Climate Change, Data Science & Computing

<table>
<tr><th colspan="2">Unit Plan: Climate Change, Data Science & Computing</th></tr>
<tr><td>Unit Title</td><td>Climate Change, Data Science & Computing
Climate Champions, UC San Diego</td></tr>
<tr><td>Lesson Creator</td><td>
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<tr><td>Aletia Trepte
Lincoln High School
San Diego Unified School District</td><td>Yassir Eddebbar
Advising Climate Scientist
Scripps Institution of Oceanography, UC San Diego</td></tr>
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<tr><td>Unit Goal

Essential Question</td><td>Climate scientists use land, ocean and atmospheric measurements to study the full history of Earth's climate, from the latest satellite observations to samples of prehistoric ice extracted from glaciers. That data provides the basis for the forecasts made in the short-term, and climate patterns over years and years, it shows how the climate is changing. In this way, it provides crucial clues about what the future may hold as man made carbon emissions continue to alter the planet. This Unit provides students an overview of the interconnectedness of analysis, data, and tools related to climate change, exploring connections of data science and climate change. Through hands-on activities in this unit students will learn how data analysis helps turn raw data into useful information about climate change. Students learn how to use various data visualization and analysis tools to find patterns inside of data sets and learn how this data analysis process is being used in contexts like Open Data, Crowdsourcing, and Computing to help make decisions or learn more about Climate Change.

Computing can be used to gather, process and visualize data, which allows users to discover information and create new knowledge.
How can we use data and computing to respond to Climate Change?</td></tr>
<tr><td>CA CS Standards</td><td>
<table>
<tr><td>9-12.DA.10</td><td>9-12.DA.10</td><td>9-12.AP.15</td></tr>
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<tr><td>Create data visualizations to help others better understand real-world phenomena.</td><td>Refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.</td><td>Iteratively design and develop computational artifacts for practical intent, personal expression, or to address a societal issue by using events to initiate instructions.</td></tr>
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<tr><td>CSTA Standards</td><td>
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<tr><td>3A-DA-11</td><td>3B-DA-05</td><td>3B-DA-05</td></tr>
<tr><td>Create interactive data visualizations using software tools to help others better understand real-world phenomena.</td><td>Use data analysis tools and techniques to identify patterns in data representing complex systems.</td><td>Select data collection tools and techniques to generate data sets that support a claim or communicate information.</td></tr>
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<tr><td>AP CSP 2021 Standards</td><td>
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<tr><td>DAT-2.A, DAT-2.B, DAT-2.C</td><td>DAT-2.A, DAT-2.E</td></tr>
<tr><td>● 2.3 Extracting Information from Data
○ 5.B Explain how knowledge can be generated from data.
○ 5.D Describe the impact of gathering data.</td><td>● 2.4 Using Programs
○ 2.B Implement and apply an algorithm.
○ 5.B Explain how knowledge can be generated from data.</td></tr>
<tr><td>IOC-1.C</td><td></td></tr>
<tr><td>● 1.C Explain how people participate in problem-solving processes at scale.
○ 1.E.4 Crowdsourcing is the practice of obtaining input or information from a large number of people via the Internet.</td><td></td></tr>
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<tr><td>Interdisciplinary</td><td>Math:
● MP.2 - Reason Abstractly and Quantitatively</td></tr>
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<tr><td>Standards</td><td>
MP.4 - Model with Math
ELA:

RST.11-12.7 - Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem
RST.11-12.9 - Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

NGSS:

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.
HS-ESS3-5 - Analyze geoscience data and the results from global climate models to make evidence-based forecasts of the current rate of global or regional climate change and associated future impacts to Earth’s systems.

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<tr><td>Performance Expectation</td><td>
Students will be able to:

Follow the Data Analysis Process to create a descriptive model about climate change(c02).
Write a short explanation that describes the climate metadata in a data set.
Recognize and explain potential bias in a dataset or interpretation.
Create a Visualization with Climate Data

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<tr><td>Terminology</td><td>
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<td>
CSV Files
Metadata
Clean Data
Filtering Data
Open Data
Big Data
Crowdsourcing
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<td>
Weather versus Climate
Greenhouse Gasses
Keeling Curve
C02
ppm
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<tr><td>Resources</td><td>
<table>
<tr><th>Data Sets & Videos</th><th>Website Links</th><th>Activity Resources</th></tr>
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<table>
<tr><th>Datasets</th><th>Videos/Data Visualizations</th></tr>
<tr><td>World Climate Data Sets</td><td>Earth Has A Fever
Global Temp</td></tr>
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<td>EPA
NOAA
NASA</td>
<td>Lesson 1
Lesson 2
Lesson 3</td>
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	<table><tr><td>**ourworldindata.org** **United States Climate Data Sets** **epa.gov**</td><td>Keeling Curve How Scientists Measure CO2 GHG Rap</td><td>**Berkley Earth** **Keeling Curve UCSD**</td><td>Lesson 4 Lesson 5</td></tr></table>
Teaching Methods	Depending on your classroom culture, students work in pairs, as buddies or alone. Allow time for “Notice and Wonder” within the class either in pairs, small groups or as a whole group. **Notice and Wonder** **Buddy Programming** **Pair Programming**

Lesson Preview		
Lesson:	**Learning target: Students will**	**Activities:**

Lesson 1:
Intro to Climate Datasets
	• Learning Objectives
	  ○ **DAT-2.A**
	  ■ **Describe** information that can be extracted from data.
	  ○ **9-12.DA.10**
	  ■ **Create** data visualizations to help others better understand **real-world phenomena.**
		• Earth Climate
		• Climate vs Weather
		• **Analyze** Global Temperature Data
		  ○ Ocean and Land Temperatures
		  ○ **Relate and compare** climate data in tables and graphs.

