Lesson 2: Finding Patterns in Large-scale Data

Tab 1: Overview

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Using a jigsaw activity, students discuss generalizability, representation, and short-term variability using four different large-scale data sets related to climate change: global temperature, sea level rise, long-term atmospheric CO_2 concentration, and short-term atmospheric CO_2 annual cycle.

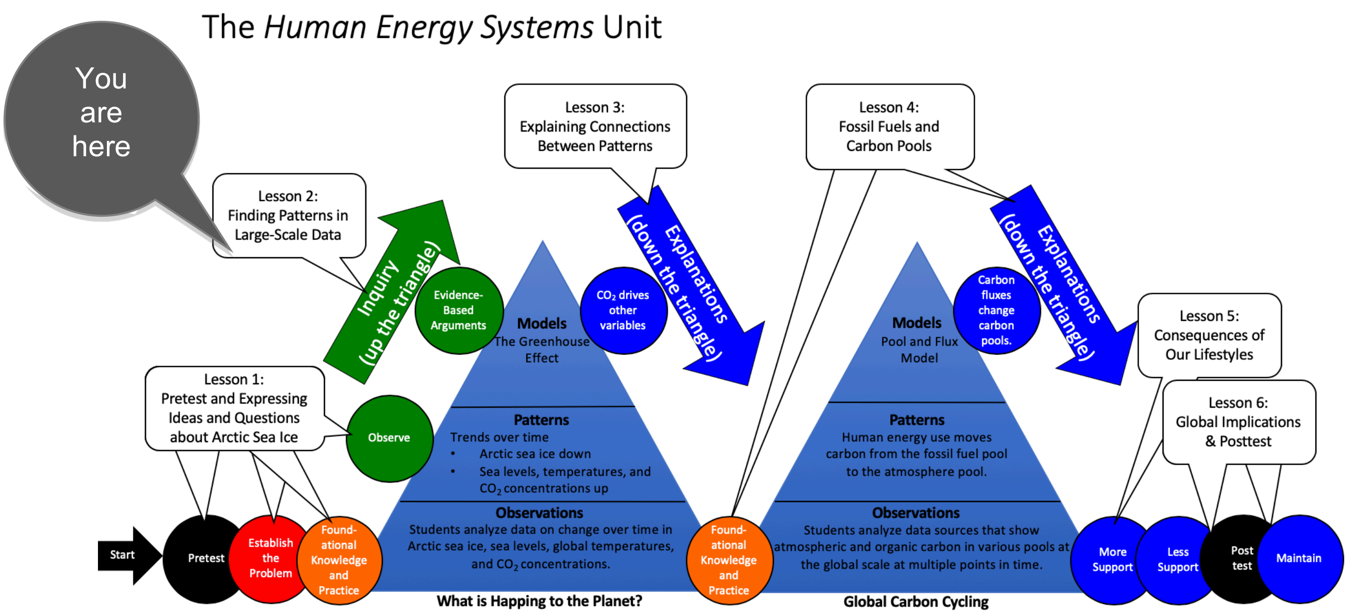
Guiding Question

What is happening to global temperature, atmospheric carbon dioxide, and sea level?

Activities in this Lesson

- Activity 2.1: Home Groups: Four Considerations for Large-Scale Data (45 min)
- Activity 2.2: Expert Groups: Analysis of Large-Scale Data (45 min)
- Activity 2.3: Home Groups: Share Expertise (60 minutes)
- Activity 2.4: Evidence-Based Arguments for Patterns in Earth Systems (30 min)

Unit Map



Tab 2: *Learning Goals*

Target Performances

Activity	***Target Performance***
Lesson 2 – Finding Patterns in Large Scale Data (students as investigators)	
Activity 2.1: Home Groups: Four Considerations for Large Scale Data (45 min)	Students in home groups express initial ideas about patterns and changes over time for four variables in Earth systems: global temperatures, global sea levels, Arctic sea ice, and atmospheric CO_2 concentrations.
Activity 2.2: Expert Groups: Analysis of Large-Scale Data (45 min)	Students in expert groups investigate multiple representations of the four variables in and the Earth systems that they measure, generating explanations and questions.
Activity 2.3: Home Groups: Share Expertise (60 min)	Students return to home groups and share their expertise about patterns of change for four variables in Earth systems: global temperatures, global sea levels, Arctic sea ice, and atmospheric CO_2 concentrations.
Activity 2.4: Evidence-Based Argument for Earth Systems (30 min)	Students compare patterns of change for the four Earth systems variables and record questions about what causes the patterns and how the patterns are related to one another.

