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The Vera C. Rubin Observatory on Cerro Pachón during a snowy day.

Photo Credit: NOIRLab/NSF/AURA/C. Corco

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Message from the Editor

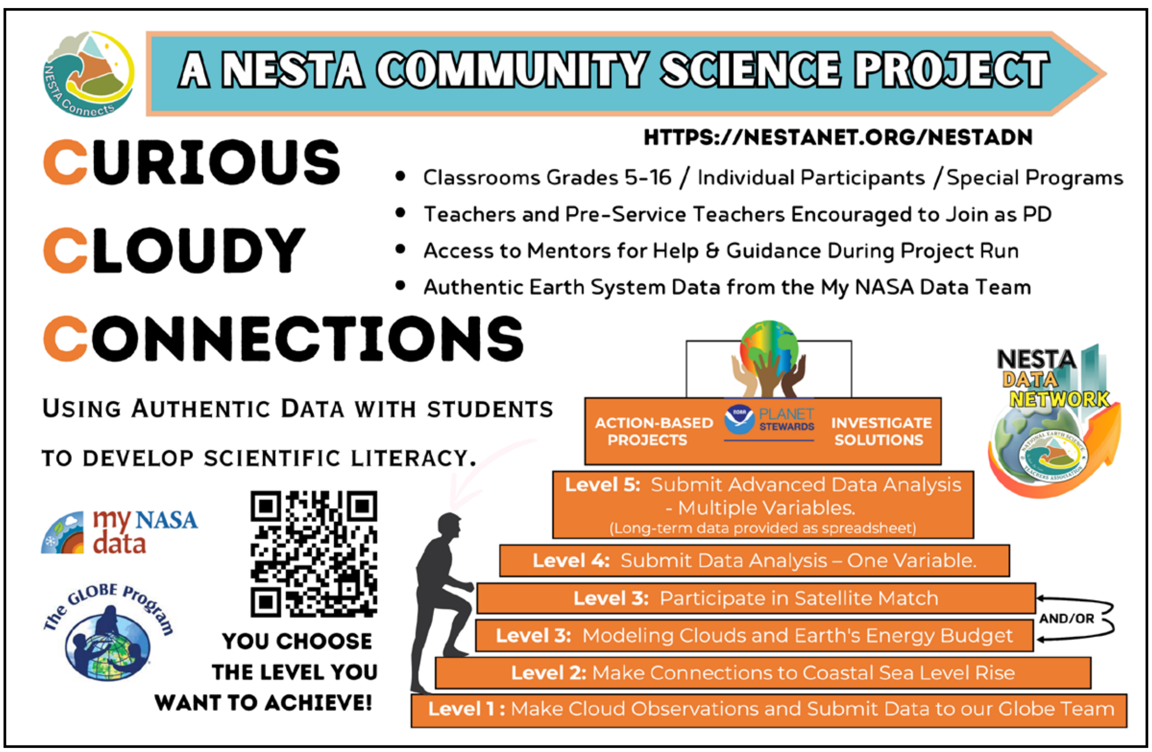
By Peg Steffen, Editor, The Earth Scientist

The focus of this issue of *The Earth Scientist* is on data literacy and engaging students in the practices of science, specifically the Earth sciences, in grades 6-12. This issue highlights ideas, websites and initiatives to help develop data literacy with investigations that help students understand systems of the Earth, learn about technology tools to study the Earth, its ocean, and deep space, and to tackle the challenges of climate change and environmental problems. This issue also features an article from the American Geosciences Institute about Earth Science Week. The week-long celebration happens each year at the beginning of October. However, the resources, webinars and opportunities are available year-round.

This issue is open access and we hope that you will share this with colleagues who may not be members of NESTA. Consider this an invitation to you and your teaching colleagues to embrace data literacy at all levels of education.

Enjoy!

Peg Steffen



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NESTA'S MISSION

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EARTH SCIENCE WEEK 2024: Appreciating Earth Science Everywhere

Lindsay C. Mossa, Lauren Brase, Sequoyah McGee, and Edward C. Robeck, AGI

Educators around the world are invited to celebrate Earth Science Week 2024 all year round as we focus on the theme "Earth Science Everywhere." Through this theme, the American Geosciences Institute (AGI) and our partners – including NESTA, the Geological Society of America (GSA), National Park Service (NPS), NASA, and many others – aim to increase knowledge about Earth's systems and their interactions. We also call attention to global issues by connecting educational materials with the United Nations' Sustainable Development Goals (SDGs). The SDGs were adopted by UN member countries in 2015 to improve living and environmental conditions around the world. Awareness of how the geosciences help people achieve the SDGs can lead to a greater appreciation for earth science education and related fields.

Earth Science Week 2024 took place on October 13-19, but AGI hosts the Earth Science Week website where free resources can continue to be accessed. As part of the celebration, AGI and our partners have created a toolkit with posters, games, and other instructional materials for K-12 and informal educators that be used in classrooms, clubs, camps, and outreach events for learners of all ages. 2024 Earth Science Week Toolkits are available for the cost of shipping and handling. The toolkit includes a calendar in which we highlight geoscience-related dates,

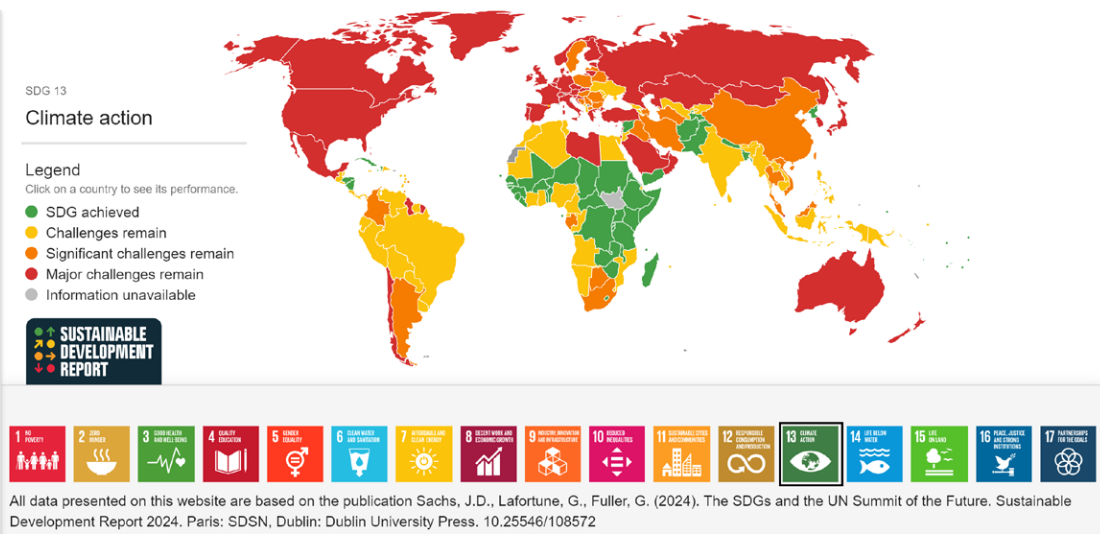

Figure 1. EO4SDG's interactive map can be used by students who complete their calendar activity to see each country's progress toward the SDGs based on reported data. This figure shows data for SDG 13: Climate Action.
Photo Credit: Sustainable Development Report

Geoscientists without Borders® (GWB) projects, and learning activities designed by our partners. The calendar dates such as Earth Day, National Geocaching Day (sponsored by GSA), and World Soil Day (sponsored by the Food and Agriculture Organization of the United Nations) can inspire conversations about how earth science ties into many parts of our lives.