Lesson 2:
CO2 Data
	• Learning Objective
	  ○ **DAT-2.A**
	  ■ **Describe information** that can be **extracted from data**.
	  ○ **9-12.DA.10**
	  ■ **Create data visualizations** to help others better understand **real-world phenomena.**
	  ○ **DAT-2.D**
	  ■ **Extract information** from data **using a program.**
		• Graphing Activity - Our Changing Atmosphere
		  ○ Plot Mauna Loa & South Pole Data
		• Phenomena: Keeling Curve
		  ○ Patterns in the graphs
		  ○ Student worksheet/journal
		  ○ Import and Graph Data in App Lab
		  ○ **Metadata**

Lesson 3:
Filter Greenhouse Gases Data
	• Learning Objectives
	  ○ **2.3 Extracting Information from Data**
	  ■ 5.B **Explain** how **knowledge** can be generated from data.
	  ○ **3B-DA-05**
	  ■ **Select** data collection tools and techniques to **generate** data sets that support a claim or **communicate information**.
	  ○ **9-12.DA.10**
		• Data Filtering
		  ○ **Relate** and **compare** greenhouse gas data
		  ○ **Filter** GHG data via EPA site
		  ○ Display categorical data using visualizations
		  ○ Upload Data into Google Sheets
		  ■ Create filters
		  ■ Create charts
		  ○ Gain **knowledge** from climate data

	■ **Refine computational models** to better **represent the relationships** among different **elements of data collected** from a **phenomenon or process**.	○ Use data to combat climate change
Lesson 4: Crowdsourcing Climate Change	• Learning Objectives ○ **IOC-1** ■ 1.C **Explain** how **people participate** in **problem-solving processes** at scale. ■ 1.E.4 **Crowdsourcing** is the practice of **obtaining input** or information from a **large number of people via the Internet.** ○ **3B-DA-05** ■ Use **data analysis tools** and techniques to **identify patterns** in **data** representing complex systems.	• **Crowdsourcing** in the classroom • Explore ways individuals and groups of people are addressing climate change and finding solutions. ○ Governments, private industries and individuals addressing climate change. • Use collaborative research ○ Discover solutions to climate change • Citizen Science
Lesson 5: Python Programming	• Learning Objectives ○ **9-12.DA.10** ■ **Create data visualizations** to help others better understand **real-world phenomena.** ○ **DAT-2.A, DAT-2.E** ■ 2.4 Using Programs • 2.B **Implement** and **apply** an algorithm. • 5.B **Explain** how **knowledge** can be generated from **data.**	Data Visualizations in Python
Lesson 6: Climate Models	Under Construction	

Lesson 1: Introduction to Climate Data

Using data, scientists have concluded that our climate is changing and global temperatures are on the rise. The trends learned from climate data reveal serious consequences to these rising temperatures like worsening many types of disasters, including storms, heat waves, floods, and droughts.

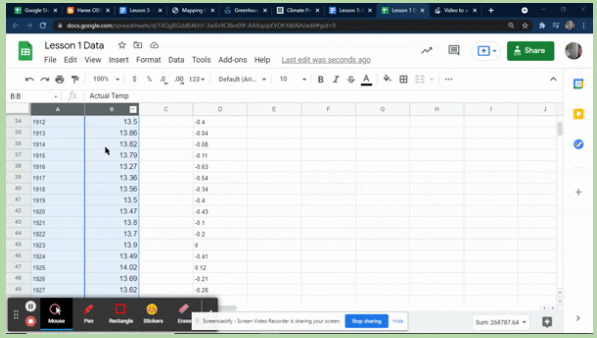
Description: This activity is designed to help students understand changing global temperatures through studying data. By the end of lesson 1, students should know that climate is defined as a long-term (30 years or more) average of weather conditions of a place or area, and that climate is measured primarily in terms of temperature and precipitation, although scientists also track other components of weather. Students should know the difference between Global Warming and Climate Change. Students will learn to use App Lab Data tables and visualizers and make a simple app that displays temperature data.

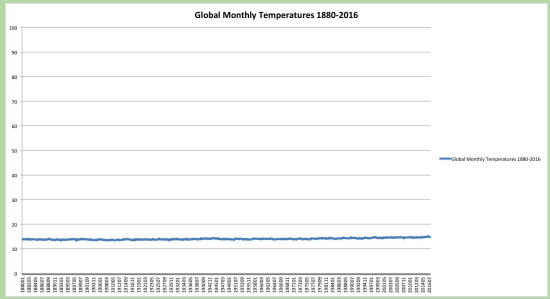
Data & Computing Learning Objective: Students will relate and compare climate data in tables and graphs and use computing to display them.

