"Is U.S. Air Pollution Getting Better or Worse - How and Why?"

Students work in four regional teams to determine the state of pollution in the United States by examining and analyzing actual data from the U.S. Environmental Protection Agency. Students will create scatterplots, generate and analyze statistics, determine appropriate mathematical models, develop new quantitative measures, and generate new data sets.

Packet Contents

Introduction

The U.S. Environmental Protection Agency is tasked with monitoring 6 common air pollutants - carbon monoxide, nitrogen dioxide, sulfur dioxide, lead, particulate matter, and ozone. Most of this data has been collected from thousands of monitoring sites daily since 1980, and is publicly available on the EPA's website. Regional data sets for each criteria pollutant have been created and will be made available to students in Google Sheet form.

In this project, students will be assigned one of 4 regions of the United States - Northeast, South, Midwest, or West. Within each regional group, every student will be assigned one of 5 criteria pollutants (lead is excluded, in part because airborne lead has been well controlled for several decades now, but also because the history of lead pollution is used as a project launch). The project begins with each student being tasked to become an "expert" in his/her pollutant (Task 1).

Once each group has an expert for each pollutant, the group moves to the second stage of the project - to create an "Air Quality Measure" that is based upon the five criteria pollutants (Task 2). No formula is offered - the groups are free to construct this formula in a way that seems right to them based on the expert knowledge of the pollutants in each group. This task culminates with the groups generating a data set for this new air quality measure, based on the actual pollutant data from EPA.

In preparation for the final whole-class task that answers the driving question for the project, the regional groups will take on one final preparatory task. Each region will attempt to determine the effects of people on air pollution by comparing data from rural and urban monitoring sites (Task 3). Students will select the subsets to be examined, and use statistical analysis to attempt to quantify the effects of human beings on the criteria air pollutants.

With each regional group having thoroughly explored the issue of pollution in their portion of the United States, the culminating task brings the class together to try to piece together an answer to the driving question - Is Air Pollution in the U.S. Getting Better or Worse (Task 4)? Each region contributes to the overall picture, and students are asked to find a creative and visually provocative way to consolidate their findings.

Curriculum Alignment

Academic Standards - AFM Standards (NCSCOS)

1.01 Create and use calculator-generated models of linear, polynomial, exponential, trigonometric, power, and logarithmic functions of bivariate data to solve problems.

a) Interpret the constants, coefficients, and bases in the context of the data.

b) Check models for goodness-of-fit; use the most appropriate model to draw conclusions and make predictions.

1.02 Summarize and analyze univariate data to solve problems.

b) Apply statistical principles and methods in sample surveys.

c) Determine measures of central tendency and spread.

e) Interpret and create graphical displays of univariate data.

f) Compare distributions of univariate data.

Process Standards - Standards for Mathematical Practices (NCTM)

SMP.1 Making sense and perseverance
SMP.2 Reason abstractly and quantitatively
SMP.3 Construct viable arguments
SMP.4 Modeling with mathematics
SMP.5 Using appropriate tools
SMP.6 Attend to precision
SMP.7 Make use of structure
SMP.8 Look for and express regularity

Objectives

Upon successful completion of this project, students will be able to

- Create and interpret appropriate models for real-world data
- Determine and understand the significance of measures of center and spread
- Create appropriate graphical displays to both analyze data and present data
- Work collaboratively to analyze, construct models, and justify findings
- Choose and use appropriate tools for data analysis

Time & Location

This lesson was designed to be the basis of a Project Based Unit on univariate data. As such, the project is viewed as ongoing work during a unit that may last upwards of two weeks or more. In an effort to make this specific work useable, approximate times for each task have been provided. As is often the case for teachers, the expectation is that other teachers will adapt this timeline to meet their needs and plans for their classes.