New this year, each month has a callout box describing a GWB project. These projects have taken place around the world, using innovative geophysical techniques and technologies to access clean water sources, mitigate impacts of natural hazards, and maintain biodiversity. The callout boxes also connect to an educational resource to learn about the earth science concepts with which each project relates. Each month's educational activity relates to the Next Generation Science Standards (NGSS) and the SDGs. Showcased as an academic year calendar, activities begin in August. Each activity is written by Earth Observations for the SDGs (EO4SDG) in partnership with the Earth Science Information Partners (ESIP). The activity has students collect data to monitor the environment and shows them how this data can also track progress being made on certain SDGs. We intentionally made this the first activity in the calendar so SDGs could be introduced early in the school year, helping students make connections to global issues and work being done to address them as they learn new earth science concepts.

In addition to the toolkit, AGI hosts a webinar series each day of Earth Science Week to provide background, data, and strategies for bringing topics related to the theme into the classroom. The 2024 webinar topics include: sustainability; plastics and human health; geologic mapping of impact craters on the Earth and Moon; earth science being conducted at the poles; and regenerative agriculture. The recordings of these webinars are available on AGI's YouTube channel.

AGI also hosts four annual Earth Science Week contests. Although the 2024 contests are now closed to entries, check back in December to see submissions from this year's winners and finalists. The visual arts contest is for U.S. students in grades K-5. Submissions for the 2024 visual arts theme, "Putting the ART in eARTh Science," should illustrate the diversity and beauty of Earth's features and processes. The essay contest asks U.S. students in grades 6-9 to write about "How Earth Science Affects Us All," with a focus on how earth science concepts can be used to address a current global challenge. The photography and video contests are open to people of all ages in any part of the world. Photo submissions should show "Earth Science in Action" by capturing Earth processes. Video submissions can be created by teams or individuals and should address how "Earth Science Connects Us" as people around the world

Figure 2. In the winning submission of the 2018 Earth Science Week Visual Arts Contest, Namit Vernekar of Charlotte, North Carolina, depicted both a realistic and an imaginary Earth. Photo credit: AGI

The Earth Scientist

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Patty Schuster, Page Designs

can experience the same Earth processes. The 2025 Earth Science Week Contests will open for submissions starting in late spring, so check back for descriptions of those contests!

Every year, many individuals and organizations host presentations, interactive exhibits, and other events that engage students and the public with the Earth Science Week theme. Many of these events center on the week's Focus Days and highlight a specific aspect of the geosciences, from geologic maps to archaeology and fossils. Our Earth Science Week website has guidance on hosting events, as well as a map showing last year's events, from which you can discover who in your area typically hosts events in addition to drawing inspiration from what others have done. We encourage you to consider hosting an event for Earth Science Week 2025, which will occur on October 12-18, 2025.

Whether you're an educator, student, or community member, there are countless ways to get involved and discover the importance of earth sciences in our daily lives and global sustainability efforts. Visit the Earth Science Week website for more information and email us at info@earthsciweek.org to let us know how you are celebrating "Earth Science Everywhere" all year round.

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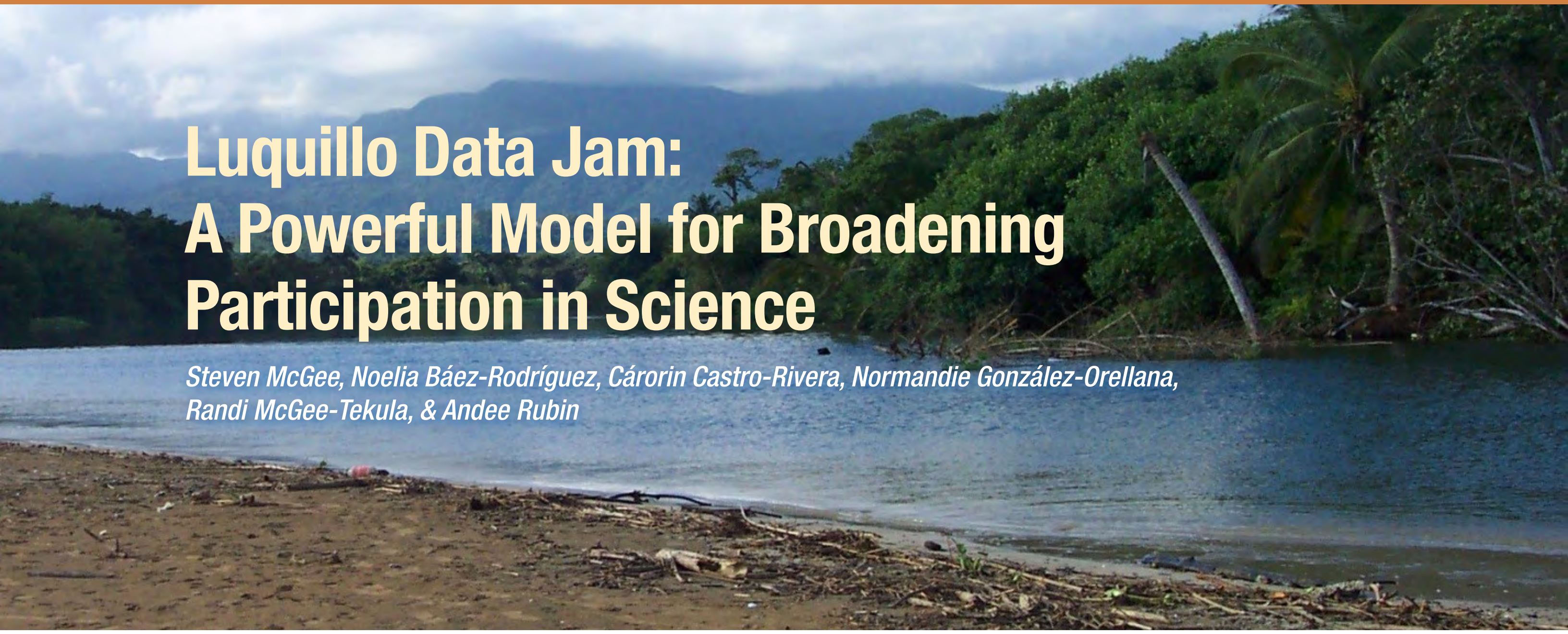
Luquillo Data Jam: A Powerful Model for Broadening Participation in Science

Steven McGee, Noelia Báez-Rodríguez, Cárorin Castro-Rivera, Normandie González-Orellana, Randi McGee-Tekula, & Andee Rubin



Pico del Este and the Rio Mameyes, El Yunque National Forest, Puerto Rico. Orographic clouds (as shown) are a significant source of annual precipitation and streamflow. Photo credit Martha Scholl, USGS.