Procedure:

Introduction and Discussions	1. Ask students what they know about global temperature trends. Expect to hear differing opinions depending on the knowledge base of the students. (Video: Earth Has A Fever) 2. Ask if any students have ever looked at global temperature source data (data measurements from science institutions) themselves. Expect that some students will say they have seen graphs. If they do, ask them if they know whether the graphs represent all available data and what the source of that data is. 3. Discuss with students the importance of analyzing data, carefully scrutinizing graphs themselves and drawing their own conclusions rather than relying on sources that may not be factual. 4. Tell students they are going to be looking at data sets that show monthly measurements of the average global land and ocean temperature over approximately 136 years. They will make a determination about what they think is happening to the global temperature over time. a. Discussion: Climate vs Weather i. Weather is like mood, climate is like personality. Both can change, but one changes much much faster and more easily than the other. Much like weather, your mood depends on the conditions of the day (who you have seen, news, quality of night's sleep, schedule), whereas your personality depends on long term

	circumstances and conditions in the long term (family, habits, life experiences, culture, social network, work, health, etc.). ii. Weather is the day-to-day or short term condition of the changes in the atmosphere, and climate is the averaged weather condition of a particular place over a long time, about 30 years.
Terminology	A **CSV** (comma-separated values) file is a text file that has a specific format which allows data to be saved in a table structured format. **Anomaly-** unexpected change within data patterns. **Climate versus Weather**-Weather refers to short term atmospheric conditions while climate is the weather of a specific region averaged over a long period of time. **Quantitative Data**- quantitative data deals with numbers, things you can measure.
Activity 1- Gathering & Preparing Data	5. Use the data tables provided for this activity or students may download the data themselves from the National Oceanic and Atmospheric Administration. a. Students that get data from NOAA will need to download it as a CSV file in order to load it into Google Sheets. See instructions on Data uploads. 6. Data is contained in two columns. a. Global Land Temperature i. The first column contains date information, with the first four digits representing the year. ii. The second column contains Temperature Anomaly in °C, as opposed to actual temperature. b. Global Ocean Heat Content i. The first column contains date information, with the first four digits representing the year. ii. The second column contains ocean heat content in Joules, the amount of energy(heat) stored by the ocean. 7. Explain to students the concept of anomaly, why scientists often use this instead of actual temperature readings, and how to compute the actual temperature from the anomaly. 8. Students save Data as CSV files. Optional: repeat with Ocean data.
Activity 2- Displaying	9. Plot Data in Google Sheets

Quantitative Temperature Data	a. 2 Variables: Highlight Year and Anomaly Data columns. b. Go to “Insert”, select “Chart”, then select Custom Tab and adjust the Horizontal and Vertical axis. c. Repeat this process with the Global Temperature Data and World Basin Ocean Data.  **Questions:** ● Is a pattern forming when charting the data? ○ Does it slope up, down, curved or an arc? ○ What do you think causes this variability? ● What do you predict will happen in 10 years? 20 years? 50 years? ● Compare Ocean versus Land Temperatures: ○ Which is rising faster? Why do you think one is rising faster?
Discussion-Bias in Data	10. Show students this graph and explain that the same monthly data was used to create it. Ask students why the data look different and what an indiscriminate viewer might conclude from looking at this graph. (This is how the data looked in Google Sheets Chart before Horizontal and Vertical Axis were adjusted!)

	 Here's an example of how manipulating a graph could cause casual observers to make an inaccurate assumption about the data. Here we've chosen a scale far outside the reasonable possibility for the data set, so it has flattened the graph and made any details and trends too small to see. + enlarge image 11. Discuss with students the importance of choosing a relevant scale for any data set they analyze. Choosing a scale range far outside the reasonable possibility for the data set will flatten any graph. Scale is a commonly manipulated graphical parameter, either for convenience or for purposeful misleading. a. Discussion: How can we separate fact from fiction in science? i. **The way Data is represented influences its interpretation and the insight and knowledge gained.** Consult reliable sources, such as those at research institutions, especially those involved in data collection, and preferably numerous reliable sources that can corroborate information.
Exit Ticket & Deliverables	12. Ask students to determine if they think the overall trend of the data shows global temperature rising, falling or staying the same. a. Students Complete Worksheet i. Compare the class graph with a historical timeline of events in the United States and the world. ii. What associations do you see? iii. Cool Global Temp Video: where is the strongest warming(land)? **Does this reflect student graphs?** b. Students turn in Google Sheet: Google Form i. Keep track of student's graph work via Google Sheet

Lesson References & Resources

https://www.jpl.nasa.gov/edu/teach/activity/graphing-global-temperature-trends/

https://www.ncdc.noaa.gov/cag/global/time-series/northAmerica/land/1/12/1880-2016

Lesson 2- CO2 Concentrations: Our Changing Atmosphere

Carbon dioxide (CO2) is the primary greenhouse gas emitted through human activities. In 2019, data shows that CO2 accounted for about 80 percent of all U.S. greenhouse gas emissions from human activities. Data analysis reveals that human activities are altering the carbon cycle–both by adding more CO2 to the atmosphere, and by influencing the ability of natural sinks, like forests and soils, to remove and store CO2 from the atmosphere. Direct measurements of atmospheric carbon dioxide (CO2) concentrations have been recorded at Mauna Loa since 1958.

