. Tell participants that because ocean organisms are surrounded by water, not air, they must be getting the CO_2 they need for their body functions from their water environment.

2. **Introduce a new guiding question; project slide.** Ask, "**If these organisms are getting CO_2 from their watery environment, how does the CO_2 get into the water?** Project the slide and tell participants that the group will now investigate this question.

3. **Turn and Talk.** Have participants discuss their ideas with a partner. [Possible responses: *from ocean animals' respiration; from the air.*] Call on a few volunteers to share their ideas with the class. Ask, "How sure are we?" "How could we be more sure?" Tell participants that they will do an investigation to get more evidence to support their explanation.

4. **Introduce Investigation Materials**. Distribute the tray of materials and let participants know they will be working in small groups. Explain that the containers of water and air represent the ocean and atmosphere, and that some BTB (the same indicator used in previous investigations) has been added to the water. Remind them that BTB changes color if carbonic acid is present in the water, due to CO_2 being added to the water (and thus is can be used as a proxy for carbon dioxide). Let participants know that they may explore the materials, but not to remove the lids of

the containers, just yet. Ask participants to think of investigations that could be set up to answer the question, '**How can CO_2 from the atmosphere get into the ocean?**'

5. **Planning Investigations.** Project the prompt slide. Tell participants to use the prompts as they discuss their different ideas.
    a. What would happen if we ____________, and
    b. That would tell us that ____________ about the real ocean.

    While they discuss, make two columns on the board or on chart paper under the heading *"How CO_2 gets into the ocean"* to record their ideas. Label the first column: *description of investigation*, and the second column: *what that can tell us*.

6. **Investigation Ideas from the group.** After a few minutes, ask participants to share investigation ideas. Remind them to use the sentence frame prompts, and encourage them to describe what different results would tell them. Record their ideas on the board or chart paper.
    Some possible investigation ideas are (suggest these if no one else does):
    - Exhale into jar, close it, and leave it alone. BTB changing color would tell us that calm ocean water can absorb excess CO_2 from the surrounding air, while no change would tell us that water can't simply absorb excess CO_2 from the surrounding air.
    - Shake the jar without breathing into it. BTB changing color would tell us that simply agitating water adds CO_2 to the water, while no color change would tell us that agitating water alone is not enough to change the concentration of CO_2 added to the water.
    - Exhale into jar, close it, and shake it. BTB changing color would tell us that agitating water (such as through storms or wave action) moves excess CO_2 to the water, while no color change would tell us that agitating water with excess CO_2 in the air does not transfer CO_2 to the water.

7. **Carry out Investigations.** Explain that all groups will now carry out as many of the different investigations they have described as they can in the time allotted. This will provide multiple sources of evidence to answer the question about how atmospheric CO_2 gets into the water. Give participants five minutes to carry out the investigations. Tell them to describe what they notice and discuss possible claims using evidence that answers the question, '**How can CO_2 from the atmosphere get into the ocean?**'

8. **Participants share claims.** Get the attention of the group and call on a few volunteers to share their claims about how CO_2 from the atmosphere gets into the ocean. Ask some of the following probing questions:
    - Did anyone else conduct that investigation?
    - Did you get a similar or different result?
    - Why do you think that is?

   Remember not to correct or confirm their ideas. Probe them to elaborate on their reasoning with questions like, "What makes you think that?" or "what is your evidence?" Encourage participants to share different ideas and reiterate the role that multiple trials played in helping to show the reliability of the results.

10. **Share your prepared jar of BTB.** Even if participants have conducted the experiment in which they blew into the top of the jar of BTB water, sealed it, and then left it sitting still, they likely won't have had enough time to see results. Share that you tried a similar experiment. Hold up your prepared jar, which should have at least a layer of color changed BTB on top at this point. Ask participants what they think your results might mean. [*Water can absorb excess CO_2 from the surrounding air over time.*]

11. **Summarize how CO_2 from the atmosphere gets into the ocean.** Summarize that CO_2 appears to be absorbed into the ocean from the atmosphere when it is mixed or shaken, because the water in the jar immediately changed color from blue to green. This could happen through wave action or storms. CO_2 appears to be absorbed even when air and water are not agitated together, though it happens more slowly than when there is physical mixing. This could happen when ocean water is calm.

