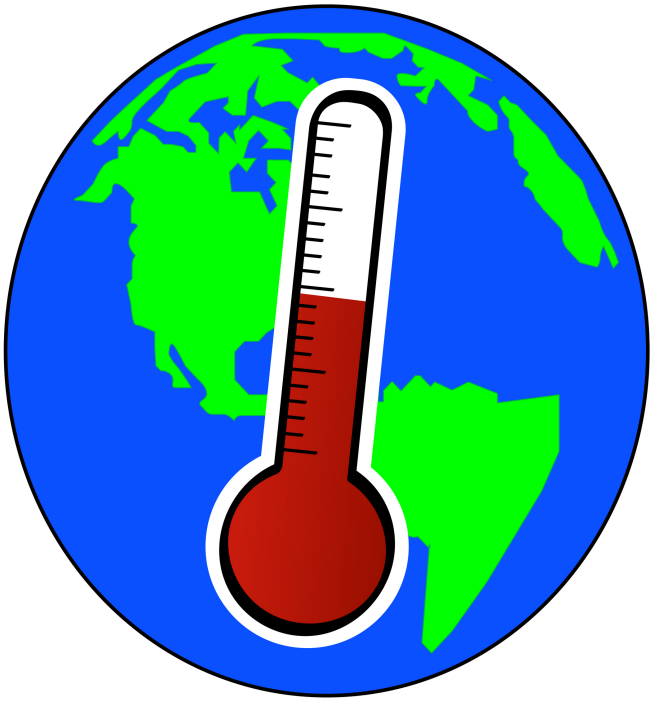
Science helped create and diagnose the planet's fever, and it is our only hope to slow its acceleration.
- Eric Roston, The Carbon Age

UNIT 2
EARTH FEVER



Unit 2 Guiding Question

How are humans driving present-day climate change?

A NOTE FROM THE HOT AUTHORS

The Hot: One World, One Climate curriculum and simulation is a collaborative effort among secondary teachers, educational experts and journalists with faculty and staff from the NASA Goddard Institute for Space Studies (GISS) and the Columbia University Earth Institute. This interdisciplinary team – known as The GISS Climate Education Advisory Group – has been able to draw on many perspectives and areas of expertise to advance a real world, problem-based approach for student learning around many climate change topics.

The curriculum is designed to reinforce academic knowledge and skills outlined in national education standards with an eye toward student inquiry and research-like experiences. While exploring the science and stories of climate change, our goal is for students to use scientific research to propose climate change solutions and literacy skills to share those solutions with the larger process.

Our development process has been an iterative. The Climate Change in the Classroom (CCIC) Teacher Workshop at NASA GISS/Columbia University on August 5 and 6, 2013 is a continuation of this process as we broaden the Hot collaboration to include the review, critique and recommendations of 30 more educators and scientists participating in the 2013 CCIC.

It is important to note that we are in the active stage of review and development of the Hot curriculum and simulation. Hence, the materials being field-tested at CCIC are not in their final form and require additional educational and scientific review. This is one of the major goals of the CCIC Teacher Workshop.

We hope that the Hot curriculum and simulation will prove to be a meaningful way for you and your students to engage in learning about Earth in the context of an important global issue – climate change. We also hope Hot is personally relevant students, and motivates a lifetime of interest and critical thinking about our planet and the special role humans have in the Earth system.

Carolyn Harris
Education Coordinator, Columbia University Earth Institute/NASA GISS and Founder, Real World Matters

Pushker Kharecha
Research Scientist, Columbia University Earth Institute/NASA GISS

Ryan Goble
Professional Development Leader Chicago Public Schools and Founder, Mindblue Productions

Acknowledgements

Members of the GISS Climate Education Advisory Group contributing to the ongoing review and development of Hot:

Brian Cairns, NASA GISS
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Ciara Foldenauer, a Georgetown University student, for editing and developing the Hot youth roles in the simulation and for serving as our summer intern.

The generous financial and in-kind support provided by NASA Climate Change Education Program, the Science Museum of Minnesota, Real World Matters, NASA Goddard Institute for Space Studies and the Center for Climate Systems Research at Columbia University.

Special thanks to Eric Roston, the author of "The Carbon Age," and to Gavin Schmidt and Josh Wolfe, the author-editors of "Climate Change: Picturing the Science," for the inspiration, knowledge and content their books provided to writing the Hot materials

UNIT 2 AT-A-GLANCE

Unit 2 of *Hot* allows students explore 150+ years of scientific work, an interdisciplinary body of knowledge that contributed to the discovery of global warming. Students will develop a qualitative and quantitative sense about how Earth's global mean temperature has changed over the Industrial Era and its relationship global carbon dioxide levels.

Summative Assessment

Write a short essay that addresses the analogy that Earth has a fever. Students' responses will accurately relate and explain at least two key climate science concepts (e.g., relationship between CO_2 and temperature, influence of Industrial Era on CO_2 concentrations, influence of the Greenhouse Effect on Earth's temperature, etc.) and utilize two or more lines of climate change evidence to support their ideas.

National Education Standards Addressed

Learning objectives for each lesson relate to national education standards found in the Common Core State Standards (CCSS) and Next Generation Science Standards (NGSS). Each lesson identifies the specific standards addressed.

Unit 2 Learning Progression

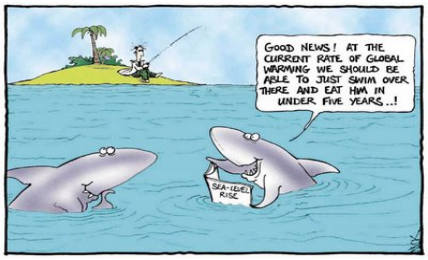
Following input received from the 2013 Climate Change in the Classroom Teacher workshop, we will prepare a learning progression for Unit II. In its final form, it will provide a short introduction and a lesson grid with brief summaries of student activities, learning objectives, standards addressed, and performance assessments.

Table of Contents

ENGAGE

Lesson 2.1 Pre-Exploration & Assessment

TIME: 60 minutes or 1 class period + homework



Credit: Creative Commons

"Climate sets the range of conditions in which humans can thrive…the problem with the change humans are inducing now, over the past hundred years or so, is that the rate, the magnitude and the spatial extent of the changes are unprecedented."

- Pushker Kharecha, Columbia University Earth Institute/GISS

overview

Students are introduced to the idea that human activities are influencing Earth's climate through short videos from noted climate scientists and the news.

objectives

The student will be able to…

- explain their current understandings about the ways humans can influence climate
- identify questions about what they would like to learn

prerequisite

None

subjects

Earth & Environmental Science, Language Arts, Social Studies

standards

NGES ESS3.D Global Climate Change

Human activities affect global warming

CCSS ELA Literacy

Present information and findings (SL.4)

Determine the central idea from text and media (RI.2)

key vocabulary

Spatial extent: the area over which something occurs.
Magnitude: the size or extent of something.
Direct and indirect scientific evidence: direct evidence comes from observation of phenomena while indirect evidence are inferences made based on available scientific information.

resources / materials

- Computers with Internet access
- LCD Projector with ability to stream video
- *Hot* video lecture 1 "The role of humans in the climate change story – Part 1" (3:46 minutes) http://realworldmatters.org/node/24
- CNN video "Climate skeptic says global warming is real" (2:19 minutes) http://goo.gl/sdJlD

differentiation guide

This lesson differentiates content, process, product based on student readiness, interests and learning profile. To be completed Full Articulation TBD

unit's student skill badges to earn

Academic knowledge / Social Emotional / Workforce and Global Citizenship / e.g., MacArthur "Open Badges" Full Articulation TBD

background

There is a big climate change experiment underway that started more than 150 years ago. And, it is happening all over the planet. We – humans are in the midst of testing how much more greenhouse gases, like carbon dioxide, we can add to the atmosphere and how much additional heat our planet can sustain without compromising life on the planet.