NGSS Performance Expectations

High School

- Earth's Systems. HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
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- Weather and Climate. HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- Earth's Systems. HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
- Earth and Human Activity. HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
- Earth and Human Activity. HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Middle School

- Earth and Human Activity. MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

Tab 3: Background Information

Three-dimensional Learning Progression (accordion)

Understanding data representations. Lessons 1 and 2 focus on helping students make sense of representations of data about Earth systems. This is difficult and challenging for many students. We see four interconnected issues:

1. Representation: Students see many different representations of data about Earth systems. For example, in Activities 2.2 and 2.3 students see (a) animations of satellite data showing maps that change over time, (b) tables with numerical representations of sea ice extent, and (c) graphs showing patterns and trends. Students need to recognize that even though they look different, these are all representations of the same phenomena. They also need to recognize that the same variables (e.g., time, location, temperature, CO_2 concentration) are represented in different ways, and that there are different choices about which data to represent from a larger data set.
2. Generalizability: Data about Earth systems are usually selected to be representative of patterns in systems, but the relationship between the patterns in the representation and the patterns in the Earth systems can be difficult and confusing. For example, the graphs of CO_2 concentrations show measurements taken in a single location—Moana Loa in Hawaii. How are patterns in these data connected to data from other places, such as Michigan or Antarctica? Other representations make other choices about time scale and geographic location, or show averages rather than data points from a single time and place.
3. Short-term variability: The data sets that student look at show two different patterns in short-term variability:
    a. Like Arctic sea ice data, the temperature and sea level data show random variation from one year to the next; there is no good way to predict whether these variables will go up or down in the next year, or how much. Most humans are very good at finding patterns, even when they don't really exist (this is why games of chance are so popular). So students need to recognize randomness

and understand how it limits our ability to make claims about short-term patterns or predictions of how these data will change in the next year.

   b. In contrast, the Moana Loa CO_2 data show a regular seasonal pattern. Students need to be able to recognize and analyze this pattern, and to expect that there *should* be an explanation for this pattern. (They will study the explanation for this seasonal cycle in Lesson 4.)

4. Long-term trends: The other Earth systems are like Arctic sea ice in that they show clear trends over longer periods of time (though in the opposite direction—as Arctic sea ice goes down, temperature, sea level, and CO_2 concentrations are all going up). Students need to use strategies they studied in Lesson 1 to identify these long term trends.

Explaining patterns in Earth systems data. Students need to recognize that random patterns in short-term variability are very difficult or impossible to explain, but that good explanations for long-term trends are often possible.

Some students will probably suggest that these variables are related, and that they are connected with "climate change" or "global warming." They need to recognize that this kind of explanation—recognizing relationships between variables—is useful, but doesn't go very far. Scientists look to understand *mechanisms:* Which variables are causing the trends, and which are effects? How do those cause-effect relationships work? We hope that Lesson 2 will end with these unanswered questions, to be addressed in later lessons.

Key Ideas and Practices for Each Activity (accordion)

In Activity 2.1, students are introduced to the first of five different large-scale data sets dealing with different phenomena in the Earth's system. The first data set deals with arctic sea ice extent. When scientists interpret any data set, there are certain pieces of information that are crucial for helping them make sense of the data. We focus on four of those in this activity: representation, generalizability, short-term variability, and long-term trends.

- The first is generalizability. One reason climate change is so difficult for the public to understand is that scientists use a combination of many global and local data sets to find patterns that are not always clear locally or on short time scales. Using other sources, they determine when and how local signals may or may not be reflective of a global trend.
- The second is representation. Scientists also need to examine what time period and data are being represented in the table, so they know if it is generalizable to other times and places or not.
- Third, scientists also need to distinguish between short-term variability and long-term trends. Short-term variability is predictable in some data sets (like atmospheric CO_2 concentrations rising each winter and falling each summer), and unpredictable and stochastic in other data sets (like arctic sea ice extent, which is subject to many factors in the earth's climate system).
- Finally, scientists also use long-term trends in data to understand what has happened in the past and to predict what might happen in the future. In this activity students are introduced to these four considerations. Students fill in the first row in the 2.1 Finding Patterns Tool together as a class.