Abstract

The Luquillo Long-Term Ecological Research (LTER) program in Puerto Rico has implemented a Data Jam initiative that fosters student engagement in ecological data science. In December 2023, over 175 middle and high school students presented 51 data- driven projects at a symposium in El Yunque National Rainforest. The initiative, rooted in the LTER's extensive datasets, allows students to develop research questions, analyze data using the CODAP tool, and present findings. The program includes professional development for teachers, with workshops and Virtual Lab Meetings that equip them to guide students through the scientific process. Teachers collaborate across disciplines, integrating Data Jam into their curricula. The program has positively impacted students, increasing their interest in local environmental issues and confidence in data analysis. The use of publicly available datasets tailored for educational purposes, alongside mentor support from LTER scientists, provides a robust framework for students to engage deeply with ecological data. This initiative not only enhances STEM education but also strengthens students' connection to their local environment and the broader scientific community.

Introduction

On December 13, 2023, more than 175 middle school and high school students from 19 schools across Puerto Rico presented 51 data science projects based on independent research they conducted related to the Luquillo Long-Term Ecological Research (LTER) program (See Figure 1). This research symposium took place in the visitor center at the El Yunque national rainforest in Puerto Rico. Twenty-one projects were related to factors that affect the abundance of shrimp in El Yunque. Eighteen projects examined the hydrology of rivers in El Yunque. Twelve projects examined factors related to the size and abundance of dragonflies in streams in El Yunque and surrounding urban areas in Puerto Rico. Roughly two dozen undergraduate students, graduate

Figure 1. Data Jam students discuss a poster at the symposium.

students, and faculty from the University of Puerto Rico attended the symposium to view the projects and provide feedback.

This symposium is the culminating activity of the Luquillo LTER Schoolyard Data Jam program. The foundation of the Luquillo Data Jam program is the vast amounts of publicly available datasets that are generated as part of the LTER program. The LTER Network was created by the National Science Foundation in 1980 to conduct research on ecological issues that can last decades and span huge geographical areas. As the largest and longest- lived ecological network in the United States, LTER provides the scientific expertise, research platforms, and long-term datasets necessary to document and analyze environmental change. Luquillo joined the LTER network in 1988. An important part of the LTER mission is to provide public access to the long-term datasets produced across the network. The Data Jam model was initially developed at the Jornada Basin LTER in 2012 to help students and teachers access and use these LTER data for educational purposes (Bestelmeyer et al., 2015). The Luquillo LTER in Puerto Rico joined the Data Jam program and hosted its first Luquillo Data Jam in 2015 (McGee & Baez-Rodriguez, 2017).

Within Data Jam, classroom teachers support middle and high school students in developing their own scientific questions that can be answered using LTER and related datasets. The Luquillo Data Jam bilingual website (https://datajam.cloud) provides access to student-friendly versions of long-term environmental data along with data science lesson plans. The projects were all conducted with data collected in Puerto Rico, thus helping students connect with the environment on their island. Each of the datasets includes metadata, which describes the structure of the data and how it was collected. While Data Jam students do not collect their own data, they are expected to become familiar with the metadata and be able to describe the data and consider how the data was collected when drawing conclusions.

Students then use a student-friendly graphing tool called CODAP to analyze the data as evidence and develop a scientific argument that addresses their scientific question. During the 2023-2024 school year, teachers implemented Data Jam in their classrooms with more than 650 students. Data Jam culminates with teachers selecting the best projects from their students to present at the Data Jam symposium. The symposium participants are provided feedback on their presentations by peers, family members, educators, and scientists.

Surveys of Data Jam participants show that students report increased levels of interest in their local environment and confidence in using data to investigate environmental science topics.

Successful Data Jam projects require that students engage in a variety of data practices that underlie the STEM field of data science. Data Jam supports students in developing high quality Data Jam research questions that anticipate statistical variability. To investigate these Data Jam research questions, students describe the distribution of the data in terms of its center, spread, and shape. They use CODAP to develop graphs as a means to display the distribution of the data. Students can compare distributions using box plots and analyze the extent of overlap between the interquartile ranges of the two distributions. Students can analyze the relationship between variables using a regression line on a scatter plot.

To support teachers in the enactment of Data Jam, we have developed a professional development model that engages teachers as apprentices to ecological scientists and provides the teachers with the support they need to engage their students in data-based ecological research. Teachers participate in a weeklong summer professional development program to improve their statistical education skills and prepare them to support students conducting their Data Jam projects. During the school year, teachers participate in Virtual Lab Meetings with their peers and a scientific mentor to examine student progress and adjust the support that they provide leading up students' culminating final project.

Data Jam Examples

For the fall 2023 Data Jam, students had access to three datasets related to shrimp, Odonata (dragonflies), and hydrology. Here we provide a project example related to each dataset. Most students developed their projects in Spanish and the remainder developed their projects in English.

- **Shrimp:** For more than 30 years, Luquillo LTER scientists have been following shrimp populations in the Quebrada Prieta, a stream located in the El Yunque rainforest. Freshwater shrimp are paramount for the ecosystem, since they help keep the water clean and distribute resources across the food web. The Data Jam version of the shrimp dataset contains weekly data on the amount of shrimp per trap in pool 0 in Quebrada Prieta from 2012-2019, along with environmental and water chemistry data (González-Orellana, 2023c). We provided students with fewer years than are available so the size of the weekly dataset would be manageable. The dataset includes the three most common shrimp species in El Yunque: *Atya lanipes, Xiphocaris elongata* and *Macrobrachium spp*. One group of students who presented at the symposium in English developed a scientific question on the relationship between water temperature and shrimp count: "Is there a relationship between water temperature and the number of shrimp per trap in pool 0?" The students hypothesized that rising temperatures due to global warming may lead to a decrease in the number of shrimp. Figure 2 shows the scatterplot and least squares line that the students produced in CODAP. The students concluded that there is no relationship between temperature and shrimp count due to the low R_2 value.