In Unit 2, students examine the question, "How are humans driving present-day climate change?" This pre-assessment lesson is designed to assess what students already think and know about the answer to this question. It also builds basic knowledge about how scientists discovered the role humans are having on the climate and what they are learning.

suggested procedure

1. Give students the CLIMATE CHANGE PRE-ASSESSMENT on the student pages (over time we might host this as a Google doc/form that we can share with teachers and use to collect data). Remind them that their responses to this assessment are not graded and will be used to see what they learn over the course of the unit. Briefly discuss students' answers in a large group.

2. As a class, watch the Hot video: Lecture 1 "The role of humans in the climate change story – Part 1" (3:46 minutes) from Columbia University climate scientist, Dr. Pushker Kharecha.

3. Have the students write responses to the following 2 questions concerning this video: What is something new you learned? What are things you heard that reveal how a scientist thinks about the world? Ask students to share out in pairs or to the whole group.

4. Show the class the CNN News clip, "Climate skeptic says global warming is real." (2:19 minutes).

5. Have the students write responses to the same questions from task 3 for this video. Ask students to share out in pairs or to the whole group.

wrap-up and discussion

This is where students can reflect on and write a response to the following questions that they will present to the class: What are some of the themes in the videos you reviewed? What do you think are main ways humans are influencing climate? Are there solutions or actions presented? If so, what are some examples? As a class students discuss their response.

Pre-assessment

Student response to the discussion prompts for the videos and class discussion.

Instructions: These four questions are designed to assess your knowledge about climate change BEFORE you explore the *Hot* curriculum. Your answers **will not** be graded. However, your responses to the questions will be collected to compare with your answer to the same questions at the end of Unit.

1. How are humans influencing the climate?

2. What is the natural Greenhouse Effect?

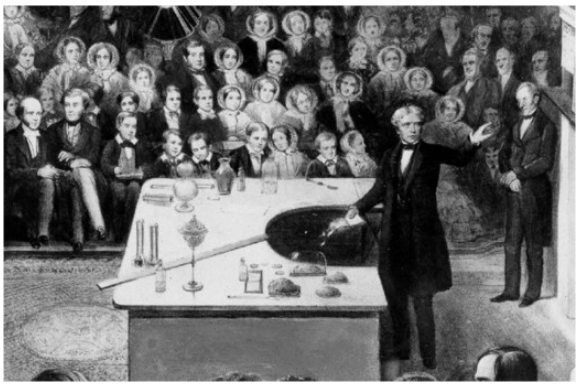
3. What do you think is meant by human enhanced Greenhouse Effect?

4. What are some important factors in explaining the relationship between atmospheric carbon dioxide and Earth's global temperature?

EXPLORE

2.2 Lighting Up the Earth

TIME: 90 minutes or 2 class periods + homework



Michael Faraday Lecture, Photo Credit: Wikimedia Commons, http://goo.gl/vjCYF

"… we have known that some gases in the atmosphere act metaphorically like blankets, making it harder for the heat at Earth's surface to escape directly to space…The industrial era, which began in the eighteenth century (say around 1750), is marked by clear signs of human activity changing the composition of the atmosphere."

- Climate Change: Picturing the Science

overview

Replicate Faraday's candle experiments to develop scientific observation skills, explain carbon, oxygen and hydrogen reactions and to connect human activities to atmospheric CO_2

objectives

The student will be able to…

- make observations to explain natural phenomena
- describe changes in matter (solid/fuel to a gas, combustion, oxidation)
- present conceptual scientific arguments about the influence of the Industrial Era on concentrations of atmospheric CO_2 and climate

prerequisite

None

key vocabulary

Combustion: the burning of something
Concentrations: the amount of a substance per a defined area, usually expressed in units of mass or volume
Metaphorically: a figure of speech to which a term or phrase is applied to something that is not literally related in order to suggest similarities
Oxidation: chemical reaction usually involving the addition of oxygen to a substance
Phenomena: an observable fact or event that is subject to scientific description

subjects

English Language Arts, Physical and Earth Science

standards

NGES

ESS3.C Human impacts on Earth systems

Human activities have altered the biosphere

PS1.B Chemical Reactions

Reacting substances rearrange to form different molecules

CCSS *ELA-Literacy*

Critically read informational text and use diverse media (RI.1-3, 7)

Write to support claims and examine a topic (W.1-2)

resources / materials

Computer and LCD that streams video
4-5 Candles and matches
Clock or two stop watches
Water, small bowl and two small drinking glasses
Poster paper and markers
Faraday's Candle, trailer (1:12 minutes), http://youtu.be/u4jqZKe7sq4
Copies of the Candle Experiments: Questions & Observations
"What is a Flame" (7:31 Minutes), http://goo.gl/qQfDf
"Christmas With Faraday: The Chemical History of a Candle," *Scientific American* reading, http://goo.gl/U9bOC
"Turning Points in History: The Industrial Revolution," http://youtu.be/3Efq-aNBkvc

background

In 1860, Michael Faraday, a British scientist lit a few candles and captivated an audience of children and adults with his now famous Christmas-time lectures on the phenomena we can observe and explain just from burning candles. These talks were published in a book called "*The Chemical History of a Candle*." By lighting a candle Faraday encouraged us to look closely and scientifically at the world around us in order to appreciate all the interconnected processes at work.

Faraday's lectures were not about climate or climate change. That said, the reactions between carbon, oxygen and hydrogen atoms observed when lighting a candle and the resulting plume of black smoke, was an early notion about the effect of human emissions of atmospheric carbon from burning fossil fuels (coal, gas and oil) for energy.

Faraday's career took off during a period known as the Industrial Revolution. This was the time when humans began "lighting up the world" by burning fossil fuels to power our lives. At the time, England's black smoke-filled air from coal-fired industry, polluting the air and causing numerous health problems. It was not long before scientists hypothesized about other effects of carbon emissions on Earth's temperature. This period set humanity on our present-day course toward doubling atmospheric concentrations of the greenhouse warming gas, CO_2.

In this lesson students use Michael Faraday's candle experiments to make observations and reflections about the phenomena happening. This is springboard to relate how everyday human acts like burning a candle or even breathing, add carbon emissions into the atmosphere. In the process, they realize that Faraday's candle experiments are part of the body of scientific knowledge about Earth's climate that has been developing for over past 150 years.

suggested procedure

Faraday's Candle

1. Show students the video trailer for the British play "Faraday's Candle" (1:12 minutes).

2. Tell students they are going to replicate some of Faraday's candle experiments. Ask them to reflect on the video and what Faraday meant by a candle is "an open door to the study of natural phenomena."