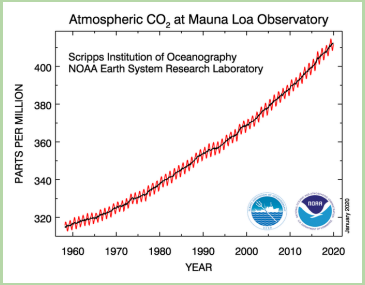
Description: This activity is designed to help students understand climate through studying CO2 data. By the end of lesson 2, students should understand that CO_2 (Carbon Dioxide) is a greenhouse gas that is strongly correlated with global temperatures … the more CO_2 in the atmosphere, the warmer Earth's atmosphere and surface become. In this exercise, students investigate the CO_2 data set from the South Pole and Mauna Loa, Hawaii, which dates from the late 1950's, and estimate the rate at which atmospheric CO_2 has been increasing recently. Students will learn to use data visualizers and learn about metadata.

Data & Computing Learning Objective: Students will relate and compare climate data in tables and graphs and use computing to display knowledge and communicate insight. Students learn that **metadata** is the summary and the description about your data that is used to classify, organize, label and understand data.

Procedure:

Introduction	This unit starts off with a CO2 graphing activity. Materials needed: ● Gridded chart paper ● Yard stick ● Marker ● Sticky dots, each group needs 12 dots per year of data; all dots should be the same color and fit on graph paper for plotting. ● Tape ● Earth globe ● Mauna Loa monthly CO2 data, 2006–2019 ● South Pole monthly CO2 data, 2006–2018; a different color of sticky dots should be used for South Pole data, 12 dots per year of data.

	• Print data sheets and cut so that each group receives one year's worth of data. Put students in groups of 3. Tell students the data they are going to graph are mean monthly atmospheric CO2 data from Mauna Loa, collected by the National Oceanic and Atmospheric Administration (NOAA). Students place the dots appropriately on the graph, and also label the graph with the year in which your data were collected. You may want to write the Mauna Loa CO2 values from your data sheet on the sticky dots–one monthly value per dot.
Terminology	**Metadata**- a set of data that describes and gives information about other data. **CO2-Carbon dioxide**- a colorless gas having a faint sharp odor and a sour taste, it is a greenhouse gas. **Ppm**- Carbon Dioxide (CO2) is measured in parts-per-million (ppm) and reported in units of micromol mol-1 (10-6 mol CO2 per mol of dry air). **Keeling Curve**- Name given to the longtime series (upward curve) of CO2 measurements made by Charles David Keeling since 1958, and continued by his son, Ralph Keeling since 2005.
Activity 1 - Mauna Loa Data	1. Students start the class by graphing mean monthly atmospheric CO2 data from Mauna Loa, collected by the National Oceanic and Atmospheric Administration (NOAA) on paper. a. Use the globe to locate Mauna Loa. Is it in the Northern or Southern Hemisphere? 2. Students place the dots appropriately on the graph paper, and label the graph with the year in which your data were collected. You may want to write the Mauna Loa CO2 values from your data sheet on the sticky dots–one monthly value per dot.
Discussion 1	a. What do you notice? b. When are the values the highest? The lowest?
Activity 2- South Pole Data	3. Students also graph South Pole data, they should be added to the same graph paper (be sure the data are from the same year) using sticky dots that are a different color. a. What do you notice about the seasonal fluctuation pattern in the Northern Hemisphere and in the Southern Hemisphere? b. Why do you think these different patterns occur in the data? i. There is a clear difference between levels of carbon dioxide measured in the Southern and Northern hemispheres, because industrial and other population-based sources of carbon dioxide emissions are concentrated in the Northern Hemisphere.

Discussion 2	4. Students bring all of the graphs together in chronological order, overlapping the “month 0” and “month 12” to create a continuous graph of multiple years’ data. a. What do you notice?
Phenomena - Keeling Curve	5. **Show this video:** Following Carbon Dioxide Through the Atmosphere a. What do you notice? What do you wonder? What do the colors represent? 6. **Keeling Curve**: Direct measurements of atmospheric carbon dioxide (**CO2**) concentrations have been recorded at Mauna Loa since 1958. **a. Show Video, how CO2 is measured: Keeling Curve**  b. Units of atmospheric carbon dioxide measurements are ppm—parts per million. For every million molecules of air in our atmosphere, some number of them are carbon dioxide molecules.
Activity 3- Metadata & Computing	7. Students work in pairs and Download CO2 CSV data file from https://scrippsco2.ucsd.edu/data/atmospheric_co2/primary_mlo_co2_record.html a. Students should open their file in Google Sheets and start a new tab, then answer the following questions about the data. i. Where did the data come from? ii. How much data is included? iii. When was it collected? Over what length of time? iv. Answer the questions for the temperature data from lesson 1. v. What similarities do the Temperature Data and the CO2 data have? b. Bring the class back together and discuss questions. i. Explain to the students that this information about the data is called **metadata**. 1. Used to find, organize, and manage information. 2. Increases effective use of data by providing extra information.