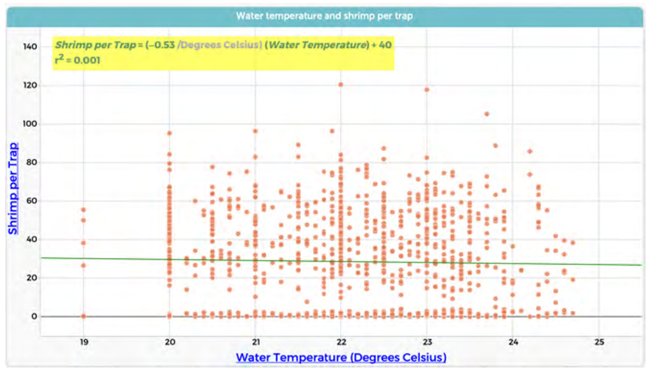


Figure 2. Student graph shows the relationship between water temperature and shrimp count.

  As part of their poster, students share what they are still curious about after their analyses. This group of students asked, "How long could shrimp live if the water temperature was higher than the data provided?" The students seem to recognize that although water temperature does not have an impact within the typical range, it is possible that it could impact the shrimp if water temperatures rose beyond this range.

- **Odonata** often serve as bioindicators (a species whose abundance can reveal information about the status of an ecosystem) because of their dependence on fresh water and prey availability. Odonata larvae are aquatic and rely on good water quality for proper development. A significant part of the diet of an Odonata is insects, so they rely on the abundance and availability of other insects to survive. Hence, if there is an abundance of Odonata, it can be concluded that the ecosystem is healthy enough to sustain an abundance of Odonata. The metropolitan area of Puerto Rico is one of the most inhabited and anthropogenically developed areas of the archipelago. This may have detrimental effects on biodiversity. To study the abundance of the Odonata in the streams of the mountains of El Yunque after the impact of the Hurricane Maria, researchers did a survey of Odonata larvae and their size at a stream in the El Yunque National Rainforest and a stream in the metropolitan area of San Juan. This dataset contains species richness and abundance of Odonata (González-Orellana, 2023b). One group of students who presented at the symposium in Spanish developed a scientific question about differences in body length between two species of Odonata: "¿Es diferente el largo del cuerpo

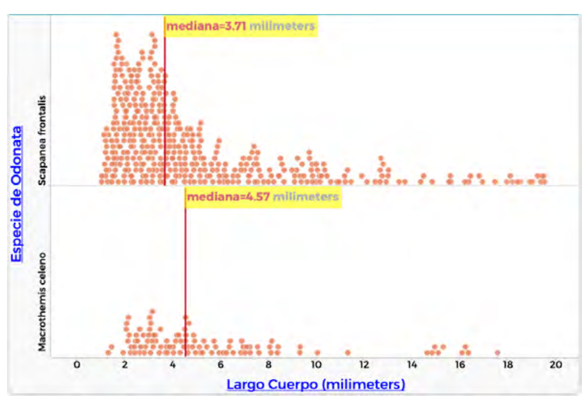


Figure 3. Student graph compares the body sizes of two different species of Odonata.

de las larvas del género Odonata según su especie?” *“Is the body length of larvae of the genus Odonata different according to their species?”* As part of their background information, the students reported that Odonata species are differentiated by body size, wings, and eye position. Therefore, they hypothesized that there would be a difference in size between the two species. Figure 3 shows the graphs of the two distributions of body size by species. CODAP displayed a line where the median is for each distribution.

The students concluded that the *M. celero* species are generally larger than *S. frontalis*. These findings led the students to wonder whether the life spans of the two species were different: “¿Las libélulas y las damiselas tienen el mismo largo de vida?” *“Do dragonflies and damselflies have the same life span?”*

- **Hydrology:** The data on the hydrology and meteorology of El Yunque were constructed from data collected by the United States Geological Survey (USGS) in different bodies of water in El Yunque and data collected by scientists at the El Verde Field Station in El Yunque (González-Orellana, 2023a). There are four rivers represented in this dataset. Each river originates in El Yunque. After leaving El Yunque, the Río Mameyes, Río Grande, and Río Espíritu flow through the city of Río Grande to the north of El Yunque. The Río Icacos flows through the city of Naguabo to the southeast of El Yunque. The hydrology dataset includes monthly values for rainfall, water discharge, and water levels at the different rivers from 1990 to 2022. We are able to provide the full dataset since the data are aggregated to monthly values. One group of students who presented at the symposium in Spanish developed a scientific question about the relationship between rainfall and streamflow: “¿Existe una relación entre la descarga y la lluvia en el Río Icacos?” *“Is there a relationship between discharge and rainfall in the Rio Icacos?”* The students developed an interest in studying the river as an outgrowth of the learning activities that involved the hydrology dataset. Figure 4 shows the scatterplot and least squares line that the students produced in CODAP.

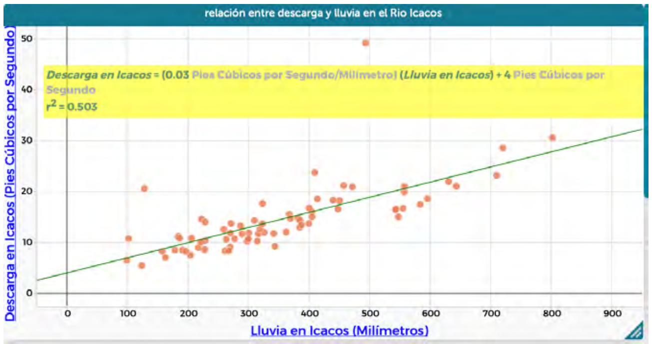


Figure 4. Student graph showing the relationship between rainfall and discharge.