3. Other questions might include: Are there science ideas from the video to consider when we repeat the experiments in class? Students may suggest: making careful observations, asking questions, looking for cause and effect or making connections from the phenomena to the world around.

candle experiment 1 – candle burns twice[1]

4. Before the experiment, discuss with students what they think are some important skills needed to make good scientific observations to explain phenomena. Some of the things to come out of the discussion: careful and as accurate as possible collection of data, effective measurement tools and methods, understanding the variables being observed and the experimental design.

5. Explain to students that they will be watching the candle burn twice. During these demonstrations students should record as many careful and insightful questions and observations as they can on the CANDLE EXPERIMENT: QUESTIONS & OBSERVATIONS student page. When everyone is ready, light a candle and let it burn for 2 minutes. Blow out the candle and watch the smoke coming up. Have a lit match ready to place near the smoke plume – it should re-ignite.

6. Ask students to share their questions and observations.

candle experiment 2 – where did the water go?

7. In this next experiment students also record questions and observations. Assign two students to be timers for

[1] These experiments are adapted from *Chemical Principles: The Candle Experiments*, http://goo.gl/Uv7wk

the experiment using either a classroom clock or stop watches. Place a candle in a small bowl, partially filled with water. Light the candle and place a glass over it. Have the student timers begin timing as soon as the glass covers the candle.

8. Students observe and record how long it takes for the flame to go out. What happened to the water? This experiment can also be repeated with a larger glass to compare results.

9. Students complete concluding questions 1-3 on Candle Experiments: Questions & Observations.

10. Discuss the student observations.

turning Point – the Industrial Revolution

11. Have students watch the video "Turning Points in History: The Industrial Revolution" (3:30 minutes). The film builds background knowledge for the final assessment essay.

wrap-up and discussion

Discuss connections between Faraday's experiments, the Faraday quote below, the quote at the beginning of the lesson, and the theme of the Industrial Era in today's climate story.

> "You will be astonished when I tell you what this curious play of carbon amounts to. A candle must burn some four, five, six or seven hours. What, then, must be the daily amount of carbon going up in the air in the way of carbonic acid! What a quantity of carbon must go from each of us in respiration! What a wonderful change in carbon must take place under these circumstances of combustion and respiration…. The horse in twenty-four hours burns seventy-nine ounces of charcoal, or carbon, in his organs of respiration to supply his natural warmth…by the conversation of carbon, not in free state, but in a state of combination…And what an extraordinary notion this gives us of the alterations going on in our atmosphere. As much as 5,000,000 pounds, or 548 tons of carbonic acid is formed by respiration in London alone in twenty-four hours. And where does all this go? Up in the air."[2]

EXTENSION: Students read *Christmas With Faraday* and watch *What is a Flame* (7:31 minutes), the winning video of a contest sponsored by actor Alan Alda. Students' explain what they are learning about the reactions between carbon, oxygen and hydrogen atoms and how this relates to Earth's climate. They can write a short description explaining the process. They may choose processes such as combustion, oxidation, some gases ability to absorb heat, etc. For extra credit, students can represent the process in a mathematical equation.

assessment

Students develop what they believe are six important questions about the Faraday's candle experiment and one of the videos they viewed. These questions are each written on one note card along with the student name at the top. Pair students up with one another to interview each other with the questions they developed. The person being interviewed should first answer the question orally and then write the response on the back of the note card, along with his or her name.

feedback

The authors of Hot value your thoughts and feedback on this curriculum. Please feel free to send us any suggestions or share anything your students found particularly interesting or engaging.

Comments can be sent to cah40@columbia.edu

[2] Excerpt from Faraday's lectures found in Eric Roston's The Carbon Age, page 167.

STUDENT PAGE LESSON 2.2 Lighting Up the Earth

Candle Experiments: Questions & Observations

Name: _____

Date: _____

DIRECTIONS

1. In the first table, record as many questions and observations as possible about Candle Experiment #1.
2. Follow the same process to complete the table for Candle Experiment #2. Try to quantify some of your observations.
3. Complete the first 3 concluding questions.

Experiment 1

QUESTIONS as many as possible	**OBSERVATIONS** as many as possible

Experiment 2

QUESTIONS as many as possible	**OBSERVATIONS** as many as possible

Concluding Questions

1. Describe and explain what you think is happening and changing for one of your observations in Experiment 1.

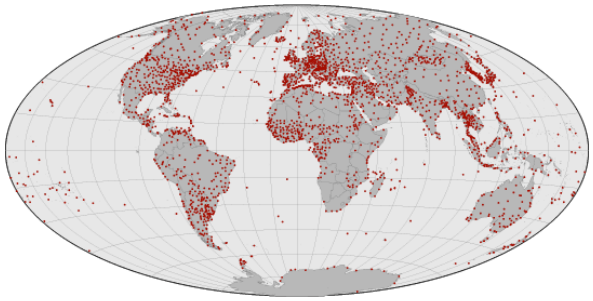
2. Describe and explain what you think is happening and changing for one of your observations in Experiment 2.

3. List at least 3 cause and effect relationships represented in the experiments.

OBSERVE AND ANALYZE

2.3 Global Temperature Record

TIME: 90 minutes or 2 class periods + homework



Global Weather Stations, Credit NASA Earth Observatory and National Climate Data Center, http://goo.gl/AfDw7

"Since 1850 or so, a sufficiently large number of stations have covered about 80 percent of the globe, making reliable estimates of global surface temperature of the Earth possible…This modern instrumental trend is now well accepted by scientists because the record is long enough and the warming is so large that its reality is clear."

- Climate Change: Picturing the Science

overview

Explore the analogy that Earth has a fever by analyzing global mean surface temperature data for trends from 1880 to the present.

objectives

The student will be able to…

- plot historical temperature data trends
- analyze global temperature by computing averages, trend line, rate, and slope
- discuss the present-day and future implications of global temperature trends with reasoned arguments supported by evidence
- critique the analogy that Earth has a fever

Prerequisite

None

key vocabulary

Anomaly: a comparison between similar features of two different things, e.g., heart and pump.
Systematic: according to a regular plan or method.

subjects

English Language Arts, Earth Science, and Mathematics

standards

NGES ESS2.D Weather and Climate

Historical weather patterns can be studied

CCSS Math

Graph and describe proportional relationships (EE.B.5)

CCSS ELA-Literacy

Write up arguments to support claims (W.1)

resources / materials

Computers for students with Internet access

Hot: Lecture 1 "The Big Climate Change Experiment," (5:53 minutes), http://realworldmatters.org/node/24

Climate in a Nutshell: Sick Planet (2:13 minutes) http://youtu.be/v006xb5nVtM

"GISS Global Temperature" Excel file, 1880-2012 (available at http://realworldmatters.org/node/24)

Copies, Global Temperature Analysis

Copies, Lines of Evidence-Global Temperature

"Global Temperature Anomaly Animation," http://goo.gl/2UY7a

background

Sometimes, scientists and others explain what's happening to Earth's global temperature by using the analogy that Earth has a fever – its global temperature is higher than normal. This medical analogy is useful to describe what's happening to modern day climate. Our climate situation has symptoms that scientists observe around the world. Each "symptom" is a line of evidence that indicates something is wrong. These include melting mountain glaciers, increasing frequency of hotter than normal seasons, migration of species from their usual habitat, and—in extreme cases—loss of species. Climate scientists, or climatologists, also diagnose the causes for symptoms based on years of research. In many cases, climatologists find that various human activities (like burning fossil fuels or deforestation) are forcing changes across the Earth systems – on land, in the oceans, and in the atmosphere.

