

**Annotated Reading on a NYT Article about Long-Term Data taken at
Mauna Loa:
A Lesson on Long-Term Data, Scientific Uncertainty, and the Nature of
Science**

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Developed as part of the ARET@LTERS program, Summer 2023



Teacher: Jacob DeGroot	Unit: Mini Unit on Long-Term Data
Grade/Course: High School Environmental Science/ Earth Science (usually taken in 11th or 12th grade)	Lesson Title: Annotated Reading on a NYT Article about Long-Term Data taken at Mauna Loa
<p>NGSS Performance Expectation: HS-ETS1-1: Analyze a major global challenge</p> <p>Asking Questions and Defining Problems</p> <p>Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.</p> <ul style="list-style-type: none"> Analyze complex real-world problems by specifying criteria and constraints for successful solutions to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. 	
<p>Real World Phenomena Addressed in the Lesson: Research/ Data gathering is often presented to students as a neat process where the scientists follow the scientific method exactly, they set out to answer a single question, and the data comes back quickly, neatly, and without disruption.</p> <p>This lesson seeks to show students that in reality, scientific inquiry often is much messier; my experience at the Andrews serves as proof. Major events such as pandemics, wildfires, volcanic eruptions, or earthquakes can disrupt data collection. In a future extension, I also want to show students that scientists do not always begin with a clearly defined trend in mind; in many cases, patterns emerge only after data have been collected over long periods of time. In Dr. Joe Lamanna’s research at HJ Andrews, long-term data are collected to compare plots of trees at various elevations, and data such as species prevalence, tree size, understory growth under a given tree, etc are collected. While there are hypotheses at the outset of this data collection, future uses that were not planned on can present themselves, such as comparing data before and after a wildfire.</p> <p>This is one of the values of long-term data. Through annotating this article, students can get an introduction to long-term data, the importance of it, the unique advantages of it, and the challenges in collecting it.</p>	
<p>Learning Objectives</p>	

By the end of this lesson, students will be able to:

- Explain why conclusions drawn from short-term datasets can differ from conclusions drawn from long-term datasets.
- Interpret and compare graphical representations of atmospheric CO₂ data collected over different time scales.
- Describe challenges associated with long-term scientific data collection, including disruption by natural events.

Additional Notes

This lesson was developed as part of my participation in the ARETs @ LTERS program and is grounded in my experiences working with scientists at long-term ecological research sites. The lesson is intended to introduce students to the nature of scientific research, particularly the value and challenges of long-term data collection, rather than to focus on a single experimental result.

During my time with ARETs, I worked at the HJ Andrews Experimental Forest, where long-term datasets are central to understanding ecological change. Across two consecutive summers, wildfire activity at the site (the 2023 Lookout Fire followed by the 2024 Ore Fire) disrupted field access and delayed the availability of post-burn datasets. While this prevented the completion of a planned follow-up Data Nugget using pre- and post-disturbance data, it provided an authentic example of how long-term scientific research is often shaped by unexpected constraints and interruptions.

Additional perspectives on long-term ecological research were gained through continued engagement with the LTER community beyond the field experience. During an ARETs-supported trip to the NSTA National Conference in Minneapolis, I participated in an excursion to the Cedar Creek Ecosystem Science Reserve (Cedar Creek LTER). During this visit, Kara Baldwin shared long-term datasets and instructional materials that demonstrate how conclusions drawn from short-term data can differ from those based on longer records. These materials showed a study consistent with the way that long-term data is framed in this lesson, and I would like to find a way to use them in an extension of this lesson.

Since the start of the 2024–2025 school year, my teaching assignment has shifted from Environmental Science to Earth Science. While this lesson was originally designed with Environmental Science standards in mind, its core ideas—data interpretation, temporal scale, and scientific uncertainty—remain applicable in Earth Science contexts and can be adapted to align with different standards as needed.