Activity 3 Continued- Data Computing	8. Prepare CO_2 data for visual display in their Google Sheet: a. Students open a new tab in Google Sheets. i. Ask students what data they think is needed to plot. ii. Students copy/paste Columns D & E into a new tab iii. Students plot data 1. Plot Data in Google Sheets 2. Highlight Year and CO_2 Data columns. 3. Go to “Insert”, select “Chart”, then select Custom Tab and adjust the Horizontal and Vertical axis.
Exit Ticket & Deliverables	Reflect on the day’s activity of graphing the CO_2 levels by hand versus graphing in Google Sheets, . Google Form Metadata Worksheet AP Question Extended Activity: Cool Interactive Plot

Lesson References & Resources

https://www.exploratorium.edu/snacks/our-changing-atmosphere

https://keelingcurve.ucsd.edu/

Lesson 3: CO2 Emissions: Filtering Greenhouse Gasses Data

Data filtering is the process of choosing a smaller part of your data set and using that subset for viewing or analysis. Carbon dioxide (CO2) data has been monitored science 1958, it is the primary greenhouse gas emitted through human activities. In 2019, CO2 accounted for about 80 percent of all U.S. greenhouse gas emissions from human activities. Human-related emissions are responsible for the increase that has occurred in the atmosphere since the industrial revolution. The main sources for CO2 emissions is fossil fuel combustion and are described in 5 categories, transportation, electricity, industry, residential & commercial and other non-fossil fuel sources. Filtering CO2 data in a spreadsheet allows only certain categories to display. Filtering CO2 data allows us to focus on specific information in a large CO2 dataset.

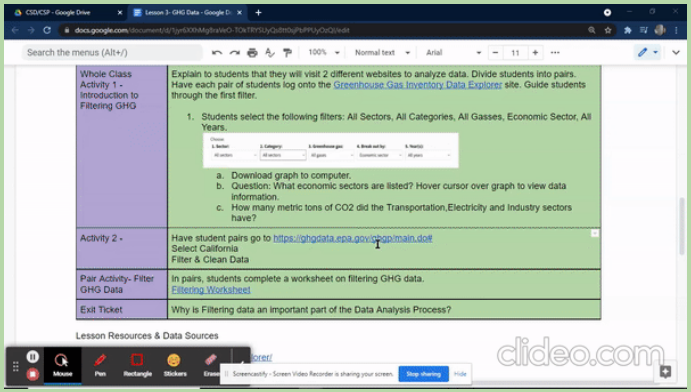
Description: In this lesson, students explore datasets at the EPA website by using filtering tools at the Greenhouse Gas Inventory Data Explorer site and Google Sheets to answer data questions that require filtering a dataset.

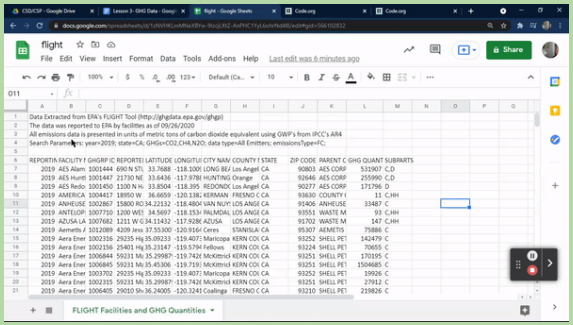
Data & Computing Learning Objective: Students will relate and compare greenhouse gas data in tables and use pie graphs to display the categorical data in a programming language. Students will be able to answer questions about data using visualizations of filtered data.

Procedure:

Introduction & Discussion	Go HERE and watch the GHG introduction video on the front page. Discuss the major greenhouse gasses with students HERE View the list of the major greenhouse gasses and discuss where each of them comes from and which ones are emitted in the largest quantities as a result of people's activities. Put the focus on CO2. **Key discussion points include:** ● Greenhouse gasses trap heat in the atmosphere, which makes the Earth warmer. ● Greenhouse gasses come from burning fossil fuels for all sorts of everyday activities, such as using electricity, heating our homes, and driving vehicles. ● Greenhouse gasses that people are adding to the atmosphere include carbon dioxide, methane, nitrous oxides, and fluorinated gasses. ● Ask WHERE and HOW we gather CO2 data? ○ Mauna Loa, Hawaii ○ Show Video How Scientists Measure CO2 ■ Discuss how to determine where the CO2 came from. ● Cars, plants, the ocean, etc..