To explore how scientists came to this diagnosis, students first need to know what is the normal or average global temperature for the planet. What is the average temperature for a particular season in a particular place? Scientists at NASA Goddard Institute for Space Studies (GISS) developed the Global Surface Temperature data set to study changes in temperature over the Industrial era, 1880-Present. This is an important period to study for several reasons. First, this is the start of systematic measurements of global temperature based on data collected from weather stations around the world. Second, this time span covers a period when humans started emitting large amounts of greenhouse warming gases, like CO_2, mainly from fossil fuel burning. The more of these gases we send up into the air, the more we increase the concentration of these gases and change the composition of Earth's atmosphere. It is also when Earth's population began to explode.

How do we decide if a change in global temperature or other climate factors (like precipitation, winds, humidity etc.) are just a normal fluctuation or indications of a significant change in our climate? Dr. Anthony DelGenio, a climatologist at NASA GISS, says scientists think a change is significant when they observe: "a change or difference relative to the norm that is large enough so that it's probably not just a random deviation from the norm."

To identify global temperature changes in this lesson, students are going to calculate the average temperature for a base period of over 30 years. Using this data, it is possible to analyze how temperature is changing compared to this average, from one decade to another. By analyzing global temperature trends, students can answer several questions to inform their thinking about global climate change and the debates that often surround discussions about taking action to mitigate it. Questions that students will examine include: Is there a way to change "diagnosis" and "prognosis" given by climatologists for the situation?

suggested procedure

Climate Analogy – Earth Fever

1. Watch the videos *Hot*: Lecture 1 "The Big Climate Change Experiment" (5:53 minutes) and "Climate in a Nutshell: Sick Planet" (2:13 minutes). Students review the videos. Suggested questions to put up in front of the class and have students write responses to as they watch: What are main scientific points? How is scientific evidence and knowledge used? Do they raise questions? What more do you want to know? Alternately, students can be divided in two groups, each responsible for reviewing one of the videos and then sharing what they learned with one another. The videos provide background and act as a transition to the lesson's main activities to analyze global temperature data.
2. Tell students that sometimes people discussing what's happening to Earth's climate use the analogy that Earth has a fever. Review the definition of an analogy and why the fever analogy may or may not help illuminate the topic of climate for the public.
3. Ask students to identify climate conditions that scientists might observe to monitor climate change. They may suggest winds, precipitation, sea level, glacier and ice cover, ocean temperature, composition of air, plant and animal life found in an area, etc.

observing and analyzing global temperature

4. Individually, and in small groups, students are going to study historical global temperature records for the period 1880 to 2012. Their goal is to determine if changes in global temperature should be considered a line of evidence for global climate change.
5. Plot and Analyze Global Temperature Data
   a) Students will use the NASA GISS Global Annual Land-Ocean Temperature Anomalies (1880-2012) to calculate global averages and temperature trends for various multi-decadal periods in order to understand changes over the Industrial Era. The temperature data is provided in an Excel file that can be downloaded at http://realworldmatters.org/node/24. Instructions for the computations are on the GLOBAL TEMPERATURE ANALYSIS student page.
   b) Students are going to perform the following analysis:
   Step 1: Calculate the average temperature and trend (slope)
   Step 2: Plot global temperature versus time and
   Step 3: Plot the trend lines.

evaluating lines of evidence

6. Students complete LINES OF EVIDENCE-GLOBAL TEMPERATURE on the student pages to further analyze their results and evaluate whether global temperature change should be considered a line of evidence for climate change. On the page they write up the analysis, describing the data, methods and results and a providing a brief discussion of what they find to be the most important results and why.

wrap-up and discussion

7. Discuss why or why not changes observed in Earth's global average temperature should be considered a line of evidence for climate change. Students support their claims with results from their research and address the question - Is the change observed significant?

8. Ask students if there is additional information they need to determine the answer to this question. Some teachers might want to explain that there is additional analysis that can be conducted to find the statistical significance of change by calculating the standard deviation.

EXTENSION: Dig deeper by analyzing a global temperature time-series (1880-2012) animation prepared by GISS scientists that can by downloaded and viewed at the GISS web page, http://goo.gl/2UY7a. Students answer several questions including (but not limited to):

- If you stop the animation during the period when you were born, can you estimate the temperature anomaly?
- Which regions of the globe are most anomalous? Is the temperature in these regions cooler or warmer?
- By viewing the data in this format, what different and additional perspective do you gain for your analysis of global temperature?

assessment

Completed student pages – Global Climate Data Analysis and Lines of Evidence – Global Temperature

feedback

The authors of *Hot* value your thoughts and feedback on this curriculum. Please feel free to send us any suggestions or share anything your students found particularly interesting or engaging.

Comments can be sent to cah40@columbia.edu

STUDENT PAGE LESSON 2.2 GLOBAL TEMPERATURE RECORD **Global Climate Data Analysis**	Name: _____ Date: _____

Description of the data

*The Excel Data File – GISS Global Temperature can be downloaded at http://realworldmatters.org/node/24

The data contained on your Excel spreadsheet is provided by NASA Goddard Institute for Space Studies and consists of Global Annual Land-Ocean Temperature Anomalies for the period 1880-2012. Climate scientists use temperature anomalies to represent a deviation from typical or normal temperature conditions for a particular period in time. For example, in this GISS dataset, temperature anomaly values represent deviations (differences) from the global average temperature for the 30-year period, 1951-1980. This baseline period was chosen because it represents a time of relatively stable global temperatures, for scientists to compare with other periods for possible changes.

Instructions for data analysis

Using the NASA-GISS global annual land-ocean temperature anomalies for 1880-2012, calculate the global average temperature averages and trends for different multi-decadal periods:

1880-1920 1921-1950 1951-1980 1981-2012

Step 1: calculate average temperature and trend (slope)[3]

a. Download the Excel file for the global annual land-ocean temperature anomalies from http://realworldmatters.org/node/24.

b. In the Excel file, calculate the averages using the function "average". Here is an example you can use to calculate the average for each time period. Suppose we were looking at the period 1900-1950. The temperature data for this time period is in column 2, cells b23 to b73. So to take the average, pick an empty cell and type =average(b23:b73).

c. To calculate the trends (slopes) use the function "linest". This function calculates statistics for the line on a graph, like rate, slope, and regression. Using the same example for the period 1900-1950, again pick an empty cell and type =linest(b23:b73). Think about how the slopes compare over the different time periods. Is there a recognizable trend?

Step 2: plot global temperature versus time

a. To plot the temperatures in all four time periods as a function of time (year) select both the appropriate years in column 1 and the temperature data in column 2.

b. Next, (depending on which version of Excel you have) select Insert→Chart. Make sure you use the XY scatter option. Think about the scale or magnitude of the change.

Step 3: plot temperature trendlines

a. On the graphs just created, plot the trend lines for the temperature data. To do this, right-click on each line, then select "Add Trendline". The default type should be "linear". That is the correct to use because it will insert a trendline to your graph. These instructions may vary depending on the version Excel.

b. Next, under the Option tab, check "Display equation on chart." In that equation, the slope of the line is the number multiplying "x." For each time period, this number should match the number you calculate using linest in step 1.