C. Activity: *Carbon Cycle Diagram and Defining the parts of the Carbon Cycle (OSS 2.6 and 2.7)*

1. **Review homework notes.** Ask participants to take a minute to review the answers to the reflection prompts about photosynthesis, respiration and fossil fuels they were assigned for homework and any notes they took as they watched the fossil fuel videos.

2. **Turn and Talk.** Ask participants to discuss the following prompts with their partner:
    a. After responding to the reflection prompts, what questions do you still have?

b. How might using the reflection prompts with students help a teacher to understand where students are in their understanding of the science concepts? Be specific.

3. **Whole group Share out.** Ask for volunteers to share their ideas. Accept all comments and record their questions. *[Ideas that might come up: a teacher might have a sense of students' ability to apply the concepts from class to novel situations or see holes in student understanding; they might be useful for formative evaluation—teachers might use them as an informal evaluation tool to see where students are in their thinking and what other types of experiences might be useful to help deepen student understanding, if necessary. Some of the prompts often leave room for more than one possible response and allow for application of concepts.]*

Revisit Carbon Cycle Diagram

1. **Review Carbon Cycle Diagram.** Remind participants that they started their Carbon Cycle Diagram during the last session. Have them pull out their Carbon Cycle Diagram and review what they included previously regarding carbon reservoirs and flows they have already gathered evidence about.

2. **Adding to the Carbon Cycle Diagram.** Ask participants to add to the carbon reservoirs and flows, using additional details from the videos and prompts assigned for homework about photosynthesis, respiration and fossil fuels, as well as what they explored so far this session (absorption into the ocean). Remind them to use words to label the reservoirs and flows. Give them about 5 minutes to work.

3. **Remind about Carbon Cards.** Remind participants that the Carbon Cards can be used as a reference to provide them with ideas of what additional reservoirs they might include.

4. **Turn & Talk**. Have participants refer to their Carbon Cycle Diagrams as they discuss their diagrams with a partner. Remind participants that they should encourage their partners to provide details and reasons for their ideas and additions to the diagrams by asking, "Why do you think that?" Tell them that they should also feel free to add to their diagrams based on what their partner shares.

5. **Display decomposition prompts slide.** Project decomposition image slide with prompts, 'What happens to the carbon in organisms after they die?' and 'Could the answer be different depending on where the organism dies?' Give participants about a minute to think about their response.

6. **Whole group share.** After 1 minute, ask for volunteers to share their ideas. *[If they don't mention it, remind participants to discuss coal; crude oil; decomposition; and limestone.]*

7. **Display carbon flow from fossil fuels reservoirs prompts slide**. 'Carbon flows into reservoirs of coal, crude oil, and limestone when organisms die. This process takes a VERY long time. How do you think carbon might come out of these reservoirs?' Give participants about 30 seconds to 1 minute to think about their response.

8. **Whole group share**. After 1 minute, ask for volunteers to share their ideas and then show answers on the slide. *[Fossil fuel reservoirs: Natural leakage and breakdown of fossil fuels; and human industry - combustion. Limestone reservoirs: weathering, volcanic eruptions; and human industry - making cement]*.

9. **Add to Carbon Cycle Diagrams.** Have the participants take 1-2 minutes now to add any additional carbon reservoirs and carbon flows that have just been discussed to their Carbon Cycle Diagrams if not already added.

10. **Calling out the processes in the Carbon Cycle.** Distribute *Defining the Carbon Cycle* handout to each participant. Explain that over the last two sessions, as they tracked the flows of carbon on Earth, they learned about a number of processes that are cycling the carbon matter through the system. Give participants 1-2 minutes to recall and write in what these processes were called. Review the processes as necessary. *[Respiration; photosynthesis; decomposition; fossil fuel and limestone formation; and absorption in the ocean/shell formation. The last flow, combustion, will be emphasized in this session.]*

D. Activity: *Carbon Cycle Investigation Stations*

Note to Instructors: *These activities are set up to reflect the phases of the learning cycle instructional model, although the participants may not encounter them in order, depending on which activity they start with. This design encourages participants to reflect on, discuss and apply their understanding of the learning cycle and the five foundational ideas about learning in preparation for designing their own activity.*

Introduction

1. **Show slide of Sydney Harbor (from session 6) and add to diagram.** Ask participants to put their carbon cycle diagrams away for now. Have them work by themselves to quickly add to their sketch of the image of Sydney Harbor they started in Session 6, labeling any additional carbon reservoirs and flows they learned about. As they work, instruct them to write down any additional questions that arise for them, and to try to answer any of their original questions.