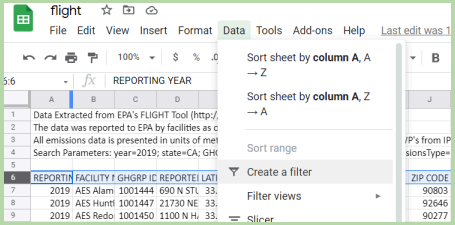
	• What do you notice? What do you wonder?
Terminology	**Data filtering-** the process of choosing a smaller part of your data set and using that subset for viewing or analysis. **Clean Data-** Data cleaning is the process of fixing or removing incorrect, corrupted, incorrectly formatted, duplicate, or incomplete data within a dataset. **Greenhouse Gasses-** gas that absorbs and emits radiant energy within the thermal infrared range, causing the greenhouse effect.
Whole Class Activity Skill 1 - Introduction to Filtering GHG	Explain to students that they will visit 2 different websites to analyze data. Divide students into pairs. Have each pair of students log onto the Greenhouse Gas Inventory Data Explorer site. Guide students through the first filter. 1. Students select the following filters: All Sectors, All Categories, All Gasses, Economic Sector, All Years.  a. Download graph to computer. i. Graph will be added to the student worksheet. b. Question: What economic sectors are listed? Hover cursor over graph to view data information. c. How many metric tons of CO2 did the Transportation,Electricity and Industry sectors have? i. Thinking about 1 Million Metric Tons ii. 1 Million Metric Tons iii. An adult elephant weighs somewhere between 2.5 and 7 metric tons depending on gender and species. iv.  v. Using 5 metric tons as a rough average. vi. 1 Million Metric Tons is therefore the weight of 1,000,000 / 5 = 200,000 elephants.

Activity Skill 2 - Filter & Clean Data	Have students buddy up and go to https://ghgdata.epa.gov/ghgp/main.do# * Any State can be used for this activity, however, a few adjustments with cleaning and filtering will need to be made. ** Expand GIFs and Images for better viewing. ● Select California ● Select All County, All Fuel, Select the first 3 GHG ● Select Apply Search ● Select Export Data > Current Reporting Year ● Open new tab in your Google Sheet  **Clean & Filter Data** Datasets can bring about challenges, no matter what their size. There can be incomplete data and invalid data. You might want to combine two tables, with inconsistent data. All of this requires data to be cleaned. Before we begin to clean this data, students will need to make a copy of the dataset. This is an important first step so that you always have your original dataset. ● Select all of the dataset ● Select Edit > Copy ● Add New Sheet ● Select Edit > Paste ● Rename > Original



Apply Filter

- Highlight Row 6
- Select Apply Filter



Cleaning Missing Data

Have students filter by CITY NAME > Maricopa
Sometimes data is missing or inconsistent and needs to be “cleaned”.
Have students fill in KERN COUNTY in the missing cell. They can Copy/Paste for accurate spelling.
Students should scan down to another CITY with a missing County:
Have students filter by CITY NAME > Coalinga
Have students fill in FRESNO COUNTY in the missing cell. They can Copy/Paste for accurate spelling.
Students should repeat this process to fill in missing city names by scanning empty cells then filtering by COUNTY.
If the City says, “OFFSHORE” let students decide what to put in the missing county space. Just be sure that students stay CONSISTENT with what they decide to use. You might have students notice that sometimes the County or City names are in all caps and sometimes not. Ask them how this might make filtering more challenging. Is the filter sensitive to casing?

Pair Activity- Filter	In pairs, students complete a worksheet on filtering GHG data.

GHG Data	Filtering Worksheet
Climate Chat Wrap Up	**History of the greenhouse effect** **VIDEO** Fourier was the first person to study the Earth's temperature from a mathematical perspective. He examined variations in temperature between day and night, and between summer and winter, and concluded that the planet was much warmer than a simple analysis might suggest. The greenhouse effect is essential for sustaining life on Earth. The intensity of the warming effect depends on the concentration of the radiatively active gasses, called greenhouse gasses. Human activities, mainly the burning of fossil fuels, have increased their concentrations and the result is a warming of the atmosphere.
Exit Ticket & Deliverables	Exit Ticket Why is Filtering & Cleaning data an important part of the Data Analysis Process? AP Question on Clean Data Student Worksheet Cool GHG Emissions Video

Lesson Resources & Data Sources

https://cfpub.epa.gov/ghgdata/inventoryexplorer/

https://archive.epa.gov/climatechange/kids/documents/mapping-emissions.pdf

Lesson 4: Crowdsourcing for Climate Change

In the United States, daily observations at monitoring stations are used to document weather and climate. All the original temperature readings from both land-based weather stations and ocean-going ships and buoys are publically available and can be used to create a “raw” global temperature record. Public data is called **Open Data**. Open datasets can play an important role in monitoring climate policies and programs by improving knowledge and data sharing across agencies and levels of government. In addition to monitoring stations, individual people participate in collecting data and in the problem solving process! **Crowdsourcing** is a way to find solutions to problems by asking a large group of people to contribute information, ideas, data, and content about a certain idea. Crowdsourced data may or maynot be open data, depending on the project. Crowdsourcing is being used to address climate change and help implement solutions.

Description: In this lesson, students use crowdsourcing in the classroom, to explore ways individuals and groups of people are addressing climate change. In this lesson, students will use collaborative research to discover different ways governments, private industries and individuals are finding solutions to address climate change.