[3] In its final form, this page will have screenshots that will make it easier and more visual to follow instructions.

STUDENT PAGE LESSON 2.3 GLOBAL TEMPERATURE RECORD **Lines of Evidence – Global Temperature**	Name: _____ Date: _____

1. METHODS

Describe your data:
Explain how you analyzed the data (tools, calculations, visualizations)?
What are the independent and dependent variables? How do you know?

2: RESULTS

Explain your results. What has happened to Earth's global mean temperature since the 1880? How do you know?
How do temperature averages for the different multi-decadal periods compare? How do you know?
When you compare the slopes/trend lines, what was the rate of change? How do you know?

3: DISCUSSION

Explain your most important results. What they tell us about global temperature change? How do you know?

What do these results imply about future climate? How do you know?

EXTRA CREDIT #1: Where does all the additional heat go? How do you know?

EXTRA CREDIT #2: What specific human activities contribute to warming? How do you know?

MODEL AND EXPLAIN

2.4 CLIMATE CHANGE SCIENCE 101
-the Greenhouse Effect

TIME: 90 minutes or 1.5 class periods + homework

Skyline on NYC's Upper Westside, *Photo Credit:* GISS Institute on Climate and Planets

"Climatologists, [scientists] who study the causes of climate change, have looked into many natural causes, some more plausible than others, put forth to explain the current warming…The one plausible cause that has stood up to all tests based on direct observations is the increase in certain gases in the atmosphere in response to human industrial emissions."

- Climate Change: Picturing the Science

overview

Students use diagram models to explain their understandings of natural and human enhanced Greenhouse Effect.

subjects

Earth and Environmental Science, English, and Math

objectives

The student will be able to…

- Relate causes and impacts of climate change to evidence
- Develop understandings about how the natural Greenhouse Effect works using diagrams and models
- Compare and contrast the natural vs. human-enhanced Greenhouse Effect in descriptions and diagrams to explain processes and factors

standards

NGES ESS3.D Global Climate Change.
Human activities affect global warming; complex interactions influence climate

NGES ESS2.D Weather and Climate
The role of radiation and interactions with land, air and water are foundation of climate

CCSS ELA Literacy
Analyze ideas/claims from text (RI.5)

Engage in collaborative discussions and claims and findings (SL.1-3, 4)

Prerequisite

None

key vocabulary

Climate system: Physical, biological and chemical processes on land, air and water that interact to produce a region's climate.
Combustion: The burning of something.
Industrial Era: A period from the18th Century to the present of major technological advancement transforming the world from agrarian to a commercial and manufacturing-based society. Many advancements during this era relied on coal and other fossil fuels.
Infrared Radiation: Solar energy heats up the land surface and some of the heat is re-emitted into the atmosphere as longwave radiation in the form of infrared rays (these are what make sunlight or a light bulb feel warm).
Model: A quantitative description or qualitative analogy or diagram to represent a process; a computer model is a numerical simulation of processes.
Oxidation: chemical reaction usually involving the addition of oxygen to a substance.
Shortwave Radiation: Solar energy enters our atmosphere as shortwave radiation mostly as ultraviolet (UV) rays (the kind that gives you a sunburn) and visible light.

resources / materials

Computer with LCD that streams video

Planet Nutshell Video: "Evidence of a Warming Planet" (2:40 minutes) at http://goo.gl/dhQ93

NASA website: "Vital Signs of the Planet Vital Signs" at http://goo.gl/LyyeO

Planet Nutshell Video: "Too Much Carbon Dioxide" (2:45 minutes) at http://goo.gl/sBKvw

"Steroids, Baseball and Climate Change" video: (2:04 minutes) at http://goo.gl/QgSlj

differentiation guide

This lesson differentiates content, process, product based on student readiness, interests and learning profile. To be completed…

background

Greenhouse gases, like carbon dioxide (CO_2), that exist naturally in Earth's atmosphere are important players in the story of how Earth evolved a habitable average global temperature and climate. It turns out that the element, carbon, found in carbon dioxide, has a much more complicated role influencing life on the planet.

On the one hand, carbon is a building block of life - found in every living thing. It is a natural resource we most depend on for energy that has fueled the development of civilization. On the other hand, when we burn carbon in the form of fossil fuels (coal, oil and gas) for energy it combusts and oxidizes, transforming into the greenhouse gas, CO_2. We have been emitting and adding more CO_2 and other greenhouse gases to the atmosphere over the entire Industrial era. This is the main cause of global warming. Here's why.

Our atmosphere and surface absorbs most of the solar energy that reaches Earth, thereby heating up our planet. As CO_2 and other atmospheric gases build up in the atmosphere, they block some of the Earth's heat from escaping to space. Without the help of humans, this process happens as the Greenhouse Effect. It is one of the most important reasons why we have a habitable planet. This process happens because CO_2 and other gases exist naturally in our atmosphere. They absorb some of the Sun's heat and radiate it back to space. Some heat absorbed by greenhouse gases stays in Earth's atmosphere and is radiated back toward the surface. Some of the Earth's heat travels directly out to space. All these processes are at work to help balance Earth's incoming energy (in the form of shortwave radiation from the Sun) and outgoing energy (in the form of infrared radiation from the surface and atmosphere).

Over the past century, humans have been rapidly increasing Earth's levels greenhouse gases, especially CO_2, though activities like burning fossil fuels and deforestation that emit these gases. As humans add CO_2 and other greenhouse gases to the atmosphere, they build up. This changes the concentration of atmospheric greenhouse gases, blocking an increasing amount of heat from leaving the planet and enhancing the natural Greenhouse Effect. This has caused the entire planet to warm about 1.5° F over the Industrial era.

suggested procedure

gathering evidence

1. To start class, ask students the question "How do you think scientists know humans are changing Earth's climate?"

2. After a brief opening discussion, view as a class or in student pairs on a computer the video: "Evidence of a Warming Planet" (2:40 minutes)

3. After viewing the video, students use the graphic organizer WHAT WE KNOW AND HOW WE KNOW on the student pages to enter the information from their brainstorm session and any additional thoughts gleaned from all prior learning and the video. It may be helpful to review the difference between climate change causes (factors altering climate conditions, like activities that cause Earth to warm) from climate change impacts (things that are happening or may happen as a result of changing conditions, like sea level rise).

4. Have a sample group of students share out their responses. Encourage students to collect peer responses on their sheets.

5. Build on this work by having students use information on the NASA web pages *Global Climate Change: Vital Signs of the Planet*, either on computer or in print form, to complete the WHAT WE KNOW AND HOW WE KNOW.

6. Have a sample student group share out their responses. Encourage students to collect peer views on their sheets.

diagram

7. Present the Global Greenhouse diagram on the teacher page to the class. Working individually, students summarize the information on the diagram in 3-4 sentences. They also provide their thoughts on the questions: What would Earth be like without the Greenhouse Effect? What are some human activities that may influence the Greenhouse Effect? Have students share out some of their responses.

8. View as a class or in student pairs on a computer the video: "Too Much Carbon Dioxide." Tell students that they should pause the video to take notes and make sure they understand the information being presented. The main

purpose of watching the video is for students to begin to conceptualize the concepts of the natural Greenhouse Effect and "enhanced" Greenhouse Effect that is caused by the additional greenhouse gases building up in our atmosphere.