Science & Engineering Practice(s) Used:

- Scientific Investigations Use a Variety of Methods
- Science investigations use diverse methods and do not always use the same set of procedures to obtain data. (HS-ESS3-5)

Crosscutting Concept(s) Used:

- Science is a Human Endeavor
- Science is a result of human endeavors, imagination, and creativity. (HS-ESS3-3)

Disciplinary Core Idea(s):

- HS-ESS3 Earth and Human Activity
- HS-ESS2 Earth's Systems
- ESS3.B: Natural Hazards

Background Information

Prior Student Knowledge: This lesson is an introductory lesson that can be done at any time of the year. Very little prior knowledge is required for it. That said, after the first year using this lesson, it was clear that students were uncomfortable with this being their first experience with annotated reading according to the JMAC Annotation Guide (electronic version of the guide attached at the end of this lesson). I will use smaller articles to introduce students to annotated reading.

Possible Preconceptions/Misconceptions: As stated above, students often think of data collection as a neat, uninterrupted process. Textbooks often only present experiments that went smoothly and led to revolutionary discoveries. The reality that will be shown to students that science, like all other undertakings, is prone to hiccups in the process.

Content Information for Teacher:

- **Websites:** <https://www.nytimes.com/2023/02/06/climate/mauna-loa-carbon-dioxide-eruption.html>
- **Books:**
- **Videos:** <https://www.youtube.com/watch?v=3jOAlC2dVtA>
<https://www.youtube.com/watch?v=NAuycMXDM4U>

5E	Evidence of Use/Student Activity
<p>Engagement</p> <ul style="list-style-type: none"> • Capture attention • Activate prior knowledge • Connects to the real world phenomenon 	<ul style="list-style-type: none"> - Very little prior knowledge is needed. This activity is more about exploring the nature and methods of science than it is about any particular scientific discipline. For example, I used this lesson last year in my Environmental Science class and plan on using it again this year in my new Earth Science class. - Students will fill out a “Do-Now” slip. These have different names at different schools, but essentially, this will be a half sheet of paper given to students at the start of class with a few questions meant to compare understandings before and after an activity. Even a single question like “Why would it be harder to collect similar data over the course of 60 years instead of 1 year?” - Even though very little prior knowledge is needed for this lesson, it should probably not be the first exercise of the year in which students use the JMAC Annotation Guide. My first year using this lesson, it became clear that I should have introduced the annotation style with smaller articles. - The links above to YouTube videos will be shown to give students an understanding of what happens at the Mauna Loa and Mauna Kea observatories - I will also explain to students how this relates to my experiences at the HJ Andrews Experimental Forest.
<p>Exploration</p> <ul style="list-style-type: none"> • Test ideas and develop knowledge using explorations, investigations, experiments • For NGSS, provide an initial activity/lab that allows for investigation of real world phenomenon (ABC: Activity Before Content) 	<ul style="list-style-type: none"> - Students read the article individually with different colored pens or pencils for the different annotation marks (?, circle, underline, lightbulb, and !). They will be encouraged to make notes in the margins - Students will be instructed to complete the “Paraphrase, Comment, Predict, Connect, Question” section of the worksheet. The classroom will have both the “JMAC Annotation Guide” poster and the “Say Something” displayed for students to work off of. - Once the Data Nugget to accompany this lesson is ready, this lesson will serve largely as the “Activity Before Content”
<p>Explanation</p>	<ul style="list-style-type: none"> - Go over the part of the worksheet students have already