Project Launch and Region Assignments - 1 class period (90-minute block)
Task 1 - Becoming a Pollutant Expert - 2 class periods
Task 2 - Creating and Using an Air Quality Index - 2 class periods
Task 3 - Addressing the Effects of Human Beings - 2 class periods
Task 4 - Answering the Driving Questions - 1-2 class periods

Teacher Materials

There are no supplies necessary to be gathered for this project.
Students will need access to an internet-connected computer.
Teacher should be comfortable with data analysis in Google Sheets.

Student Materials

Students will need access to an internet-connected computer.

Safety

No safety precautions are necessary for this project.

Student Prior Knowledge

Students should have some experience working with data in Google Sheets.
Students should be comfortable using data to generate various regression models.
Students should be able to interpret the significance of values in regression models.

Teacher Preparations

- Regional groups will need to be formed. The project is designed for 4 U.S. Regions, so 4 teams. Each team will consist of 5 pollutant experts. Repeated region teams can be formed for larger numbers of students.
- Launch and Task 4 will require a display device for computer, like a projector, as well as internet access.
- Teacher should be comfortable with working in Google Sheets.

Activities

Prior to Launch

- Have students complete **"Lead Reading Assignment"** the evening prior to launch. Assign one of the three article links to each student and distribute **"Lead Organizer"** to be used for recording notes.
- Make your team assignments. The project is set up for 4 teams (one for each U.S. region - northeast, midwest, south, west), with each team having up to 5 members (one for each of the criteria pollutants - ozone, PM, SO_2, NO_2, and CO). For classes with more students, some regions may be repeated. For odd number, teams may be smaller than 5 members, leaving out one or more of the air pollutants. *Author's note: I would recommend leaving out SO_2 first, then NO_2.*

Launch

The following is offered as a sample launch for the project. PLEASE take these ideas and make them your own, creating a launch that will work for you!

- Students should sit in their assigned teams as class begins.

- Teacher begins launch by showing a video of the 1952 London fog.
    - *Author's note: The Netflix series The Crown, episode 4, Act of God, covers this event, if you have the ability to stream this at school.*
    - https://youtu.be/bSlwGIapFJI is a decent approximately 6-minute video of the basics
    - Discuss what caused the deadly fog, has anyone experienced smog, etc.?

- Teacher shares Power Point, **"A History of Air Pollution Events"** with class.
    - Gather student reaction to historical incidents of air pollution.
    - How is our air now? What kinds of things pollute our air?

- Driving Question: Is U.S. Air Pollution Getting Better or Worse - How and Why?

- Teacher shares EPA 6 Criteria Air Pollutants

- Teacher leads discussion about LEAD (from student prep work)
    - **What is Lead?** (one of the elements, a heavy metal, a neurotoxin - damages the nervous system, found in many common materials like pipes, paint, batteries, and, in the past, gasoline)
    - **Why is it harmful?** (it is a neurotoxin and affects the nervous system, it is easily distributed throughout the body, interferes with production of red blood cells, particularly harmful to bones)
    - **What are the health effects?** (decreased bone and muscle growth, damage to the central nervous system, developmental delay in children, speech and language problems, ultimately death)
    - **Where is it found? (**abundant supplies, easily extracted, found in many common items)

- Teacher does walkthrough with EPA data on LEAD
    - Adaptable here depending on your curriculum goals
    - In "LAUNCH-Lead-Data" spreadsheet you will find examples in Tab 1055003
        - Lead levels - averages by decade
        - Bar graph of averages by decade
        - 5 Number Summary for entire data set (including outliers)
        - Comparison of data to NAAQS Standards for Lead
        - Line plot w/linear regression model for entire data set
    - The key is to demonstrate analysis possible with data in Google sheets

- Teacher launches U.S. Air Pollution Project by revealing regions for each team, expert assignments for each team member, and **"U.S. Air Pollution Project Overview"**

Task ONE - "Becoming a Pollutant Expert"

This is primarily an INDIVIDUAL task, though there will be a group meeting with all common pollutant experts to summarize findings.