2. **Turn and Talk.** Have participants share their updated drawings and questions with a partner. Then have partners share their questions and answers with the whole group as you record on a class chart.

3. **Introduce the overall goals of the Activity Stations.** Point out that in this next part of the session, they will be rotating through three activity stations focused on the carbon cycle to try to arrive at a deeper understanding of this complex system while also thinking about how they are making sense of the concepts. Although they will be rotating through the stations in different orders, they should also be thinking about how the stations could be sequenced into the learning cycle. Have participants take out their learning cycle handout to use as a reminder and reference.

   – Stations designed to stimulate discussion. Let them know that these stations have been specifically designed to stimulate discussion on how people learn and the design of experiences to support learning. These station activities represent different approaches to teaching a topic of any kind.

   – Reflect on learning experience. Emphasize that although one of their goals is to perform the assigned tasks, and get "caught up" in the activities themselves, the most important objective is to reflect on the learning experience. Emphasize that as they engage with the three stations they should think about:

   - What do you think the specific content learning goals are for each station? (Why was this particular activity included in the lesson?)
   - What is one piece of science content you are taking away? Were you able to answer some of your questions?
   - What additional questions about the content arise for you as you engage in the activities? Record your questions.

4. **Introduce the station activities.** Explain that at each station they will:

   – Do the activity. Work with a small group to read the signs and follow the directions. There will be a signal given when time is almost up. They should expect to spend about 12 minutes at each station. **It is to be expected that they may not complete more than**

1 station in the time provided; the point is to engage in conversation about the content and activity design.
– Write down questions. Before leaving a station, they should spend one minute writing down answers to the three question prompts on the screen.
– Clean up the station. When they are finished, reorganize the materials for the next group before moving on to the next station.

Rotating through Carbon Cycle Stations

1. **Monitor station activities.** Check in with groups to make sure they understand the directions for each station, are making progress, and that they reorganize the station before they move on. Remind them that the point of the activity is not to get to the end of the activity, but rather to enter into conversations with their group about the content and design.

2. **Announce time and rotate groups.** Keep an eye on the progress of groups at Station B. When they have completed at least a good portion of game board #2, announce to the whole group that it's time to reorganize the station and move on to the next. Remind them to write down any questions about the content that arose during the station activity. Explain how they should rotate, with people from Station A moving on to Station B, Station B moving to Station C, and Station C moving to Station A.

3. **Complete stations and revise drawings**. After the last station has been completed, have participants individually revise their Sydney Harbor diagram to reflect anything they would like to add or change. Also encourage them to record which questions were answered so far, which are left unanswered and what new questions arose.

Reviewing What was Learned (Choose one or more of the following, depending on time.)

1. **Lead whole class discussion.** Have volunteers share which questions on the class chart were answered, which station helped them answer the question and what they discovered the answer to be. Encourage others to share their ideas and answers and challenge them to provide evidence and reasoning for their responses. Encourage participants to share whether they agree or disagree, and build on the ideas expressed. As they share, add new questions and circle any questions that remain unanswered on the chart.

2. **Quick write – what I want to remember.** Tell participants to spend a minute thinking about the science content they learned from the three activities and then record in their journal anything

they want to remember about what they learned and what helped them to learn it. Also have them write a key concept for each of the three stations and record any questions they still have.

3. **Exit Ticket - unanswered questions.** Tell participants that their exit ticket from class today will be to turn in the questions they still have and specific keywords or phrases they would 'google' to attempt to answer. They are to turn in the questions at the end of class as an exit ticket, and during the next class period they will turn in the answers to their questions.

E. Discussion: *Designing experiences to support learning*

1. **Introduce learning goals.** Share the following slide with the participants and tell them that we will be investigating these questions in relationship to the design of the activities they've been engaging in during this class session:
    - The learning goals affect what learning experiences are offered and how they are designed.
        - How were you engaging with the materials and content in the different station activities to learn about the carbon cycle?
        - What do you think the content learning goal or purpose was for each of the individual stations?