<ul style="list-style-type: none"> ● Analyze data/information and construct explanations ● Communicate understandings orally and in writing ● Describe possible solutions 	<p>completed. What did they take away from the article?</p> <ul style="list-style-type: none"> - Put the 2 different graphs of atmospheric CO2 concentration (2-year chart and 60-year chart) on the smart board for students to see. - Ask students what might be missed if only the 2-year chart was observed? Make a comparison to the yearly cycle being individual waves, and the 60-year increase being more akin to the tide slowly coming in. - Students will then complete the worksheet, either individually or in pairs
<p>Extension</p> <ul style="list-style-type: none"> ● Modify/refine procedures, prototypes, models, solutions, arguments, essays, etc. ● Apply or practice in a new setting 	<ul style="list-style-type: none"> - See <i>“Possible Extensions”</i> below.
<p>Evaluation</p> <ul style="list-style-type: none"> ● Self-assess understanding of concepts ● Demonstrate understanding of concepts through performance-based tasks ● Reflect and/or revise answers or solutions to a complex question, issue, challenge, or real world problem 	<ul style="list-style-type: none"> - While this lesson exists as a standalone lesson (without an accompanying Data Nugget), most of the evaluation will come from grading the worksheets. That said, in the spirit of making this a complete 5E lesson, students will perform some self-assessment in the following manner - Students will fill out an exit slip where they are asked if they would answer the “Do Now” question the same way.
<p>Lesson Closure</p> <ul style="list-style-type: none"> ● Summarize the lesson ● Check for understanding via exit slip or exit ticket ● Preview the next lesson 	<ul style="list-style-type: none"> - The exit slip in the previous “Evaluation” section also applies here. - Lead in to the following Data Nugget

Possible Extensions

As noted above, this lesson was originally intended to serve as a lead-in to a Data Nugget activity that I would develop for students. That follow-up lesson was planned to use pre- and post-burn data from the HJ Andrews Experimental Forest to allow students to examine how ecological conclusions can change when data are viewed across different time scales.

That Data Nugget could not be completed as originally planned because I was unable to obtain the necessary pre- and post-burn datasets. Across two consecutive summers, wildfire activity at the HJ Andrews interrupted field access and delayed the availability of post-disturbance data needed to support a meaningful comparison. As a result, the Data Nugget extension could not be developed within the project timeline.

One possible extension of this lesson would be the use of an existing, fully developed Data Nugget from the Data Nuggets website that emphasizes similar concepts related to long-term data, temporal scale, and scientific inference. Given my current teaching assignment in Earth Science, such an extension could be selected to align more directly with Earth Science standards while preserving the instructional goals of the original lesson.

Another potential extension would involve developing a Data Nugget or related data-analysis activity using long-term ecological data shared with me from the Cedar Creek Ecosystem Science Reserve (Cedar Creek LTER) in Minnesota. These data and accompanying instructional materials were shared with me by Kara Baldwin during an ARETs-supported excursion to Cedar Creek at the NSTA National Conference in Minneapolis. This dataset provides an additional opportunity for students to explore how conclusions drawn from short-term datasets can differ from those based on longer-term records.

More broadly, this lesson is designed to remain flexible as new datasets become available. Any future extension would continue to emphasize the core ideas of this lesson: the importance of long-term data, the limitations of short-term observations, and the reality that scientific research is shaped by both planned investigations and uncontrollable environmental events.

Links to Relevant Materials, Copies of the Work Packet, and a Copy of the Poster Presented at San Francisco AGU 2023

NYT Article

<https://www.nytimes.com/2023/02/06/climate/mauna-loa-carbon-dioxide-eruption.html>

JMAC Annotation Guide

https://drive.google.com/file/d/1V5O_-Lqh42cCXDGM_acmHj1FpWG0zV6J/view?usp=drive_link

Workalong sheet for project

https://docs.google.com/document/d/17W9WAGkI32FZDMfl_gDYVMj55-fWgTao/edit?usp=drive_link&oid=114291948531454932606&rtpof=true&sd=true

Authentic Research Experience for Teachers at Long Term Ecological Research Sites (ARETs @ LTERS)

<https://lternet.edu/authentic-research-experience-for-teachers-lters/>

Long-term ecological study illustrating differences between short-term and long-term conclusions (Reich et al., Science, 2018) — potential dataset for future lesson extensions; shared with me by Kara Baldwin during an ARETs-funded trip to the NSTA National Conference (Minneapolis, 2025)