Learning Objectives: Students will know how to explain how people participate in problem-solving processes at scale, describe the impact of gathering climate change data and explain crowdsourcing, how collaboration affects the development of a solution.

Procedure

Introduction & Discussion	Tell students that for this lesson the class will work collectively to explore ways that our world is/can act on climate change. Thinking of solutions to climate change can be overwhelming because it affects so many parts of our planet and our lives and might feel like nothing will change. **Crowdsourcing** is a way to find solutions to problems by asking large groups of people to contribute information, ideas, data, and content. Many people from all walks of life, all professions from Climate Scientists to Artists to CEOs are making a difference. Choose a video to play of an artist that fits your classroom culture, try this or search your own.

	1. Pair students up and show them this sign up document. Each pair will need to choose a category. If the category is full they will need to pick a different one. Make adjustments to the sign up depending on how many students are in the class, the sign up sheet assumes 36 students. 2. Explain that students will explore 4-5 solutions according to the category they picked and the climate challenges they address. For example, a student pair picks the Schools & Universities category. They find that a university has committed to completely divest from fossil fuels: a. UC Berkeley University Climate Solution: completely divest from fossil fuels b. Climate Challenge it addresses: fossil fuel emissions Overlap is to be expected, for example, private industry and private citizens may also commit to divesting in the fossil fuel industry.
Terminology	**Crowdsourcing**- the practice of obtaining information or input into a task or project by enlisting the services of a large number of people, either paid or unpaid, typically via the internet. **Citizen Science-** Citizen science is scientific research conducted, in whole or in part, by amateur scientists. Citizen science is sometimes described as "public participation in scientific research" **Big Data** - extremely large data sets that may be analyzed computationally to reveal patterns, trends, and associations, especially relating to human behavior and interactions. **Open Source Data**- data that is open and free for download, modification and re-use.
Activity 1- Research Solutions	3. Each Pair researches climate change challenges and solutions according to the category that they picked. a. Students work together but individually fill out their own Google Doc. ● Governments ● Private Industries ● Technology Sector ● International Community ● Individuals Citizens

Activity 2 - Share Solutions	4. Each Pair picks 3 solutions and the challenges from the Google Doc. a. Each pair will submit responses in the Google form with their top 3 challenges and top 3 solutions. Google Form 5. Share the Google Form Responses/Summary Charts and the Google Sheet associated with the Google Form after all students have submitted their responses in the Google Form. a. Students will make a copy of the form HERE 6. Look at the data altogether as a class. a. Discuss the ways the Google Form visualized the data b. Some data will be "messy" so discuss ways to "clean" the data
Extended Discussion- Crowdsourcing and Citizen Science	Tell the students that there are many ways individuals and groups of people are responding to climate change using crowdsourcing. Citizen Science projects are one way that people all around the world are coming together to find solutions. It uses the collective strength of the community to identify research questions, collect and analyze data, interpret results, make new discoveries, and develop technologies and applications – all to understand and solve problems. Scan the Projects Page EPA supported projects that address Climate Change NASA supported projects that address Climate Change Encourage students to find a project that they might join!
Exit Ticket & Deliverables	Individually, students attach the graphs associated with thier to their worksheet and then answer the questions. Worksheets Folder Google Form

Learning Resources:

https://k12.thoughtfullearning.com/blogpost/crowdsourcing-your-classroom

Lesson 5: Visualizing Climate Change with Python

Using data and programming languages like Python, data scientists can analyze data to help better understand and help people make strategic decisions. Through analyzing climate change data, scientists have concluded that our climate is changing and global temperatures are on the rise. The trends learned from data analysis reveal serious consequences to these rising temperatures like worsening many types of disasters, including storms, heat waves, floods, and droughts.

Description: This lesson will use Python and the Pygal graphing library to visualize the data you gathered from the Climate Change, Data Science & Computing unit.

Learning Objectives: Create data visualizations to help others better understand real-world phenomena, using Python programming language by creating and applying algorithms. Students will explain how we can use data knowledge and computing to respond to climate change.

Procedure

Introduction	How can we use computing to respond to Climate Change? Computing can be used to process and visualize data, which allows users to discover information and create new knowledge. This lesson will use Python and the Pygal graphing library to visualize the data you gathered from the Climate Change, Data Science & Computing unit to make their own cool interactive plot. Python is an open source, high level language and is one of the best languages used by data scientists for various data science projects/applications. One of the main reasons why Python is widely used in the scientific and research communities is because of its ease of use and simple syntax which makes it easy to adapt for people who do not have an engineering background.
Terminology	**Python-**open source, high level programming language. **Module-**discrete piece of code which can be independently created and maintained to be used in different systems. **String-**a data type that is used for data values that are made up of ordered sequences of characters, such as "hello world".