2. **Reflect on and discuss their experiences as learners.** Draw attention to Station A, the Open-ended Investigation, and ask for their reactions to the station. Be accepting of all responses. Be prepared for (and welcome) some disagreement. If only positive reactions to the station are brought up, ask if anyone had a negative reaction, and vice versa.

3. **Discuss the possibilities and limitations of the design of Station A.** If it has not come up already, challenge students to think about how the activity at Station A is designed, and how the design affected their learning experience.
    - What were you able to do in the activity?
    - What were you not able to do in the activity?
    - Point out that in this example, the Open-Ended Exploration station was intentionally unstructured in an *exaggerated* fashion, in order to provoke reaction and discussion. Exploration need not be completely unstructured, and more specific procedural directions, data recording charts and debriefing discussions can make it a more rewarding and educational experience for all learners.

4. **Briefly discuss the possibilities and limitations of the design of Stations B and C.** Repeat the discussion in step 3 above with stations B and C.

5. **Ask participants to suggest some possible learning goals.** Ask what science concept learning goals each of the activities might serve. Lead a brief discussion about their ideas. Some content ideas to consider include:
    - ***Station A:*** *This activity provides an opportunity to see the carbon cycle in a new and yet familiar way since it is designed to be similar to the carbon cycle diagram that participants have been working on for a few sessions. This interactive diagram provided additional information to answer questions that arise through small group discussions.*
    - ***Station B:*** *This activity was designed to specifically address the common misconception that Earth is getting more carbon, rather than the normative science understanding that essentially no new carbon is entering the system, but rather it is cycling more quickly between the reservoirs. Human activities have taken carbon which was stored long-term in the fossil fuel reservoirs, and caused it to flow much more rapidly than it naturally would into the atmosphere and ocean reservoirs.*
    - ***Station C:*** *The tabletop carbon cycle diagram provided the opportunity to work together to learn more about the carbon cycle, while also enabling learners to realize what they individually know and don't know about the carbon cycle. It also provides the opportunity to make sense of the content in individual ways as there are many correct ways to make the model.*

6. **Note other factors that may impact educator's choices.** Point out that the design of learning experiences also depends on many other factors, such as available time, context for the experience, home and school culture, and previous experiences of the audience and the educator.

Revisiting the Learning Cycle

1. **Review the learning cycle.** Have participants take out their learning cycle handout as a reference for the next part of the session. Tell them that since they all rotated through the stations in a different sequence, they might not have experienced the learning cycle instructional model.

2. **Display Learning Cycle and remind about phases.** Use the following information to briefly review each phase.

– **Invitation**: An invitation is a question, problem, observation, or demonstration that initiates the learning task. It should make connections between past and present learning experiences, anticipate activities and organize learners' thinking toward the learning outcomes of current activities. If learners are not engaged, they may not retain what they learn, and are probably only involved in rote learning.

– **Exploration**: Learner is engaged in open-ended investigation of real phenomena, and can also involve some discussion about discoveries, results, ideas, and questions that arise. This can be through hands-on activity or through discourse and thought processes. It can be more or less structured, but the idea is that exploration should be driven mainly by the learner's interest and questions.

– **Concept Invention**: The concept invention phase involves the active processing of the experience by the learner. Learners now review evidence and data gathered through exploration and try to make sense of it. With interest and attention focused, new ideas can be discovered and the learner can solve problems and begin to construct new meanings. When possible, learners should be free to invent and discuss their own understandings directly from their hands-on experiences, through discussion with their peers and with those with more knowledge.

– **Application**: Armed with new ideas and concepts, the learner applies knowledge and abilities to different situations than those they have already encountered. Researchers agree that in-depth learning requires being able to transfer knowledge from familiar circumstances to novel ones.

– **Reflection**: After trying out new ideas in different settings, learners reflect on how their original notions have been or need to be modified. They may also generate new questions that can initiate a new learning cycle.