In Activity 2.2, students begin a jigsaw activity to examine the other four large-scale data sets: sea level, global temperatures, historic atmospheric CO_2 concentrations, and annual patterns in atmospheric CO_2 concentration. The ideas introduced in this Jigsaw are extended through the rest of the Lesson. For more information about the Jigsaw discussion strategy, see https://www.jigsaw.org/. To begin, students form home groups and discuss the goals for the Lesson. Then, students form expert groups to examine a large-scale data set that represents a global phenomenon. They read about their expert group topic and work with their groups to discuss the “four considerations” covered in Activity 2.1 for their own phenomenon. They fill in their expert group’s corresponding row on the 2.1 Finding Patterns Tool. At this point in the Unit, the students may have a difficult time understanding why these considerations are valuable, and this activity aims to help establish why these considerations are important.

In Activity 2.3, students return to their home groups to share their expertise about their phenomena, using the four considerations as a frame for their presentation, and fill in the remaining rows in their Finding Patterns Tool. This provides yet another context for helping students work through the challenges of interpreting large-scale data sets. Why, for example, is a measurement of carbon dioxide concentrations in the atmosphere representative of a global pattern? How do scientists know that? Some of these questions will remain unanswered at the end of this activity, which is intentional. Students will revisit these questions later in the unit.

Finally, in Activity 2.4 students use the Finding Patterns Tool for Earth Systems to identify patterns across data sets and discuss what may be causing these patterns. At this point in the unit, students will have collected evidence of various global trends related to climate change. However, they may not have evidence that explains that the driving factor of all of these trends is the increase in carbon dioxide in the atmosphere due to human activity (primarily the combustion of fossil fuels). The unanswered questions in this tool set students up for learning that takes place in the following lessons, when the students delve deeper into the Keeling Curve and learn about the driving forces for all phenomena they studied in this lesson.

Activity 2.1: Home Groups: Four Considerations for Large Scale Data (45 min)

Tab 1: Overview and Preparation

Target Student Performance

Students in home groups express initial ideas about patterns and changes over time for four variables in Earth systems: global temperatures, global sea levels, Arctic sea ice, and atmospheric CO_2 concentrations.

Resources Provided

- 2.1 Considerations for Large Scale Data PPT
- Arctic Sea Ice Video: https://www.youtube.com/watch?v=c6jX9URzZWg
- 2.1 Finding Patterns Tool for Earth Systems
- 2.1 Assessing the Finding Patterns Tool for Earth Systems
- Jigsaw Cards

Setup

Print one copy of 2.1 Finding Patterns Tool for Earth Systems for every 4 students. Print one copy of Jigsaw Cards and cut out the cards. Use the instructions on the first page of the cards to determine which cards to use with your class size. Prepare a computer with an Internet connection and a projector to display the presentation and watch the Arctic Sea Ice video.

Tab 2: Directions (accordion for individual steps in directions)

1. Use the instructional model to show students where they are in the course of the unit.

- Show slide 2 of the 2.1 Considerations for Large Scale Data PPT.

2. Introduce students to the activity.

Explain to students the purpose of this lesson is to examine other phenomenon in addition to Arctic sea ice. In this lesson, they will look at our different data sets and try to understand them. To prepare for the lesson, they will work in "home" and "expert" groups. In this first activity, they will begin in "home" groups.

- Give each student a jigsaw card (see instructions on the first page of the cards for how to distribute cards). The worksheet for the CO_2 trend line (Group B) is the longest and most complex. Consider assigning cards labeled "B" to more advanced students when you pass out the jigsaw cards in this activity.
- Tell students to form groups with people who have a similar **picture** on their card. For example: airplanes find other airplanes, gas tanks find other gas tanks. *Note: see instructions on the first page of the cards for how to remove cards if your students do not divide evenly into groups of 4. Tell students who do not have a home group of 4 that they are "free agents" and have them choose a home group to join (each should choose a different home group).*
- Give each home group one copy of 2.1 Finding Patterns Tool for Earth Systems.
- Have students create a name for their group (optional) and write their group name (and group members' names) at the top of their worksheet.