<https://www.science.org/doi/epdf/10.1126/science.aas9313>

Poster presented at AGU for the lesson plan

https://docs.google.com/presentation/d/1j6fOnGiudF5k3ROGFH71IBWO_SF2qYvt/edit?usp=sharing&oid=114291948531454932606&rtpof=true&sd=true



ANNOTATION



Circle

Draw a circle around new vocabulary and unfamiliar words

Question Mark

Underline any phrase you question and sketch a ? in the margin



Check Mark

Underline main ideas in the text and place a check mark in the margin to note key concepts

Exclamation Point

Indicate surprising info or ideas using an exclamation point in the margin



Light Bulb

Scribble a light bulb in the margin to show clarity and "a-ha" moments

EXAMPLE

You may have heard about e-cigarettes, and even heard from other kids that using e-cigarettes (also known as **vaping**) is a safer alternative to smoking conventional cigarettes. But the truth is that vaping exposes you to lung-damaging chemicals and can lead to a severe health problem: addiction. And if you think that getting addicted could never happen to you, think again. You're actually more vulnerable than adults to

addiction because your adolescent brain is still developing. ?

NICOTINE DANGER

You may have seen some kids using a vape product like Juul or Puff Bar. Maybe you've even thought about trying vaping, whether from curiosity or boredom, or because you feel peer pressure. You may have heard that it's no big deal to vape once in a while. But vaping even "just a little" can open the door to addiction.

That's because the liquid inside most vapes contains nicotine, the same highly addictive chemical in tobacco cigarettes. This liquid also contains flavorings and other chemicals. Instead of producing smoke, the device creates an aerosol for a user to inhale that resembles a **vapor** (that's where the term "vaping" comes from). You can't always rely on a label to tell you exactly what's in a vape. Some vapes claim they are nicotine-free, but they actually contain nicotine. 

SAY SOMETHING

Paraphrase

"The way I think of this..."

Comment
"Weight training has improved my balance"



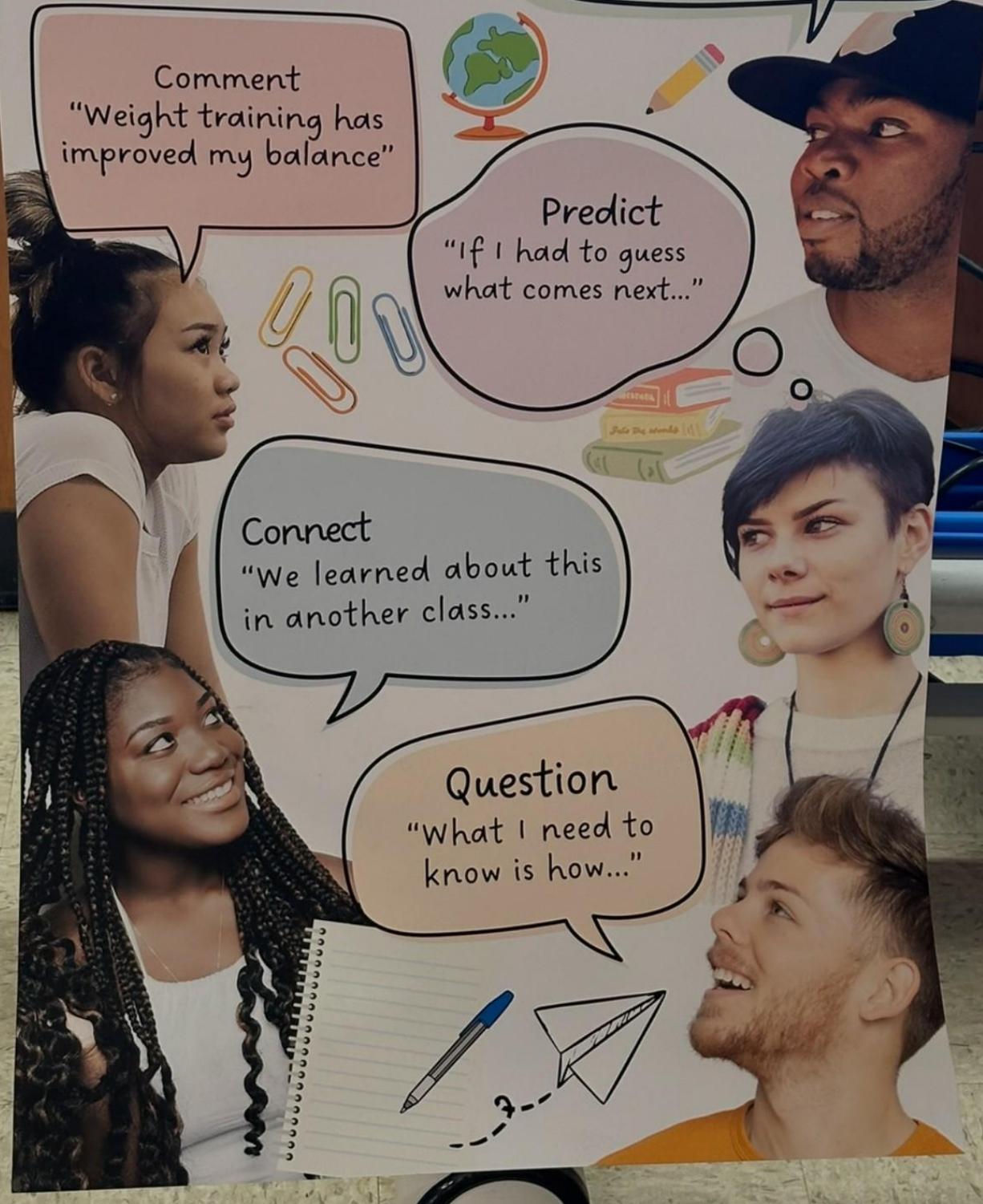
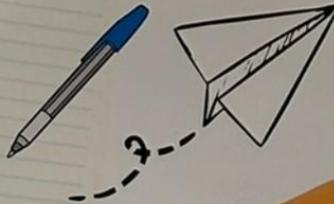
Predict
"If I had to guess what comes next..."