The students concluded that there is a moderate relationship between rainfall and discharge based on the R2 value of 0.503. The students pointed out that the outlier value with significantly higher discharge is from September 2017 when Hurricane Maria struck Puerto Rico. These findings led the students to wonder how discharge affects the shrimp in the river: “¿Cómo la descarga del Río Icacos afecta la población de camarones” *“How does the discharge of the Rio Icacos affect the shrimp population?”*

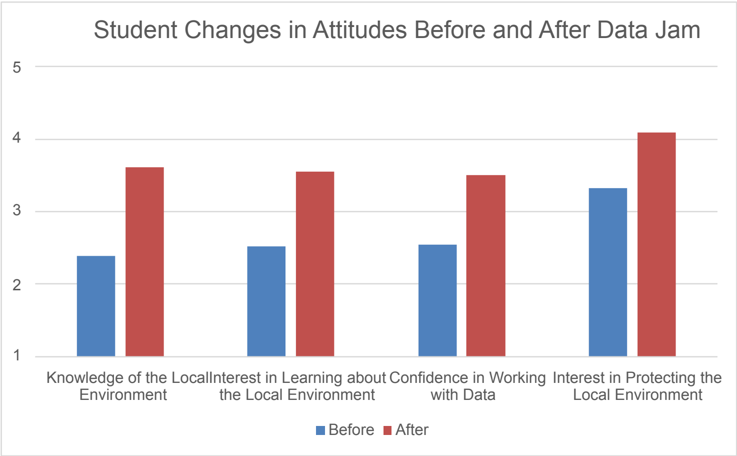


Figure 5. Student changes in attitude before and after the Data Jam.

Student Reactions

All participating students were surveyed about their experiences with Data Jam. Students felt the most confident in working as a team to choose a dataset and create the graphs. The students felt the least confident in analyzing the data and developing their scientific argument. Overall, students reported a significant increase in their knowledge of the local environment, their interest in learning more about the environment, their confidence in working with data, and their interest in protecting the local environment (Figure 5).

Forty percent of the students indicated that participating in Data Jam increased their interest in majoring in a science discipline when they go to college. We interviewed a randomly selected subset of students who participated in the symposium. Many of the comments about their experiences with Data Jam were consistent with the survey results. Below are representative student quotes.

What did you like the most about Data Jam?	
Lo que más me gustó de Data Jam fue graficar, porque ahí es donde podías sentido a lo que estábamos tratando de graficar. Y también el diálogo con los científicos de ayer. Me hicieran sentir exitoso, como si lo que hice valiera la pena y que descubriera algo importante.	What I liked most about Data Jam was graphing, because that's where you could make sense of what we were trying to graph. And also, the dialogue with the scientists yesterday. They made me feel successful, like what I did was worthwhile and that I discovered something important.
Lo más importante eran los gráficas buscar los puntos para poder conectarlos. Eso es lo que más me gustó.	The most important thing was the graphs, looking for the dots to be able to connect them. That's what I liked the most.
How has Data Jam changed your view of yourself as a scientist?	
Siento que encajo, porque al final, son datos que ya existen, pero lo estoy haciendo, y lo analizo con mi forma de pensar y cómo interpreto los datos.	I feel like I fit, because at the end of the day, it's data that already exists, but I'm doing it, and I analyze it with my way of thinking and how I interpret the data.
Siempre he dicho, que he querido ser más como un médico. Ahora estoy cambiando. Sobre todo mis amigos me dicen "últimamente te he imaginado más como un científico, como si quisieras encontrar una solución a todo". Mis padres se dan cuenta. Ayer llegué con mi afiche y se lo expliqué. Como que ven que esa parte de la ciencia me emociona más.	I've always said that I wanted to be more like a doctor. Now I'm changing. Especially my friends tell me "lately I've imagined you more like a scientist, like you want to find a solution to everything". My parents notice. Yesterday I came in with my poster and explained it to them. They kind of see that that part of science excites me more.

Professional Development and Implementation

Data Jam aims to impact math and science teachers from the public and private education system in Puerto Rico. The professional development model (Delgado-Quiñones et al., 2023) aligns to the five key features of effective professional development outlined in Desimone and Garet (2015)'s empirical framework and includes:

1. Sustained duration of more than 20 hours of professional development,
2. A focus on disciplinary content through investigations of data,
3. Actively engaging teachers in learning with and reflecting on data,
4. Supporting coherence with course goals, and
5. Fostering collaboration among teachers.

The Data Jam professional development model includes a total of 34.5 hours of professional development spread over a weeklong summer workshop (30 hours) and three 90-minute Virtual Lab Meetings. Math and science teachers from the same school are encouraged to participate in Data Jam together. At the summer workshop, teachers actively engage in Data Jam activities using a "student hat" (Lowell & McNeill, 2020) to develop an understanding of the phenomena, the datasets, and CODAP as well as develop a sense of what the student experience is like. Taking on the role of student during the workshop, teachers engage in active learning to develop an understanding of data analysis and interpretation of graphs. The features of CODAP enable teachers and their students to interrogate data by making it easy to organize data, visualize distributions and see relationships in the data. We provide the metadata and background information for each dataset so that the datasets are easier for teachers and students to understand and use in their analyses. Throughout the summer workshop, teachers engage in a sequence of activities related to (a) using box plots to characterize the center, spread, and shape of the distribution of a single variable, (b) using box plots to compare two distributions of data, (c) using percentages to compare categorical data, (d) using scatterplots to examine the relationship between two numerical variables, and (e) using time series graphs to examine changes in a numerical variable over time.

During the workshop, teachers complete three formative challenge activities similar to what the students complete during the Data Jam implementation. The teachers then participate in a collaborative protocol for examining student work (discussed below). The weeklong workshop culminates with teachers completing a mini Data Jam project similar in structure to the students' Data Jam projects (see Figure 6).

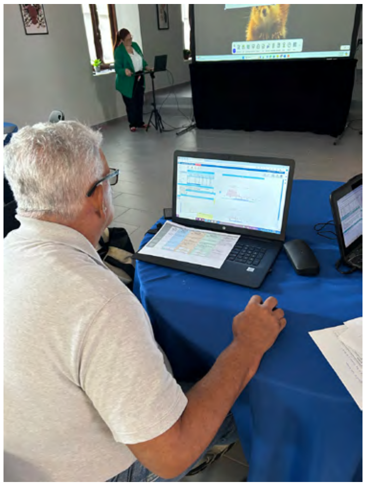


Figure 6. A Data Jam teacher completing the mini Data Jam Project.

Figure 7. A Luquillo graduate student provides feedback on the mini Data Jam Project.

Teachers are provided with structured planning time to make decisions about where the Data Jam lessons fit within their curriculum. Each year, the Data Jam team recruits LTER scientists who serve as Data Jam mentors during the professional development. Throughout the workshop experiences, the Data Jam mentors give presentations to the teachers about their current research work and their career trajectory that brought them to where they are today. The mentors provide feedback to teachers on their mini Data Jam projects in preparation for supporting students' projects (Figure 7).

Data Jam Implementation

Teachers implement the sequence of learning activities that they experienced in the workshop during the next fall semester. About once per month from September to November, the students complete a formative challenge task. These challenge tasks are administered online and serve a formative assessment purpose. Each challenge contains an investigation question, brief background information, and a link to the necessary CODAP dataset. Students demonstrate their data science abilities by conducting the necessary analyses and uploading their graph. Students submit a written argument that uses the data as evidence to respond to the investigation question. The expectations of the challenge tasks provide a vision of what skills teachers need to develop with their students prior to the challenge task administration window.