3. Introduce the worksheet.

Tell students that in their home groups, they are going to practice analyzing the arctic sea ice data they worked on in the previous lesson. Show slide 3.

- Draw students' attention to the four columns on their worksheet. Tell them that during this activity they are going to consider four different features of the arctic sea ice data: representation, generalizability, short-term variability, and long-term trends.
- Show slide 4 of the PPT and overview these four considerations. Point out that these four considerations are also visible on their worksheet. The goal of the jigsaw activity is to consider each of these factors for different phenomena.
- Explain to students addressing the issues of representation, generalizability, short-term variability, and long-term trends are important for understanding large-scale phenomena such as the decline in Arctic Sea ice which takes place over large spatial and temporal scales.
- First, we will practice in our home groups with arctic sea ice before moving on to other phenomena.

4. Watch and discuss the Arctic sea ice video.

Begin by showing the video from NOAA that shows arctic sea ice extent from 1990-2016 (https://www.youtube.com/watch?v=c6jX9URzZWg). You may wish to pause the video and help students interpret what they are seeing. Students should notice the overall trend: the extent and age of Arctic Sea ice appears to decrease over the period of 1990-2016.

- Use slide 5 of the PPT to display the graph of the Artic Sea ice data and give students a minute to individually interpret it.
- Ask students to share their interpretation of the graph with their home groups, then have a few students share with the whole class to check for understanding.
- Students should recognize that the October average Artic Sea ice extent demonstrates a negative trend for the period 1979 – 2013.
- Show slide 6. Discuss as a class the answers to the questions about arctic sea ice. You may choose to show the short video on why arctic sea ice matters (https://youtu.be/MIMuPW4Lebg).

5. Have students complete the tool for Arctic Sea Ice in their home groups.

Instruct each group to complete the first row of their tool as a small group. Students may find it helpful to designate one person as the recorder.

- Explain to students they will use this table as a tool for making sense of five different phenomena: Artic sea ice extent, global temperature, sea level, atmospheric CO_2 concentration, and the atmospheric CO_2 annual cycle. The first row of the table will be filled out as a class to demonstrate the process
- Give students about 10 minutes to complete the row, circulating in the classroom and helping them with questions.
- Listen to the types of questions that come up in the groups and bring common questions to the class.

6. Help the class reach consensus.

Tell students that in scientific communities, an important practice is to discuss evidence and data to come to a shared understanding of what is happening. This is called "reaching consensus."

- Use slide 7 to record the class consensus (type on the slide) about the four considerations for the Arctic sea ice graph.

• Help students revise the ideas until consensus is reached for each box. • Use the example in the assessment section below to help guide students to the ideas represented in the example chart.
7. Discuss the consensus. Use slide 8 to prompt more discussion of the answers you reached during the consensus discussion. Use this as formative assessment to see if all of your students understand what is meant by “representation,” “generalizability,” “short-term variation” and “long-term trend.” • When we talk about “representation,” we want to know which data are represented, how they are represented, and over what time period. • When we talk about “generalizability,” we want to know if the data in one graph or data set are representative only of their local region, or if they are generalizable to other places on the planet, too. • When we talk about “short-term variation,” we want to look for how the data change in a short period of time. Note: a “short period of time” will change depending on the time period represented in the graph. In the arctic sea ice graph, “short-term” is year to year, and “long-term” is the entire span of the graph. This is different for different graphs. • When we talk about “long-term trend,” we want to know what overall change you see in the entire graph.

Tab 3: ***Assessment***

A key opportunity for formative assessment in this activity is during the consensus-building discussion about the arctic sea ice column. During this discussion, encourage the students to compare and contrast each other’s ideas, with the goal of finding an answer to each box that they all agree is supported by the evidence. Use this key as a guide:

Representation • What variables? • What time period?	**Generalizability** • Which regions are included? • What does this tell you about global patterns**?**	**Short-term variability** • What is the short-term variability in the data? • Is it predictable or unpredictable?	**Long-term trends** • What is the long-term trend? • Is it predictable or unpredictable?
The extent of Artic sea ice (millions of square kilometers) each October from 1979-2013 is represented on the graph.	This graph is specific to ice in the Arctic Ocean and may not be representative of patterns in ice in other bodies of water.	The extent of ice fluctuates up and down in an unpredictable way each year, but the overall trend is a decrease in sea ice extent over the period of 1979-2013.	The long-term trend shows that arctic sea ice has decreased. It is predictable.