Connect
"We learned about this in another class..."



Question
"What I need to know is how..."



Name: _____ Date: _____ Block: _____

Material to use alongside New York Time Mauna Loa article

Paraphrase:

Comment:

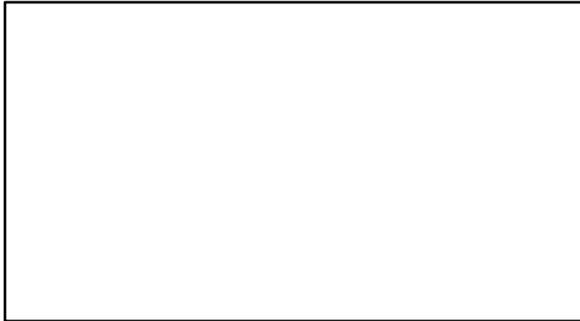
Predict:

Connect:

Question

Look at the board. There are 2 graphs of CO₂ data taken at Mauna Loa. One of them shows data over the course of 2 years, and one of them shows data over the course of 60 years.

Listen to Mr. DeGroot's explanation of the yearly cycle of CO₂ concentration, and then roughly sketch the shape of the 2 graphs in the following boxes, with the 2-year data on the left and the 60 year data on the right



2 Year

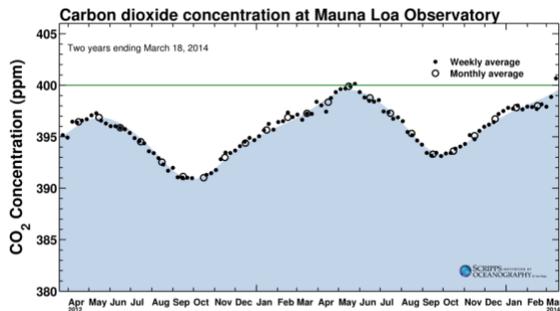


60 year

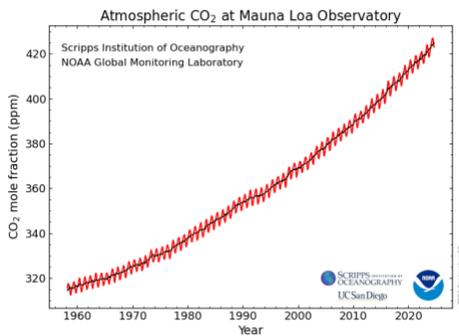
1. Why, in this particular instance, was it very important to have long-term data?
2. What are some reasons that it is more difficult to collect long-term data rather than short-term data? (There are several reasons, and the article mentions some)
3. There are some instances where long-term data isn't an option. An example may be trying to properly test the safety and effectiveness of a vaccine for a disease that is actively causing a pandemic. What alternatives are there to long-term data?
4. Even though the volcano knocked out the station at Mauna Loa, and instruments have been set up on the neighboring mountain Mauna Kea, scientists would like to keep gathering data at Mauna Loa. Why is this important? If you don't have an exact answer, a guess is great.

Pictures of Graphs for Comparing Long Term Data and Short Term Data Taken at Mauna Loa

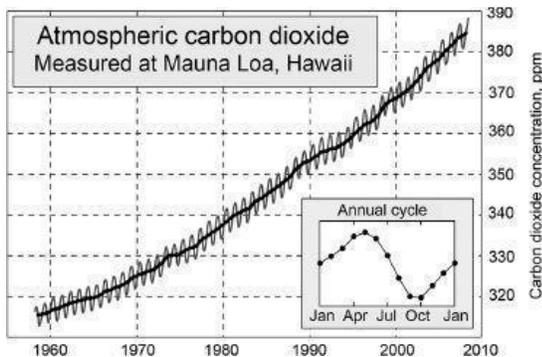
2 years of data



60 years of data



Graph that shows data at both scales



2023 AGU Poster for Presentation on the Lesson Plan

Transferring Data Literacy Skills from ARETs to the Classroom, with Emphasis on Long-Term Data

Jacob DeGroot

Science Teacher at James Madison Academic Campus, Attending AGU Conference Through ARETs at LTERS



ABSTRACT

In an era where more value is placed on standardized testing than arguably ever before, it is important to understand what is expected of students. Rather than specific scientific content knowledge, much more emphasis is now placed on scientific practices and data literacy since the Next Generation Science Standards were implemented. For example, it is much more important for a student to be able to read and analyze a graph that compares the diameter of *Pseudotsuga menziesii* trees to the elevation of those trees than it is for students to be able to know and recognize the scientific name of the Douglas Fir.

Similarly, while the field work done through the ARETs (Authentic Research Experience for Teachers) at LTERS program provides participants with a rich opportunity to see how science is actually done, the specific content knowledge teachers gain in topics like aquatic insects, understory data, or spider diversity are all of minor importance in our classrooms. What is of major importance, on the other hand, is being able to show students how data is collected, analyzed, and used to ask questions and find answers. One specific thing that has been impressed upon the participants, and should likewise be impressed upon students, is the importance of long term data collection.

Using my experience with data literacy professional development in the ARETs program as a model, I teach my students that not all data is created equally. I work with my students to help them understand what constitutes "long-term" data, stress the importance of it, and show ways in which a study may try to get around a short time frame by trying to replicate the benefits of long term data. To accomplish this, I use information gathered from the data literacy professional development workshop series, data shared with me and articles published by LTER researchers, and my experience collaborating with researchers at the H.J. Andrews Forest LTER site.

Objectives

- Collaborate with educators and scientists, developing strategies to improve data literacy in students
- Discuss my time at the HJ Andrews with the ARETs program
- Present and make available a lesson plan crafted with the James Madison Academic Campus Annotation Guide, which seeks to improve student literacy in general and scientific literacy in particular
- Emphasize the importance of long-term data collection

ARETs Timeline



Authentic Research Experience for Teachers (ARETs) has a two-year cycle for each cohort of teachers. In addition to the HJ Andrews Forest, the 2022 cohort also placed teachers at LTERS stations located in Santa Barbara and in the North Slope of Alaska.