The challenge tasks are also a component of the professional development plan. The responses to the challenge tasks are collected by the Data Jam team and a random sample of the responses is selected for discussion with teachers. The teachers meet in a cross-school Virtual Lab Meeting (VLM) with a small group of their peers to examine the student work using a validated looking at student work protocol (McDonald et al., 2013). The protocol ensures that teachers have equal amounts of time to contribute to the discussion. The VLMs are facilitated by a Data Jam team member with the active participation of a science mentor. The protocol provides a systematic means for teachers to focus on how the work demonstrates what students know, what they still need to learn, and stimulates discussion of how to support student learning in subsequent lessons. At the end of the 45-minute student work protocol, teachers have 45 minutes of unstructured time with the scientific mentors to get feedback about their implementation of Data Jam and ask questions about the phenomena underlying the datasets. This unstructured discussion between the teachers and mentors is designed with the intention of clarifying statistical concepts, data analysis strategies, and interpretations.

Figure 8. Science mentors and teachers provide feedback to students at the symposium.

The scientist mentors provide in-person or virtual presentations to the students that are focused on science identity, STEM careers, and each scientist's particular research. These presentations provide Data Jam participants with a vision of what Puerto Rican scientists do and what opportunities are available. The mentors' engagement and familiarity with the students' projects throughout the implementation as well as the students' familiarity with the mentor's research and practice enhances the level of interaction when the students and mentors meet at the symposium (Figure 8).

Teacher Reactions

We conducted focus groups with new and experienced Data Jam teachers to identify strengths and recommendations following the 2023-2024 implementation of Data Jam. Unlike individual interviews, focus groups allow researchers to explore the diverse individual perspectives of participants, enriched by the interaction among them during the discussion. The questions aimed to explore experiences related to the main components of Data Jam: summer workshop, VLMs, Data Jam activities, and the mentor presentations.

- Teachers reported that during the workshop, the opportunities to collaborate were particularly beneficial, especially when science teachers interacted with mathematics teachers, as this facilitated the sharing of interdisciplinary knowledge.
- Participants noted that the examples of active practices (such as activities, exercises, and the use of the CODAP platform) incorporated into the workshop design were crucial for enhancing their understanding of concepts and facilitating the practical application of the content taught.
- Teachers expressed appreciation for the efforts of the staff and presenters in fostering a collaborative and supportive learning environment.

Participants expressed that the VLMs were highly positive and beneficial, particularly during mentor-teacher interactions. Engaging in this type of exercise helped increase teacher confidence in their teaching practices.

- The teachers felt that the science mentors supported and facilitated the transfer of workshop materials into the classroom and enhanced their statistical knowledge.
- Teachers highlighted the relevance of data in the activities and the CODAP platform. They believe that one of the greatest benefits of the project is that students can interact with data contextualized to Puerto Rico.
- Teachers noted that the CODAP platform has a user-friendly interface for students and is easy to navigate.
- Teachers felt that these activities foster student empowerment, leadership skills, critical thinking, question formulation, effective communication, and research skills and developed their public speaking skills and the ability to defend their research perspectives.
- The teachers reported that the interaction between students and mentors was very positive. Students really enjoyed the presentations and were very excited about having the opportunity to interact with a real scientist. One of the highlights was that teachers believed that the presentations awakened students' curiosity about science.
- The teachers expressed a desire to have the science mentors give direct feedback on students' final projects prior to the symposium, which will be implemented for the 2024-2025 Data Jam.

Teachers reported that some of the primary implementation barriers included (1) schools undergoing reorganization which changed some of the teacher's roles and reduced the class period length from 90 minutes to 50 minutes, (2) slow internet connection at their schools, (3) feeling anxious about not being able to complete the challenge tasks by the due date, (4) interruptions of unplanned school activities, and (5) lack of director support.

CODAP

A significant part of each student project is an analysis of a complex ecological data set. Understanding the evidence these data provide requires creating, manipulating and interpreting graphical representations. Data Jam uses [CODAP](https://codap.concord.org) (https://codap.concord.org), a free, web-based visualization and analysis tool that has been specifically designed to facilitate this process for students in middle school and high school. CODAP makes it easy to create and modify graphs with a drag-and-drop interface, so that students can quickly engage in interpreting data, rather than laboriously plotting points. CODAP allows students to build graphs one step at a time, rather than having to declare that they want a particular type of graph (e.g. "a bar graph") before they begin. With CODAP, it is simple to create multiple graphs from the same dataset and to see how a case is represented across graphs. For example, Figure 9 displays data about dragonfly (Odonata) larvae found in two different habitats.

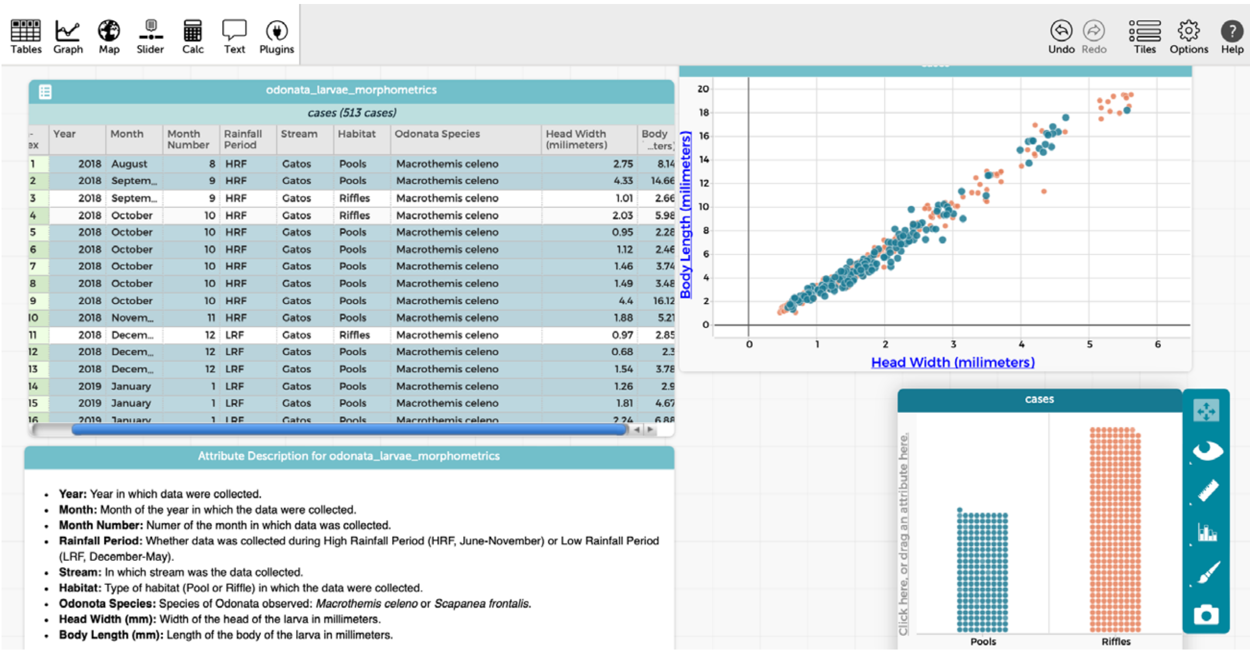


Figure 9. CODAP screenshot of multiple graphs related to Odonata larvae.