Tips

- It is best not to move on to the next activity until students have a solid understanding of the "four considerations" presented in this activity.
- Tell students to keep their jigsaw cards for the next activity.
- Collect and keep students' 2.1 Finding Patterns Tool for Earth Systems in a place where they can be found easily again later. Use the 2.1 Assessing the Finding Patterns Tool for Earth Systems to assess their ideas at this stage in the unit.

Tab 4: Differentiation & Extending the Learning

Differentiation (Accordion)

- Strategic grouping with strong speakers
- Provide sentence stems for discussion and filling in the 2.1 Finding Patterns Tool for Earth Systems.
- Allow students to watch the video on individual devices, if available, to allow for personal interaction.

Modifications (Accordion)

Extending the Learning (Accordion)

Activity 2.2: Expert Groups: Analyzing Large Scale Data (45 min)

Tab 1: Overview and Preparation

Target Student Performance

Students in expert groups investigate multiple representations of the four variables in and the Earth systems that they measure, generating explanations and questions.

Resources You Provide

- Jigsaw Cards (already distributed during previous activity)

Resources Provided

- 2.2 Expert Group A Worksheet (1 per student in Group A)
- 2.2 Expert Group B Worksheet (1 per student in Group B)
- 2.2 Expert Group C Worksheet (1 per student in Group C)
- 2.2 Expert Group D Worksheet (1 per student in Group D)
- 2.2 Assessing the Expert A Worksheet (1 per class)
- 2.2 Assessing the Expert B Worksheet (1 per class)
- 2.2 Assessing the Expert C Worksheet (1 per class)
- 2.2 Assessing the Expert D Worksheet (1 per class)

Setup

Print one copy of the Expert Group Worksheets for each student in each expert group. For example, print one copy of 2.2 Expert Group A Worksheet for each student in Group A. Reserve or provide one computer with an Internet access for each expert group. You may choose to have duplicate groups (e.g., Expert Groups B_1 and B_2) and if so, you will need to prepare extra materials and a computer for each group.

Tab 2: Directions (accordion for individual steps in directions)

1. Have students recall their home groups.

Have students regroup in their home groups from the previous activity. Each student should have a jigsaw card with the same picture and different letters. Review briefly the difference between "generalizability," "representation," "short-term variability," and "long term trends" from the previous activity.

2. Have students find their expert groups.

Tell students to find members in the class who have the same **letter** on their jigsaw cards.

- For example, all students with A_1 on their card should form a group.
- Their expert groups should be no larger than 3 and no smaller than 2.

3. Set up the space for the activity.

Give each student a copy of the 2.2 Expert Group Worksheet for their assigned group. Make sure they have adequate collaborative workspace and access to the internet. Tell students that in their expert groups it will be their job to become "experts" on one phenomenon. It will be their job in the next activity to explain their phenomenon to their home group. Each group will be responsible for reading about their data (labeled in the reading by expert group letter), watching a video, looking at a graph, and answering questions about the four considerations for each: “generalizability,” “representation,” “short-term variability,” and “long term trends.”

- Note: Groups A and D require downloading a short (less than 2 minutes) video before watching. These videos are included in the curriculum materials if you’d like to provide the students with the videos ahead of time.

4. Have expert groups complete their tasks.

Give the expert groups 30-40 minutes to complete their expert group worksheets. Circulate during their work and check to see what questions arise. The main objective for the worksheet is to support students in addressing the four considerations for large-scale data: representation, generalizability, short-term variability, and long-term trends. Encourage students to discuss their ideas in their groups and to support their claims with evidence. Emphasize that the goal is not to complete the worksheet but rather to be able to explain their phenomena and the graph that represents it to other students.

- Emphasize that students in their expert groups may have questions that they are unable to answer simply from looking at the graph.
- Encourage students to reach consensus for each question, using evidence to support their ideas.