3. **Discuss the sequence of the stations**. In the previous discussion, participants' preferences regarding the order of the stations may have been mentioned already. Ask if they liked the order they did the activities, or if there was a different order they think would be more effective. Have each group suggest the order they think would be the most effective way to organize the stations. Encourage them to explain the reason underlying their ordering preference and how the order they suggest reflects the learning cycle. Make sure to acknowledge that the activities could go in different orders depending on your learning goals and how you structured each activity. They should place activities in an order that makes sense for their particular learning goals.

4. **Connect the structure of this session with the Learning Cycle model.** Draw participants' attention to the elements of the carbon cycle activities that fit with the Learning Cycle model. Share the following information to provide a synthesis of their discussion about the phases.

   – **Invitation**: Sydney Harbor Sketch and recording questions; interactive computer model

   – **Exploration:** The interactive computer model, and the tabletop diagram

   – **Concept Invention:** The tabletop diagram, paperclip model, revisiting diagram and discussing questions and concepts.

   – **Application:** Was this missing? Introduce the second interactive computer model, "Change the Flow" and describe it as providing scenarios and opportunities to describe and provide evidence and reasoning about what will happen.

   – **Reflection:** Quick write about what was learned, how it was learned, and generating new questions; discussion of crosscutting concepts coming up at the end of this session.

5. **Slide reviewing five foundational ideas.** Project the five foundational ideas about learning slide, and share the following information and question.
   - The Learning Cycle is a model that was developed to provide a method for organizing and delivering educational experiences that are consistent with what is known about how people learn.
   - Now, turning to the five foundational ideas about learning, which of these ideas were included in this series of carbon cycle activities?

   Have participants discuss the prompt in small groups, and then lead a group discussion about their ideas.

F. Discussion: *Framing the Carbon Cycle with Crosscutting Concepts*

1. **Introduce how a crosscutting concept frames the science ideas.** Remind participants that in the last few sessions, they built an understanding of the carbon cycle by following carbon as it flows from reservoir to reservoir, and connecting photosynthesis and respiration and the other processes that carbon flows through. Each of the processes that make up the Carbon Cycle were framed with the big idea, or crosscutting concept, *Matter and Energy*.

2. **Participants read about Systems and System Models and Scale, Proportion and Quantity Crosscutting Concepts.** Explain to participants that the Carbon Cycle might also be framed or looked at through the lens of a system or in terms of scale, proportion, and quantity. Give each participant a copy of the NRC *Framework for K–12 Science Education,* pp. 89-94, and either a

copy of the NGSS- Scale, Proportion, and Quantity ***OR*** the NGSS- Systems and System Models handouts. Have half of the participants read about Systems and System Models and the other half about Scale, Proportion, and Quantity. Ask participants to read these documents using the Active Reading strategies used in a previous sessions (i.e. highlighting interesting or confusing points, and capturing questions that arise).

3. **Participants share with a partner who read the same crosscutting concept.** Have participants pair up with someone else who read the same crosscutting concept. Participants spend a few minutes discussing their ideas from the reading — what they found interesting, what they found confusing and trying to answer the questions they had.

4. **Turn and Talk.** Show an example of a completed Carbon Cycle Diagram or the Interactive Carbon Cycle animation. Tell participants that they will now do a turn and talk about the prompts relevant to their particular crosscutting concept. Project both sets of prompts simultaneously, and introduce each:

   Systems and System Models: Explain that the Carbon Cycle diagrams, the Interactive Carbon Cycle animation, the Carbon Cycle game and the Carbon Flow cards represent what we know about this system - they are models. Ask participants to discuss the following prompts with a partner:

   - What are the parts and sub-systems that make up this system? How do they work together?
   - How can our system models be made more accurate? What predictions can we make using the models?
   - What kind of data could help us understand this system? What would the data tell us about the system?

   Scale, Proportion and Quantity**:** Explain to participants that there is another big idea at play here–*Scale, Proportion and Quantity.* In thinking scientifically about any system and processes, it is essential to recognize that there is variability in size and/or time span, and in the relationships between the scales of the different quantities. Tell participants that we will consider the role of Scale, Proportion, and Quantity in how we learned about the Carbon Cycle. Ask participants to discuss the following prompts with a partner:

   - What scales or proportions or quantities were included in the Carbon Cycle models?
   - How did including this information affect your understanding of the Carbon Cycle and the predictions you could make?