9. After watching the video, students work in pairs to complete the Natural Greenhouse Effect vs Enhanced Greenhouse Effect graphic organizer on the student pages. Let students know that they should be thinking of ways to diagram what they are learning about the natural Greenhouse Effect and how humans are enhancing the Greenhouse Effect. This exercise is a way to help students develop a mental or diagram model for thinking about these concepts. Also, since video does not reference the phrase "enhanced Greenhouse Effect" it may help students to introduce this phrase prior to working on this activity.

wrap-up and discussion

10. Have a sample of student pairs present their work comparing the natural and enhanced Greenhouse Effect. Students identify some of the causes of the enhanced Greenhouse Effect, as well as hypothesize about some of the possible impacts.

11. Present to students the table "Sources of Greenhouse Gases" on the teacher pages. The table shows the percent contribution of various human emissions of greenhouse gases to the Greenhouse Effect and the sources. Ask students to make an informed guess about which sources are likely to increase in the coming years and why they think this may be the case.

EXTENSION: Continue the discussion about the how humans are enhancing the natural Greenhouse Effect. Show students the video *Steroids, Baseball and Climate Change*. Discuss the analogy and the role statistics plays in understanding climate change and interpreting the connection between extreme weather events and climate change.

assessment

WHAT WE KNOW AND HOW WE KNOW graphic organizer
NATURAL GREENHOUSE EFFECT VS ENHANCED GREENHOUSE EFFECT graphic organizer

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feedback

The authors of *Hot* value your thoughts and feedback on this curriculum. Please feel free to send us any suggestions or share anything your students found particularly interesting or engaging.

Comments can be sent to cah40@columbia.edu

STUDENT PAGE LESSON 2.4 CLIMATE CHANGE SCIENCE 101 **WHAT WE KNOW AND HOW GRAPHIC ORGANIZER**	Name: _____ Date: _____

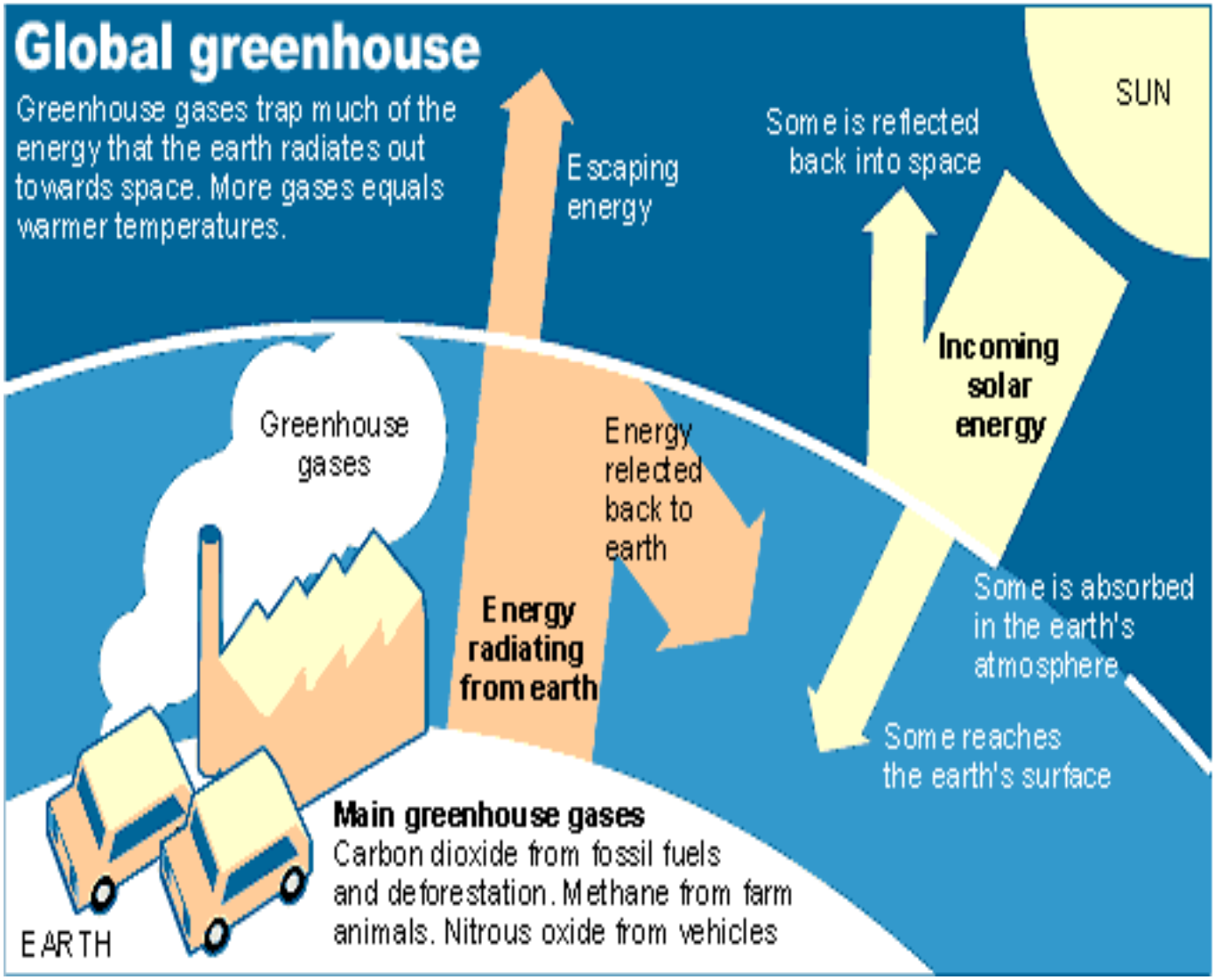
DIRECTIONS

Reflect on what you've read, viewed, heard and discussed so far and share what you are learning about causes and impacts of climate change, as well as the evidence. Identify where the information comes from – e.g. prior knowledge, a video, NASA web pages or another resource. Keep in mind that there are natural factors (like the Sun, plant and animal life, land, air and water) and human-made ones that can affect Earth's climate. Use the graphic organizer below to record your thoughts.

CLIMATE CHANGE EVIDENCE	
What we know…	How we know…
CLIMATE CHANGE CAUSES	
What we know…	How we know…
CLIMATE IMPACTS	
What we know…	How we know…

TEACHER PAGES LESSON 2.3 CLIMATE CHANGE SCIENCE 101 – the Greenhouse Effect

GREENHOUSE EFFECT DIAGRAM



Source: Guardian.co.uk, http://goo.gl/0HwOi

STUDENT PAGE LESSON 2.4 CLIMATE CHANGE SCIENCE 101 **NATURAL GREENHOUSE EFFECT VS ENHANCED GREENHOUSE EFFECT GRAPHIC ORGANIZER**	Name: _____ Date: _____

DIRECTIONS

Watch, re-watch, and pause the video "Too Much CO_2", if necessary. In the boxes below, first use words to explain what you have learned about the Greenhouse Effect, then draw images associated with what you saw and wrote. You can think of your drawings as a diagram or model to represent what you are learning about these phenomena. The text that you write next to the diagram should explain what you have learned.