Tab 3: Assessment

Before leaving their expert groups, each individual should be able to address the four considerations for large-scale data for their particular phenomena and be ready to explain it to others. Use the 2.2 Assessing the Expert Group Worksheets to assess the student’s ideas. At this point, the students may have questions about the phenomenon in their groups, and at the end of the activity they will have had no formal support from you as a teacher in understanding these phenomena. We recommend looking over their worksheets to see how well they were able to navigate the data in their expert groups. You will also have a chance in the next activity to formatively assess their ideas when they share their expertise with their home groups.

Tab 4: Differentiation & Extending the Learning

Differentiation (Accordion)

- Have students write definitions of “generalizability,” “representation,” “short-term variability,” and “long term trends” and discuss as a class before moving on.
- Provide sentence stems to assist in completion of the group worksheets.

Modifications (Accordion)

See notes on the first page of the Jigsaw Cards for instructions about how to distribute cards to different group sizes.

Extending the Learning (Accordion)

Have students research any other forms of representations of data related to their phenomena. They might be surprised to discover how many different ways there are to represent the same data

Activity 2.3: Home Groups: Share Expertise (60 min)

Tab 1: *Overview and Preparation*

Target Student Performance

Students return to home groups and share their expertise about patterns of change for four variables in Earth systems: global temperatures, global sea levels, Arctic sea ice, and atmospheric CO_2 concentrations.

Resources You Provide

- 2.1 Finding Patterns Tool for Earth Systems (from previous activity)
- 2.1 Assessing the Finding Patterns Tool for Earth Systems

Resources Provided

- 2.3 Home Groups: Share Expertise PPT

Setup

Get out students' jigsaw cards and their previously completed 2.1 Finding Patterns Tool for Earth Systems.

Tab 2: *Directions* *(accordion for individual steps in directions)*

1. Use the instructional model to show students where they are in the course of the unit.

Show slide 2 of the 2.3 Home Groups: Share Expertise PPT.

2. Explain the purpose of the activity.

Tell the students that it is their job to discuss the four considerations (generalizability, representation, and short-term/long-term) for each of their phenomena with the rest of the group. You can review these concepts using slide 3. Have students retrieve their 2.1 Finding Patterns Tool for Earth Systems. At this point, only the first row should be completed (for Arctic sea ice). Give the students the following instructions:

- First, show slide 4, have experts from Group A will have 10 minutes to explain their phenomenon to the other members of the home group. It is the experts' job to lead a discussion about what they learned in their expert group.
- When Expert A is discussing the phenomenon, other members should ask questions if they don't understand something.
- After the discussion, the group should complete the row for Group A's phenomenon, *with the exception of the final column.*

Ask the students if they have any questions about what they should be doing.

3. Give "Experts A" 10 minutes to explain their phenomenon.

When Experts A are explaining, circulate around the room. Encourage group members to ask questions about what they don't understand. Use this time as formative assessment to determine what they still may be struggling with in terms of generalizability, representation, short-term variability and long-term trends.

- If you see students struggling with different ideas across groups, pause the discussions and see if you can resolve the issue as a whole group.

4. Repeat steps 2 and 3 for Experts B, C, and D using slides 5, 6, and 7, respectively.

5. Have students overview the "four considerations" for each expert group data.

Show slide 8. Tell students that as a group they should try to summarize the "generalizability" and "representation" and "short-term variability" and "long-term trends" for each phenomenon.

- Circulate the room to see which of the "four considerations" they may be having trouble with.
- Tell them to use their Arctic sea ice column on the first page as reference if they are struggling to complete the tool.
- Tell students to leave the far-right column blank. They will complete that in the next activity.

Tab 3: Assessment

Use your time circulating through the groups to determine what ideas may be more challenging for students. It may be that in some groups they are easily able to spot the long-term trends, but they have a harder time describing the short-term variability, for example. Use the 2.1 Grading the Finding Patterns Tool to assess how well they understand the four considerations for each phenomenon.

Tips

Identify which idea students struggle with the most in the home group discussions and pull these ideas out to discuss as a whole group. Encourage students to ask questions about things they don't understand in their home groups.

Tell students early that they will leave the far-right column blank during this activity.