Field Experience at the HJ Andrews

I was told about the Authentic Research Experience for Teachers (ARETs) program by department chair last year. Professor Joe Lamanna of Milwaukee's Marquette University was overseeing several ongoing studies with the so dubbed "Plant Crew" at the HJ Andrews Forest, a Long Term Ecological Research Site (LTERS). Along with fellow teachers Matt Retterath and Ryan Herlands, 2 weeks were spent doing field work with Professor Lamanna's crew. We also had the opportunity to work with Oregon State University's Ian Arismendi, and his "Bug Crew," studying the emergence of aquatic insects near streams.



Collecting Data with "Plant Crew": teachers work on projects involving long-term monitoring of tree growth on designated plots, underground studies, and transpiring of seedlings from high-elevation areas to low. We also collected insect and animal specimens with "Bug Crew" to study their diversity near streams.

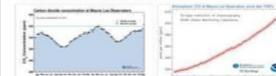
James Madison Academic Campus (JMAC)

James Madison Academic Campus (JMAC) is a school serving students on Milwaukee's North Side. Part of the School Improvement Plan strives to increase reading proficiency both on standardized tests and in general. Teachers have been encouraged to have students engage in annotated reading across curricula. The school has developed the JMAC Annotation Guide for students to follow.



Annotating an Article About Long-Term Data taken at Mauna-Loa

Piloting what will become a larger lesson called a "Data-Nugget" in accordance with the goals of the ARETs Program, a smaller lesson was introduced in which students annotate a scientific reading. A February 2023 New York Times article was selected, which reports on a volcanic eruption at Mauna Loa which temporarily disrupted data collection at an observatory located on the mountain. CO₂ readings have been taken at the Mauna Loa observatory since 1958. The article provides examples of both the benefits and the challenges associated with gathering long-term data. Students were instructed to annotate the article according to the above annotation guide, and complete an accompanying worksheet.



Students were shown these two graphs which illustrate how short term datasets often fail to show the bigger picture. They were asked questions about gathering long-term data. The brochure, article, and worksheet can be found using the QR code on this poster.

What comes Next?

Teachers from the 2023/24 ARETs cohort at all 3 LTERS have had monthly zoom meetings in which lesson plans are discussed. Some, including myself, have already implemented lesson plans influenced by our time spent in the field. This collaboration will continue for at least the next year in the following ways

- Continued collaborative meetings on Zoom
- At DataPlaza conference in Santa Barbara, July 2024, teachers will have the opportunity to discuss research sites and peer review classroom activities.
- Teachers will return to their Long-Term Ecological Research Sites to gain further field experience and to mentor the incoming cohort of ARETs teachers.
- Throughout this time, each teacher will develop a larger Data Nugget lesson plan. More information on Data Nuggets, as well as downloadable lessons crafted in the format, can be found at datanuggets.org
- Data Nugget lessons will be implemented in the classroom in 2024

Acknowledgements

I would like to thank Karl O'Connell and Amanda Morrison for helping prepare all of the teachers for the field assignments with the ARETs program and continuing to help develop lesson plans afterwards. I would like to thank Amanda in particular for helping me prepare for this conference.

Additional thanks to Dr. Joe Lamanna and Dr. Ivan Arismendi for welcoming the teachers assigned to HJ Andrews into their research teams. Also, thank you to their students and their techs, who helped the teachers so much to learn the ropes in conducting the research which was already underway

Finally, thanks go out to my Science Department Chair JoEllen Krause, and MPS Science Instructional Chief, for bringing the opportunity of the ARETs Program to my attention.

Scan this QR code to pull up a set of links with the full lesson plan, student samples, the Annotation Guide in poster form, and other relevant documents



SCAN ME