	Float-a data type that is used for data values made of floating-point number values. **CO2-Carbon dioxide**- a colorless gas having a faint sharp odor and a sour taste, it is a greenhouse gas. **Ppm**- Carbon Dioxide (CO2) is measured in parts-per-million (ppm) and reported in units of micromol mol-1 (10-6 mol CO2 per mol of dry air).
Activity 1 - Teacher led	Teacher led activity 1. Students work with programming buddy and go to Introduction to Trinket a. Trinket lets you run and write code in any browser, on any device. Trinkets work instantly, with no need to log in, download plugins, or install software. Easily share or embed the code with your changes when you're done. 2. Students go to Introduction to Graphing Global Temperature data in Python a. Recall the Global Temperature Data that you analyzed in Lesson 1 of Climate Change, Data Science & Computing. 3. Opening the temperature file a. Line 1: Import read.py file i. This file has an available function that will make our csv file into a list that we can use when graphing the temperatures and dates. b. Line 4: Use the open function to open the csv file. c. Line 5: Creates an empty list. d. Line 6: Function readit() prepares the text file to a list. i. This is the function made available to use when we imported read.py. e. Line 8: Opens the file using the built-in open() function. f. Line 9: The print() function prints list. 4. String to Float- a. How do we know our list is a list of strings? i. Nearpod Poll ii. We need to turn our list of Strings into a list of FLOATS so that we can graph it. b. Add the following code to Line 7 to change our data list from string to float. i. tmp = [float(i) for i in tmp_st] c. Change Line 9 to read: i. print(tmp) d. Press Run to see the new list of floats. 5. Chart Data in Pygal a. LINE 2 add the following code to the Trinket below: i. import pygal b. LINE 13, 14 and 15 add the following code: i. temp_chart = pygal.Line()

	ii. temp_chart.add("Temp", tmp) iii. temp_chart.render() 6. Title and Labels a. Line 14 i. temp_chart.title = 'Global Temperatures since 1880' b. Line 15 i. temp_chart.x_labels = yr
Discussion 1	What coding concepts did you learn in this activity that really sticks in your mind?
Activity 2- Buddy Programming	Computing Carbon Dioxide Student led activity 1. Tell students the objective: plot CO2 data in Python 2. Students stay with their programming buddy to write a program that displays CO2 data. a. Students will work through the CO2 course in Trinket b. Review the big steps to meet the objective: i. Import modules ii. Open & prepare CO2 data iii. Open & prepare Year data iv. Plot the chart c. Check in on student progress i. Ask questions/check in ii. Encourage students to talk with their programming buddies. iii. Tutorial videos
Discussion 2	• What did you learn from working on this activity—about the co2 data, coding in Python, and your learning process?

Extended activity Phenomena -	Discuss with your partner why you think global temperatures are rising, why is happening? Then click through the interactive Climate model. ● What do you notice, what are the parts in the climate model? ○ What are the "rules" for the model? ■ When I do this__, this__ happens. ● How many rules for this model are there? Complete the Activity Worksheet with your partner.

Lesson 6: Reverse Engineer A Climate Model

Climate models use mathematical equations to analyze the behavior of factors that impact climate such as atmosphere, ocean, ice, land surface and the Sun in a computer code. Scientists use climate models to gain a better understanding of how Earth's climate has changed in the past and make projections on future climate systems.

Description: In this lesson, students will reverse engineer a climate model of their choosing. Reverse engineering begins with the final product and goes back to recreate the engineering concepts that form the basis of the product by analyzing the design of the system and interrelationship of its components. By running various simulations and making observations of the behavior and performance of the model, students will gain a better understanding of the causes and effects of climate change.

Data & Computing Learning Objective: Gain an understanding of how the climate model works by recognizing the data input and output of the model, its purpose and if the computer model can be used to act on climate change.

Procedure:

Introduction & Discussion	A climate model is a computer simulation of the Earth's climate system, including the atmosphere, ocean, land and ice. They can be used to recreate the past climate or predict the future climate. Climate models are doing a good job predicting future global warming trends. Show a short video on global warming over time. Tell the class that today they will explore different climate models, and then share what they learned about the climate model with the class.
Explain Activity - Climate model	Climate Models Show students the interactive climate model https://c-roads.climateinteractive.org/ Ask students: What is the title of the first Climate Model on the left?

	• Global Net Greenhouse Gas Emissions What does the graph represent, what are the x and y axis? • CO2 versus time • Baseline, Current Scenario What are the interactive components of the climate model? • Climate Sensitivities • Ocean Mixing • CO2 fertilization(greening) • Sea Level Rise from Ice Sheet Melting • Carbon Cycle Land and Ocean Uptake • Methane Emissions from Biological Activity • Methane Emissions from Permafrost and Clathrates • Temperature Threshold • Economic Growth • Populations Growth https://www.carbonbrief.org/qa-how-do-climate-models-work Set the emissions * What are the "rules" for the model? * When I do this_____, this_____ happens. * How many rules for this model are there? https://docs.google.com/document/d/1-QTIteENUFWP05zDyJ4-EbO2sTmK6x6NhSZOWEZUMS8/copy
	Alternative Models https://www.inscc.utah.edu/~strong/modeling.html
Exit Ticket	Self-Analysis

Lesson Resources & Data Sources

C-ROADS - Climate Interactive
Carbon Brief >> Clear on Climate