Tab 4: Differentiation & Extending the Learning

Differentiation (Accordion)

- Complete the rows from the various group presentations together as a class after each group presentation.

Modifications (Accordion)

After the home groups have discussed the four considerations for A, B, C, and D, have them give a brief presentation to another home group and compare their tables in 2.1 Finding Patterns Tool for Earth Systems.

Extending the Learning (Accordion)

Have students share their expertise at home with family and friends.

Activity 2.4: Evidence-Based Arguments for Patterns in Earth Systems (30 min)

Tab 1: Overview and Preparation

Target Student Performance

Students compare patterns of change for the four Earth systems variables and record questions about what causes the patterns and how the patterns are related to one another.

Resources You Provide

- 2.1 Finding Patterns Tool for Earth Systems (completed from previous activity)
- 2.1 Assessing the Finding Patterns Tool for Earth Systems (from previous activity)

Resources Provided

- 2.4 Evidence-Based Arguments for Patterns in Earth Systems PPT

Recurring Resources

- Learning Tracking Tool for Human Energy Systems (1 per student)
- Assessing the Learning Tracking Tool for Human Energy Systems

Setup

Have students retrieve their completed versions of 2.1 Finding Patterns Tool for Earth Systems.

Tab 2: Directions (accordion for individual steps in directions)

1. Use the instructional model to show students where they are in the course of the unit.

Show slide 2 of the 2.4 Evidence-Based Arguments for Patterns in Earth Systems PPT.

2. Lead a whole class discussion of the four considerations.

Use the slides to have a discussion about the four phenomena and also the four considerations for each.

3. Begin with representation.

Show slide 3 of the PPT. Divide students into their home groups from the previous activity. Have them look at their completed versions of 2.1 Finding Patterns Tool for Earth Systems. Ask volunteers to explain the representation for each of the large-scale data sets. During the discussion, listen for their ideas. The class should come to consensus about the ideas for each graph and have a working definition of "representation" at this point. Listen to see if they can identify…

- **Keeling Curve (Atmospheric CO_2)**: CO_2 levels at Mauna Loa are represented. The red line represents daily/monthly (short term data) and the black line represents monthly averages. The time period is 1960-2015.
- **Sea Level:** Change in sea level in mm is represented on the graph. The black line represents the global change from the average for that time period. The graph shows data from 1993-2017.
- **Global Temperature**: Change in global temperature is represented on the graph in degrees Celsius from 1880-2010. Dots above the 0 indicate global temperatures higher than average for that time period. The black dots represent each year's average, and the red line shows a 5-year running mean.

- **Two-year Atmospheric CO_2**: Variables are time and atmospheric CO_2 concentrations. Time period is April 2013-March 2015.

4. Continue with generalizability.

Use slide 4 of the PPT to discuss generalizability with the students. During the discussion, listen for their ideas. The class should come to consensus about the ideas for each graph and have a working definition of "generalizability" at this point.

- **Keeling Curve (Atmospheric CO_2)**: These data are generalizable to the Northern hemisphere only (in the Southern hemisphere the short-term variability is the opposite, although there is a similar overall trend of increase).
- **Sea Level:** These data represent global averages, so they are not generalizable to local regions, which will vary.
- **Global Temperature**: These data represent global averages, so they are not generalizable to local regions, which will vary.
- **Two-year Atmospheric CO_2**: This represents atmospheric CO_2 concentration at Mauna Loa in Hawaii. Other locations in the Northern Hemisphere show similar patterns (but not exactly the same).

5. Continue with Short-term variability.

Use slide 5 of the PPT to discuss short-term variability in Arctic sea ice with the students. Note that changes from one year to the next are random and unpredictable.

Use slide 6 to discuss short-term variability for the other phenomena. During the discussion, listen for their ideas. The class should come to consensus about the ideas for each graph and have a working definition of "short-term variability" at this point.

- **Keeling Curve (Atmospheric CO_2)**: Short-term variability (for one year) shows a predictable pattern: CO_2 levels go up each winter and down each summer.
- **Sea Level:** Short term variability (from year to year) fluctuates in an unpredictable way. There is no clear pattern in the short-term.
- **Global Temperature**: Short term variability (from year to year) fluctuates in an unpredictable way. There is no clear pattern in the short-term.
- **Two-year Atmospheric CO_2**: Short term variability (from day to day) fluctuates in an unpredictable way. But there is a clear pattern in variability from month to month.