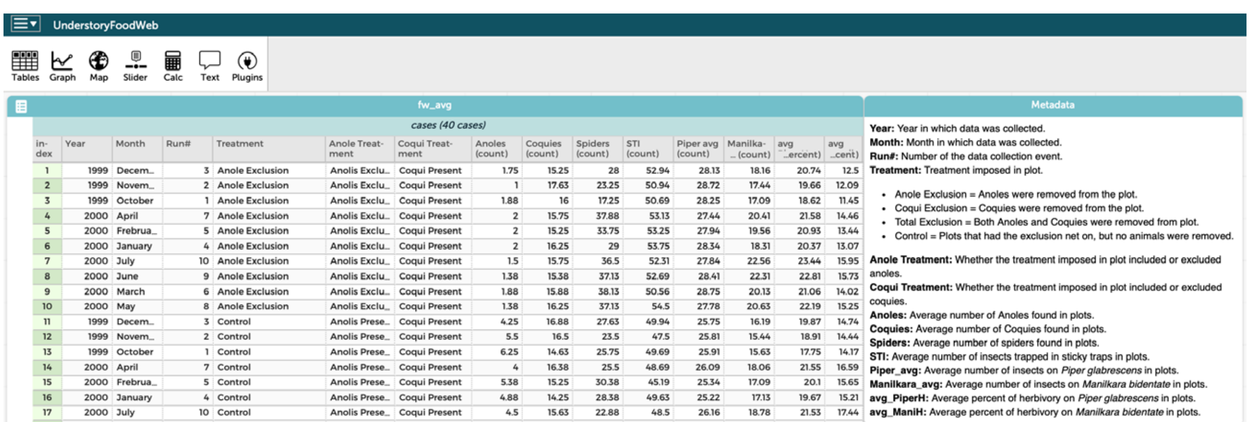
In each of the graphs, a dot represents a larva. The top graph shows the relationship between the size of each larva's head (plotted on the X-axis) and the length of the larva (plotted on the Y-axis). This graph indicates a clear relationship between the two variables; larvae that are longer tend to have larger heads. The bottom graph indicates the habitat where each larva was found, either in pools or in riffles (a shallow place in a river where water flows quickly past rocks); more larvae were found in riffles than in pools. Having both graphs on the screen at once, along with the table and the metadata, allows students to engage more deeply with the meaning of the data. But even more powerful is CODAP's ability to connect graphs together. Note in the bottom graph that the user selected all the points representing the larvae in the pools, which colored the dots blue. The dots representing larvae in the riffles are colored in the default orange. In CODAP, all the representations are linked. The selected dots in the bottom graph are also highlighted in the scatterplot and the data table. The same coloring is used across the representations, that is, all the larvae found in pools are blue and those found in riffles are orange. This allows students to consider the relationship among all three variables: head size, length and habitat. They may notice by examining the scatterplot that a group of the largest larvae are colored orange - that is, they were found in riffles. This observation, in turn, might lead them to directly compare the lengths of larvae found in ponds with those found in riffles with a new graph. This is the kind of data exploration that CODAP supports and which we hope to encourage students to engage in, where one data representation suggests a question that might be pursued with a new data representation, rather than the more common model in which there is a single correct graph to be constructed and a single correct answer.

Dataset Development

Given the complexity and size of the LTER datasets, it is necessary to create manageable datasets for students. However, an oversimplification of datasets for educational purposes is not necessarily the best practice. Small or short datasets might be perceived as boring, and might limit students on their data inquiry journey, preventing them from addressing their questions and exploring different variables (Rubin, 2021; NASEM, 2023). With the advancement of software and its increasing accessibility, it is possible to engage students with larger and more complicated datasets, since software applications like CODAP permit students to work with such datasets (Rubin 2021; Mokros et al., 2023; NASEM, 2023).

Educators have shied away from usage of the readily available raw datasets, no matter how well curated they are, as it is imperative for students to fully understand the data to come up with appropriate questions and analyses (Rubin, 2021; Mokros et al., 2023). Datasets developed by Data Jam are derived from publicly available datasets collected by scientists in the LUQ-LTER and from other federal and state agencies. We limit the datasets to no more than 5000 cases. Apart from the performance of CODAP being affected after 5000 cases, we also consider that larger datasets might be overwhelming for the students. The number of variables per dataset varies and might depend on the instructional purpose of the dataset. The first step involves creating a master dataset from the scientific dataset and identifying the subset of variables that would be most relevant for students. If the dataset contains more than 5000 cases, we decide whether to aggregate the data or to focus on a specific time period. We also create variable names that will make sense to students and develop student versions of the metadata description. From this master dataset, we can derive multiple versions for different purposes.

As students work with their teachers on learning and developing their data science skills, they go through worksheets and challenges aimed to polish different data science skills (e.g. single distributions, comparing distributions, categorical comparisons, numerical relationships, and time series). For each of these activities, a dataset might be derived that contains the elements needed for the student to work on a particular skill, without overwhelming them with information not needed at that point of their progress. For example, Figure 10 shows the master dataset for Understory Food Webs in El Yunque, which has 14 attributes.