	Explain in Words	**Explain in Pictures (model)**
Natural Greenhouse Effect		
Enhanced Greenhouse Effect		

SOURCES OF GREENHOUSE GASES

Greenhouse Gas	Amount Contributing to Greenhouse Effect	Main Sources
Methane	18%	Wetlands, cattle, rice paddies, forest and savannah burning, natural gas, landfills, termites, oceans, lakes, tundra
Carbon Dioxide	49%	Burning wood and fossil fuels, plant and animal respiration, deforestation
Nitrous Oxide	6%	Auto exhaust and fertilizer
Clorofluorocarbons	14%	Refrigerants, solvents, foamed plastic

Source: Environmental Literacy Council, http://www.enviroliteracy.org/pdf/labge1.pdf

COMMUNICATE

2.5 Discovery of Global Warming

TIME: 90-120 minutes or 2 class period + homework

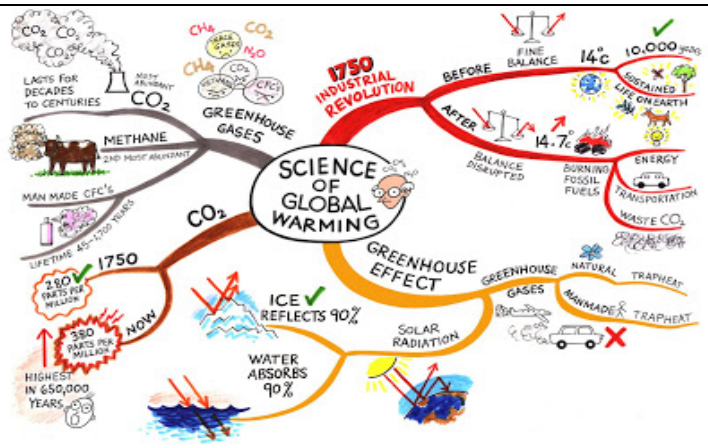


Photo credit: Live the Solution, www.live-the-solution.com

"Climate science brings together the researchers who drill the ice sheets with those that climb the trees in tropical forests, those who study cloud microphysics with those who observe the deep ocean circulations, those who study plant genomes with those who study rock formations. These experts in any other situation might never have had anything to do with each other."

- Climate Change: Picturing the Science

overview

Students learn about important climate scientists and create a mock interview to explain scientist's life and contributions.

objectives

The student will be able to…

- appreciate some important characteristics of science and scientific process
- create a mock interview with a climate scientist to explain his contributions to the discovery of global warming
- describe how scientists understand the relationship between CO_2 and temperature

Prerequisite

None

key vocabulary

Genomes: the genetic characteristic of an organism.
Interdisciplinary: combining two or more academic disciplines or fields of study.
Microphysics: study of physics that deals with particles that are so small they cannot be observed directly like some particles, molecules and atoms.
Resonates: to produce a feeling or emotional effect on someone or a group.
Theory: a group of tested, and generally accepted ideas used as principles to explain something.

subjects

Earth & Environmental Science, Language Arts, Social Studies

standards

NGES Nature of Science H

Science is a human endeavor; it is a body of cumulative knowledge that represents current understanding

CCSS ELA Literacy

Read for key ideas (RI.1-3, 8)

Write a mock interview to present scientific ideas (W.3)

resources / materials

Computers with Internet access

Slides: Generating Ideas on Scientific Inquiry

"History of the Greenhouse Effect" http://goo.gl/9yVKe

• "Two Centuries of Climate Science Parts 1-3" http://goo.gl/Iczae

• "The Discovery of Global Warming" http://goo.gl/VKuW

Unit 2 video lecture "The role of humans in the climate change story – Part 2" (4:33 minutes) http://realworldmatters.org/node/24

Scientist Interview graphic organizer

Mock Interview graphic organizer

Time travel interview with scientists, http://goo.gl/Paiau

Background

More than 150 years of science informs our understanding of carbon dioxide's role in Earth's climate. At the dawn of the Industrial Revolution, scientist Jean Baptiste Joseph Fourier came up with the Bell Jar Hypothesis to explain how Earth stayed warm due to an "invisible dome," like a bell jar that traps heat. Years later, scientists returned to Fourier's bell jar analogy to think about Earth's Greenhouse Effect.

Scientists before Fourier, and the many who followed, helped to build the body of knowledge we call climate science. These men—and in more recent times a growing number of women—work all over the world and across many disciplines studying various aspects of the climate system. They work outdoors in the field collecting data and measurements to study past and present climate. They work in labs analyzing climate data collected at and near Earth's surface, as well as from instruments in space. Massive computer programs are written to process all this data and model the physical processes of Earth's climate system. These models help scientists understand climate better and enable them to make predications about future climate.

Underlying the science of climate is a history lesson concerning how this knowledge developed. Much of this history explains the development of a body of knowledge that led to the discovery of modern-day global warming. By learning about the scientists who developed this knowledge, we can appreciate why and how scientists have come to understand that our climate is changing and the risks that this presents.

suggested procedure

1. Show the class the quote and cartoon from the teacher page GENERATING IDEAS ABOUT SCIENTIFIC KNOWLEDGE. Ask students to take a few moments to think about the quote and cartoon and then to write down ideas about characteristics of scientific inquiry and knowledge.

2. Ask students to share their ideas, discuss several characteristics of the process of science. This might include:
   - science is about investigating the world
   - ideas are not constrained by space and time
   - new knowledge leads to more questions
   - theories are thrown out or replaced with new knowledge
   - science is trying to explain the world, theories have to be supported by evidence.

   Students should also add additional ideas not represented in the quote or cartoon based on their prior knowledge.

3. Explain to students that they are going to work in pairs to explore some of the scientists whose research informed the discovery of global warming.

4. Assign each student pair a scientist to research. Once the research is done, students are going to prepare a mock interview of their scientist. One student will play the scientist and the other the journalist, responsible for asking and answering questions about the scientists' contributions to climate change science. This part of the lesson is adapted from *The Time Travel Interviews With Famous Scientists* (see resources/materials). Some students will travel back in time to interview scientists and others will focus on interviewing modern-day scientists. Working in pairs, students will choose to be or to interview one scientist from the list below:

List of Scientists	
Michael Faraday (1791-1867)	Syukaro Manabe (1931-)
Joseph Fourier (1768-1830)	Wallace Broecker (1931-)
John Tyndall (1820-1873)	Paul Crutzen (1933 -)
Svante Arrhenius (1859-1927)	James Hansen (1941 -)
Guy Stewart Callendar (1898-1964)	Stephen Schneider (1945-2010)
Gilbert Plass (1920-2004)	Tom Karl (1951 -)
Charles Keeling (1928-2005)	Richard Alley (1957 -)
	Michael Mann (1965 -)

5. Students begin exploring the contributions of their scientist using various web sites listed under resources/materials that provide a history of climate change science. They can also find additional resources. Complete THE SCIENTIST INTERVIEW BACKGROUND RESEARCH GRAPHIC ORGANIZER with information acquired from the research.

6. Using the MOCK INTERVIEW PREP GRAPHIC ORGANIZER on the student pages, students playing the journalist develop 5-7 questions. Students playing the scientist provide responses to the interview questions.

7. Together, each student pair develops and edits a written transcript of the final interview.

8. Student pairs should be prepared to share their interview with the class in 2-minute presentation. Encourage students to be as creative as they like. They may use props, costumes, visuals, etc. to present interviews that inform and resonate with the audience. See Assessment for the rubric for evaluating Interviews.