Help students notice that short-term variation follows a predictable pattern for atmospheric CO2 but not for sea level, global temperature, or Arctic sea ice.

6. Conclude with a discussion of long-term trend.

Use slides 7-8 of the PPT to discuss long-term trends with the students. During the discussion, listen for their ideas. The class should come to consensus about the ideas for each graph and have a working definition of "long-term trend" at this point.

- **Keeling Curve (Atmospheric CO_2)**: The long-term trend (black line of yearly averages) shows a positive trend.
- **Sea Level:** The long-term trend (there is no trend line on the graph) shows a positive trend.
- **Global Temperature**: The long-term trend (red line of running means) shows a positive trend.
- **Arctic Sea Ice**: The long-term trend (blue line) shows a negative trend.

Use slide 9 to help students identify that three of the phenomena have a positive trend (CO_2, sea level, and global temperatures) and one has a negative trend (arctic sea ice).

7. Discuss possible reasons for these trends.

Tell students that now they have identified these patterns in large-scale data sets, but they don't have evidence yet for WHY these trends are happening! Ask students if they have any ideas at this point, or if they have any questions.

8. Have students complete the tool and record their unanswered questions.

Have students complete the far-right column in their 2.1 Finding Patterns Tool for Earth Systems. They can complete these individually or as a group.

- Use slide 9 to record their ideas before moving on to the next lesson.
- Tell students that they will return to these questions later in the unit.
- Remind students that they do not yet have evidence to explain how these patterns are related or what causes them, but that this is what the remainder of the unit will help them figure out.

9. Have a discussion to introduce the Learning Tracking Tool for this activity.

Show Slide 10 of the 2.4 Evidence-Based Arguments for Patterns in Earth Systems PPT.

- Pass out a Learning Tracking Tool for Human Energy Systems to each student.
- Explain that students will add to the tool after activities to keep track of what they have figured out that will help them to answer the unit driving question.
- Discuss goals for this lesson.
- Have students write the activity name in the first column, "Questions for this Lesson."
- Have a class discussion about what students figured out during the activity that will help them in answering the lesson driving questions:
    - What causes the annual cycle: CO_2 concentrations in Hawaii to go down every summer and up every winter?
    - What causes the long-term trend: CO_2 concentrations to go up every year?
    - How can we predict what will happen to CO_2 concentrations in the future?
- When you come to consensus as a class, have students record the answer in the second column of the tool.
- Have a class discussion about what students are wondering now that will help them move towards answering the unit driving question. Have students record the questions in the third column of the tool.
- Have students keep their Learning Tracking Tool for future activities.
- Example Learning Tracking Tool

Activity	What We Figured Out	What We are Asking Now
2.4 Evidence-Based Arguments for Patterns in Earth Systems	*In the long run, global temperature, atmospheric CO_2, and sea level are all increasing.*	*How are changes in global temperatures, sea levels, Arctic sea ice and atmospheric CO_2 connected?*

Tab 3: Assessment

During the discussions, help students come to consensus about each phenomenon. Students may suggest connections between phenomena such as the fact that increasing global temperatures may contribute to decreased Arctic Sea ice and increased sea level. They may also suggest more specific connections such as the decrease in Arctic Sea caused the sea level rise (although this idea is incorrect because sea level rise is attributed to melting land ice, it is appropriate to let them express any ideas at this point or to direct them toward formulating this as a question to include). Use the 2.1 Assessing the Finding Patterns Tool for Earth Systems to assess students' completed tools.

Tips

Save slide 10 to return to at the end of the unit.

Tab 4: Differentiation & Extending the Learning

Differentiation (Accordion)

- Break students into strategic groups and have them discuss the questions independently before sharing with the whole class.
- Provide sentence stems for discussion.
- Compare the Evidence-Based Arguments PPT to the Predictions and Planning Tool. Have students verbalize similarities and differences in groups before sharing with the class.

Modifications (Accordion)

Extending the Learning (Accordion)

- Have students make predictions about how the results of the investigation would change if they used different phenomena.