- Student will use provided resources to research their pollutant, seeking
    - What their pollutant is and where it comes from
    - What are the potential health effects of their pollutant?
    - What are the potential environmental effects of their pollutant?
    - Any connection between their pollutant and another of the criteria pollutants?
    - The NAAQS standards for their pollutant and how they have changed

- Student will use the supplied data set for their pollutant and region
    - Select a representative sample of monitoring stations for their region
    - Create a map of their region, marked with county location of selected monitor sites

- Student will use Google Sheets to analyze the data from the selected monitor sites
    - Measures of center, spread
    - 5 Number Summary
    - Graphical displays - bar graph, box/whiskers plot, scatterplots, line plots
    - Find regression models and use them to interpret changes in pollutant levels
    - Determine percentage of time pollutant exceeds NAAQS standards in region

- Student will meet with the experts from other regions to summarize findings

- Student completes **"Pollutant Summary Report"**

Task TWO - "Creating an Air Quality Index"

Students reunite with their Regional group for the remainder of the project. The goal in this task is to create an Air Quality Index that takes into account all five criteria pollutants, then use that AQI to develop a new data set for their region that reflects overall air quality.

- Students meet as a regional team and brief one another on their pollutant.

- Team will determine a selection of common State/County monitor sites to use for this task. They may use "**AQI - Selecting Sites**" to do this.

- Team determines a formula for an Air Quality Index (AQI) and develops an AQI Rating to rate the air quality each day, summarizing work in "**AQI - Formula**"

- Using the common monitor sites and their developed formula, the Team now creates a data set for the last three years (2013-2016) for AQI, and determines the AQI Rating for each day. This information is presented in "**AQI - Data and Rating**"

Task THREE - "Addressing the Effects of Human Beings"

Students will use data from measures in mostly rural areas in their appropriate regions to establish a baseline for their pollutant. This data will then be compared to EPA data from more densely populated regions, in an effort to determine the impact of human beings on air quality. The team will then compare results to hypothesize the reasons for the differences, and to assert the overall impact to air quality.

- Region Team selects a group of rural monitoring stations from their available data.

- Using 2016 data, determine trend models for each of the criteria pollutants from the rural stations.

- Region Team selects a group of urban monitoring stations from their available data.

- Again using 2016 data, determine trend models for each of the criteria pollutants from urban stations.

- Use analysis of the trend models (focusing on the significance of constants in the models) to determine differences for any of the criteria pollutants, with an eye toward the possible impact of people.

- Summarize your findings in "Task Three - Human Effects"

- Each team will give a 7 to 10-minute brief on their region and what they found.

Task FOUR - "Is U.S. Air Pollution Getting Better or Worse?"

As a class, students will attempt to piece together their work from their respective regions, in order to draw a reasonable conclusion about air quality in the U.S. as a whole.

- Driving Question - Is U.S. air pollution getting better or worse - how and why?

- Prior to whole class meeting, each region should complete "Driving Question - Region Report," offering an answer to the driving question (re: their region), with justification from their work.

- Using a U.S. map, with region boundaries shown, allow each group a quick response, recording responses in each region on the map.

- Focus on each of the criteria pollutants - what is the trend in this pollutant in each region? Add to map.

- Possible causes, unintended consequences, interaction between pollutants found in your work?

- Answer the driving question.

PRODUCT: U.S. Map of Air Pollution

FINAL REFLECTION - "What Have We Learned?"

A final reflective piece, done individually, that asks students to think about what they have learned through the project - both in terms of the mathematical processes used and in terms of the issue of air pollution. Students will also be asked to think about things they would have liked to be able to do that were not a part of the project, or about questions that they feel remain unanswered about any part of the project.

- Students will complete "Final Reflection"

Critical Vocabulary

Regression
Measure of central tendency
Measure of spread/variability
5 Number summary
Growth factor
Rate of change

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