9. (Optional) Students can do a Pair/Share with students studying a different scientist.

wrap-up and discussion

10. Students perform their interviews to the class. On the board, a shared Google doc or wiki, write down the main contributions of each scientist covered in student presentations. Make a special notation of ones that explain (directly or indirectly) the relationship between CO_2 and temperature.

EXTENSION: The class can synthesize their collective studies about the various scientists and prepare a concept map that conveys what they are learning about the development of climate knowledge and the discovery of global warming made by the scientists studied. This mapping be done using mobile devices and the app Padlet (http://padlet.com) or using the "Connect the Minds" method articulated in Ryan Goble's article "Within Technology, Without Technology" from the Journal of Media Literacy available at http://goo.gl/Hanqp. Prompts can focus on the relationship between CO_2 and temperature, what students think we have learned over 150+ years about this relationship, and why it is important to the discovery of global warming.

assessment

Mock Interviews of Climate Scientists

EXTENSION: Each student writes a one-page reflection on the quote at the beginning of the lesson from Climate Change: Picturing the Science and why climate science demands such an interdisciplinary study. Provide at least one example of how scientists from 2 or more fields work together to investigate climate and what we are learning.

Mock Scientist Interview Rubric

Elements	5 Points	4 Points	3 Points	2 points
SCIENTIFIC CONTRIBUTIONS	Clear, concise and supported by evidence	Clearly stated without supportive evidence	Stated but does not clearly explain contribution	Stated but does not explain contribution
SCIENTIFIC METHODS	Explained well in a way that relates to contributions	Explained but needs more description of relation to contributions	Identified but does not explain relation to contributions	Does not identify
INTERVIEW QUESTIONS	All questions uncover what's newsworthy and relevant	Most of the questions uncover what's newsworthy and relevant	2 questions uncover what's newsworthy and relevant	1 question uncovers what is newsworthy and relevant
PRESENTATION - STYLE	Delivered in a creative, interesting and engaging style and format	Mostly delivered in a creative, interesting and engaging style and format	Some of the presentation is creative and engaging	Decided not to address
PRESENTATION – INFORM	Learned about 5-7 new things about climate	Learned at least 4-6 new things about climate	Learn at least 2-3 new things about climate	Learn at least 1 new thing about climate

feedback

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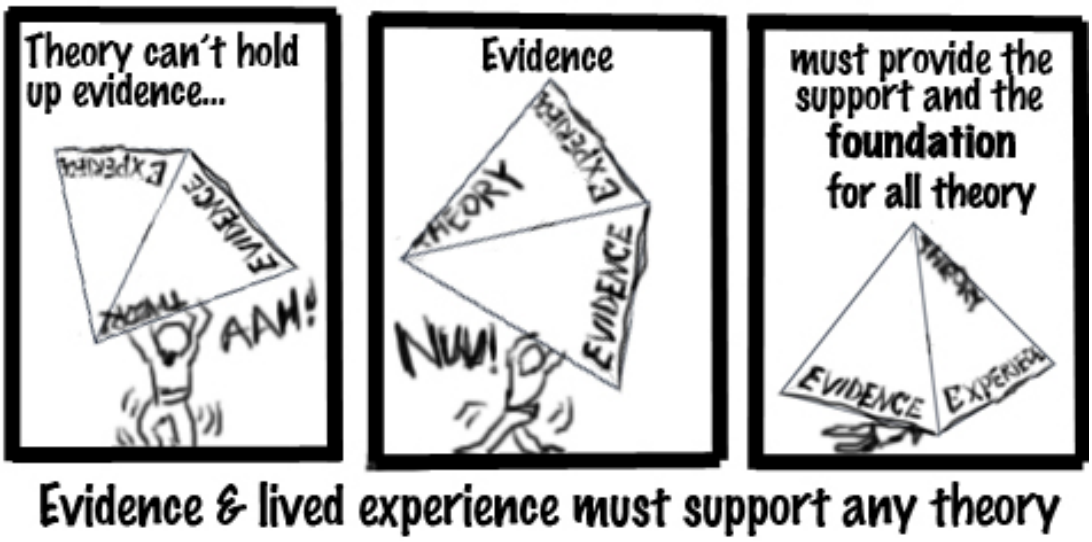
TEACHER PAGE

Unit 2.5 Slide: Generating Ideas on Scientific Inquiry

It is not enough to say that we cannot know or judge because all information is not in. The process of gathering knowledge does not lead to knowledge. A child's world spreads only a little beyond his understanding while that of a great scientist thrusts outward immeasurably. An answer is invariably the parent of a great family of new questions. So we draw worlds and fit them like tracings against the world about us, and crumple them when we find they do not fit and draw new ones.

Quote from author, John Steinbeck in
The Log from Sea of Cortez, 1941



Cartoon Credit: http://www.nickscrusade.org/tag/ablism/

STUDENT PAGE LESSON 2.5 Discovery of Global Warming **Scientist/Journalist** **Interview Background Graphic Organizer**	Name: _____ Date: _____

Instructions: Complete the information below to organize the information you and your partner learn about your scientist. Students playing the role of the scientist explain your most important scientific contributions. Students playing the journalist try to find the "hooks" for the interview that will interest and educate your audience. To create a story with "human interest" see if you can find a way to bring out relevant elements of your scientist's personal life story. Can you find examples from his life that demonstrate:

- a curiosity to ask questions others did not
- a spirit to experiment
- creativity and intellect to think critically and creatively
- confidence and integrity to dare to tell others what they learn, when it goes against current beliefs

Be prepared to share your scientist profile with another pair of students working on a different scientist profile.

Scientist Job

My major scientific contributions to understanding climate change are:

My main scientific methods for learning this knowledge included:

I sometimes like to use the following artifact or analogy to help people understand my research (for example a dice, a candle, etc.): [be sure to explain what the artifact or analogy is describing]

The 5-7 questions I'd like to answer to tell people about the importance of my research are:

Journalist Job

I think the 2-3 most interesting things about this scientist's life story are:

I think the most newsworthy things about this scientist's research are:

The best theme for the interview would be:

The 5-7 questions I have for this scientist are:

STUDENT PAGE LESSON 2.5 The Discovery of Global Warming **Mock Interview Prep Graphic Organizer**	Name: _____ Date: _____

Instructions: Now you are ready to prepare the mock interview of the scientist. Journalists – develop and write your questions in the table below. Scientists – discuss and write the responses you think your scientist might offer in the interview. No matter which hat you are wearing, scientist or journalist, the aim is to explain the scientist's main contributions to climate science, as you understand them from your background research. With your partner think about ways to edit and refine the questions and answers in way that accurately represents the scientist's contributions and that will resonate with an general (non-expert) audience. Use the table below to prepare a written transcript of the mock interview that is about 2-3 minutes in length. A model mock scientist interview with Marie Curie can be found at http://goo.gl/Paiau. The Curie interview is much longer than the one you will prepare but it may provide some ideas. You and your partner may decide to record your interview as a radio podcast you play for the class instead of performing live.

Journalist Interview Questions	**Scientist Response (include citation for information)**
1.	
2.	
3.	
4.	
5.	
6.	
7.	
Additional Questions – extra credit	