7. **Think Pair Share.** Ask participants to think about the following questions and be ready to share their ideas:
    - How does framing what we know about the Carbon Cycle through the lens of matter and energy affect a learner's understanding? What makes you think that?
    - Those who read about Systems and System Models: How does framing what we know about the Carbon Cycle as a system affect a learner's understanding? What makes you think that?
    - Those who read about Scale, Proportion, and Quantity: How does framing what we know about the Carbon Cycle through the lens of scale, proportion and quantity affect a learner's understanding? What makes you think that?

8. **Participants share with a partner.** Participants spend a few minutes discussing their ideas.

9. **Whole group discussion.** Facilitate a whole group discussion with the prompt:
    - How does framing science content (e.g., the Carbon Cycle) with one or more of the big ideas affect a learner's understanding? What makes you think that?

    Remember to use the Discussion Map to engage participants in the discussion, using some or all of the following strategies: accept all answers without correcting or confirming them, and ask others if they would like to respond to the ideas shared or if they have alternative ideas. Be sure to summarize and help to synthesize the overall discussion.

10. **Update the Crosscutting Concept Chart.** Ask for volunteers to share out some of the ways these crosscutting concepts were introduced and used by the instructor, and how the crosscutting concepts helped them as learners to make sense of the content. Record ideas on the Crosscutting Concept Chart.

G. Applying the Learning Cycle: *Final Project Showcasing a Data Activity*

1. **Introduce Final Project.** Explain to participants that for their final project they will be creating a data lesson for middle school students, similar to the professionally-collected data activities that they have and will engage in throughout the course. The final project, which will be centered around the data lesson, will give the participants the opportunity to show what they have learned from the course, and as such will include the following components:
    - Use of real or near-real time data, ideally local data, which helps to develop an explanation of a climate science related concept

- Incorporate the learning cycle instructional model into the design of the lesson
- Demonstrate knowledge of 3-dimensional teaching and learning through specifically addressing crosscutting concepts, science and engineering practices, and disciplinary core ideas (e.g. performance expectations)
- Demonstrate understanding of a climate science concept(s)

2. **Introduce and distribute guidelines.** Distribute the *Final Project Guidelines*, give participants a few minutes to review and then ask if there are any questions. Tell them that they will be provided with topic area questions to choose from to help them get started on picking their topic. With further support and activities throughout the rest of the course, the participants will focus in on a testable question for their data lesson.

H. Introduction to Topic Area Questions

1. **Introduce Topic Area Questions.** Narrowing a question about a topic area down to a question that can actually be investigated and answered using data is a huge accomplishment and challenge (for scientists too). Questions that are investigated using data can be called testable.

2. **Introduce Topic Area Questions for final project.** Distribute handout *Topic Area Questions for Final Project.* Tell participants that these questions are provided as a guideline to first select the topic area (broad concept that they are interested in investigating) from which they will come up with a more specific testable question that can be answered using sources of online data. The testable question is what they will focus their final project around for their future middle school students to investigate using real-time or near real-time data. Tell them that they will work with a partner to develop their final project, and together they will decide on which question they would like to pursue.

3. **Participants choose Topic Area Question.** Give participants a few minutes to review the provided Topic Areas and Topic Area Questions (TAQ), choose which TAQ(s) they are interested in, and then find another participant interested in the same TAQ to pair up with. Tell participants their homework assignment will be to get started on their final project by 1) getting more information about the climate Topic Area that their TAQ is focusing on and 2) answering a few related questions (see assignment below). This should be done with their partner.

I. Activity & Discussion: *Asking Testable Questions*

1. **Introduce Narrowing TAQ into a Testable Question.** Tell participants that a necessary step in the design of their final project will be to narrow down their TAQ to one that is very specific and fits a set of guidelines to make sure it is specific enough. This will be their testable question. Share with them that they will have an opportunity to do this during the next session.

2. **Quick Write - Testable Questions.** Have participants write for 3 minutes to the following prompt:
   - What criteria do you think would be included in determining whether a question is testable or not?

3. **Turn and Talk.** Tell participants to turn and talk to a neighbor about the quick write prompt.

4. **Facilitate a whole group discussion.** This discussion builds on participants' partner conversations with the goal of sharing their understanding of the characteristics of a testable question. Encourage alternative ideas and discussion and prompt participants to elaborate on their ideas and whether or not they agree.

5. **Display Characteristics of Testable Questions.** At the conclusion of the discussion, summarize their thinking. Project and read the *"Characteristics of Testable Questions"* slide. Ask participants if these ideas were similar to what they had discussed and if they have any questions.
   - **S**pecific (not too broad) – a testable question begins with *How, What, When, Who,* or *Which, (not Why, Is, or Does)*.
   - **M**easureable (there are datasets available to answer the question) – a testable question can't be answered just by doing reading.
   - **A**chievable (the question is able to be investigated with data) – data are available to and accessible by you.
   - **R**elevant (who cares and why do they care) – you can explain why you care about asking the question
   - **T**emporally and Spatially bound – the question includes when and where the data are coming from

6. **Introduce practice student questions.** Remind participants that narrowing a topic area down to a testable question is a huge accomplishment and challenge (for students and scientists too) and they will now have the opportunity to practice this skill by refining student questions, before honing in on their own specific testable question.

7. **Pairs refine student questions.** Have participants work in pairs to refine the provided questions posed by the fictional student so that it becomes a testable question. Distribute one *Sample Student Investigation Questions* strip and a *Characteristics of Testable Questions* to each pair. Make sure that each question is distributed to two different pairs of participants so that they can compare their suggested revisions. Emphasize that even if they do not know everything about the concepts included in the student question, they can make many recommendations of how to change the question so that it actually would be testable using data, following the provided checklist.

8. **Expert groups share.** Have the two pairs of participants that revised the same question get together to share their revisions and come to a consensus on a revision that best aligns with the *Characteristics of Testable Questions.*

9. **Whole group share revised questions.** Ask for volunteers to share the original question and their refined question and have the class provide feedback on how well it meets the criteria. After a few pairs have shared, ask:
    - Are there are any additional supports that might help your students to ask testable questions?
    - What challenges did you encounter in refining the questions?

    Tell participants that as part of their homework, they will be asked to do some research on their chosen Topic Area and Topic Area Question (TAQ) and to answer a few related questions.

J. Homework

1. **Science Topic Area Paper (completed individually).** Distribute the *Science Topic Area Paper Assignment* to each individual. Describe the assignment as follows. Do some research about the science concept(s) of your Topic Area Question and write a 1500 word overview of the concept. This will serve as the background and rationale/literature review for the final project and activity. Although participants will work in partners to complete the project, the science topic area paper should be completed individually. Encourage partners to discuss what they think should be included in their papers with their partners. Include the following:
    a. Topic Area and Topic Area Question
    b. Why the concept or topic area is of interest to you
    c. Why the concept or topic area is relevant to climate science

d. A thoughtful explanation of the science content relevant to your particular concept or topic (e.g., if you were writing about ocean acidification, you would include: What is ocean acidification? What causes ocean acidification? Which organisms are affected by it? How are they affected? Are there particular regions more impacted by ocean acidification than others? Why is that the case?) The Ocean and Climate Literacy Principles discussed below will be helpful in determining what additional grade level appropriate content and concepts you might include.
e. In what ways the concept or topic area can be relevant to middle school students
f. Headings for various sections within the paper to make it easy to follow

2. **Answer the following questions about the data needed (with partner).**
    a. Where might your investigation take place (geographic source of the data) to investigate the Topic Area Question?
    b. Over what time period might your investigation take place (which hours, days, weeks, months, or years) to investigate the Topic Area Question?
    c. What environmental parameters or other types of data might you need to address the Topic Area Question?

3. **Become familiar with the Ocean Literacy Framework composed of the Ocean Literacy Principles and the Ocean Literacy Scope & Sequence available at oceanliteracy.net.** These will be helpful in thinking about grade appropriate concepts to focus on in designing your activity. There are seven Ocean Literacy principles, and the complementary Scope and Sequence is comprised of 28 conceptual flow diagrams that provide grade-band appropriate concepts. Learn about the Principles and the Scope and Sequence at http://oceanliteracy.wp2.coexploration.org/ocean-literacy-framework/principles-and-concepts/**.** Climate Literacy Principles can be accessed at: http://cpo.noaa.gov/OutreachandEducation/ClimateLiteracy.aspx