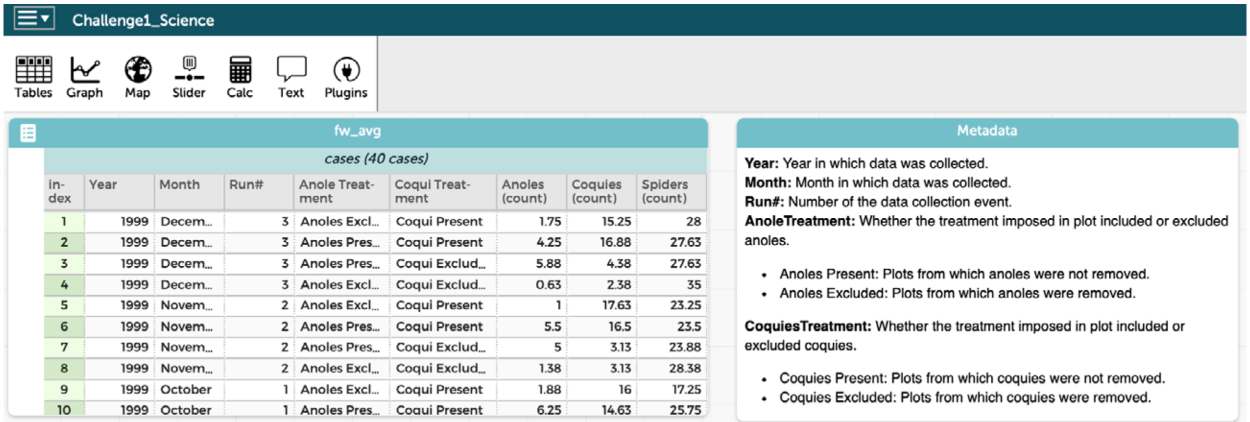
in-dex	Year	Month	Run#	Treatment	Anole Treat-ment	Coqui Treat-ment	Anoles (count)	Coquies (count)	Spiders (count)	STI (count)	Piper avg (count)	Manilka-… (count)	avg …ercent)	avg …cent)
1	1999	Decem…	3	Anole Exclusion	Anolis Exclu…	Coqui Present	1.75	15.25	28	52.94	28.13	18.16	20.74	12.5
2	1999	Novem…	2	Anole Exclusion	Anolis Exclu…	Coqui Present	1	17.63	23.25	50.94	28.72	17.44	19.66	12.09
3	1999	October	1	Anole Exclusion	Anolis Exclu…	Coqui Present	1.88	16	17.25	50.69	28.25	17.09	18.62	11.45
4	2000	April	7	Anole Exclusion	Anolis Exclu…	Coqui Present	2	15.75	37.88	53.13	27.44	20.41	21.58	14.46
5	2000	Frebrua…	5	Anole Exclusion	Anolis Exclu…	Coqui Present	2	15.25	33.75	53.25	27.94	19.56	20.93	13.44
6	2000	January	4	Anole Exclusion	Anolis Exclu…	Coqui Present	2	16.25	29	53.75	28.34	18.31	20.37	13.07
7	2000	July	10	Anole Exclusion	Anolis Exclu…	Coqui Present	1.5	15.75	36.5	52.31	27.84	22.56	23.44	15.95
8	2000	June	9	Anole Exclusion	Anolis Exclu…	Coqui Present	1.38	15.38	37.13	52.69	28.41	22.31	22.81	15.73
9	2000	March	6	Anole Exclusion	Anolis Exclu…	Coqui Present	1.88	15.88	38.13	50.56	28.75	20.13	21.06	14.02
10	2000	May	8	Anole Exclusion	Anolis Exclu…	Coqui Present	1.38	16.25	37.13	54.5	27.78	20.63	22.19	15.25
11	1999	Decem…	3	Control	Anolis Prese…	Coqui Present	4.25	16.88	27.63	49.94	25.75	16.19	19.87	14.74
12	1999	Novem…	2	Control	Anolis Prese…	Coqui Present	5.5	16.5	23.5	47.5	25.81	15.44	18.91	14.44
13	1999	October	1	Control	Anolis Prese…	Coqui Present	6.25	14.63	25.75	49.69	25.91	15.63	17.75	14.17
14	2000	April	7	Control	Anolis Prese…	Coqui Present	4	16.38	25.5	48.69	26.09	18.06	21.55	16.59
15	2000	Frebrua…	5	Control	Anolis Prese…	Coqui Present	5.38	15.25	30.38	45.19	25.34	17.09	20.1	15.65
16	2000	January	4	Control	Anolis Prese…	Coqui Present	4.88	14.25	28.38	49.63	25.22	17.13	19.67	15.21
17	2000	July	10	Control	Anolis Prese…	Coqui Present	4.5	15.63	22.88	48.5	26.16	18.78	21.53	17.44

Year: Year in which data was collected.
Month: Month in which data was collected.
Run#: Number of the data collection event.
Treatment: Treatment imposed in plot.

- Anole Exclusion = Anoles were removed from the plot.
- Coqui Exclusion = Coquies were removed from the plot.
- Total Exclusion = Both Anoles and Coquies were removed from plot.
- Control = Plots that had the exclusion net on, but no animals were removed.

Anole Treatment: Whether the treatment imposed in plot included or excluded anoles.
Coqui Treatment: Whether the treatment imposed in plot included or excluded coquies.
Anoles: Average number of Anoles found in plots.
Coquies: Average number of Coquies found in plots.
Spiders: Average number of spiders found in plots.
STI: Average number of insects trapped in sticky traps in plots.
Piper_avg: Average number of insects on *Piper glabrescens* in plots.
Manilkara_avg: Average number of insects on *Manilkara bidentate* in plots.
avg_PiperH: Average percent of herbivory on *Piper glabrescens* in plots.
avg_ManiH: Average percent of herbivory on *Manilkara bidentate* in plots.

Figure 10. Understory Food Webs in El Yunque "original" dataset developed for the Data Jam (CODAP File)



in-dex	Year	Month	Run#	Anole Treat-ment	Coqui Treat-ment	Anoles (count)	Coquies (count)	Spiders (count)
1	1999	Decem...	3	Anoles Excl...	Coqui Present	1.75	15.25	28
2	1999	Decem...	3	Anoles Pres...	Coqui Present	4.25	16.88	27.63
3	1999	Decem...	3	Anoles Pres...	Coqui Exclud...	5.88	4.38	27.63
4	1999	Decem...	3	Anoles Excl...	Coqui Exclud...	0.63	2.38	35
5	1999	Novem...	2	Anoles Excl...	Coqui Present	1	17.63	23.25
6	1999	Novem...	2	Anoles Pres...	Coqui Present	5.5	16.5	23.5
7	1999	Novem...	2	Anoles Pres...	Coqui Exclud...	5	3.13	23.88
8	1999	Novem...	2	Anoles Excl...	Coqui Exclud...	1.38	3.13	28.38
9	1999	October	1	Anoles Excl...	Coqui Present	1.88	16	17.25
10	1999	October	1	Anoles Pres...	Coqui Present	6.25	14.63	25.75

Figure 11. Dataset derived from the "original" Understory Food Webs (Figure 10) dataset for Challenge 1.

Figure 11 shows a dataset derived from the master Understory Food Webs dataset aimed specifically for one of the challenges where students are prompted to answer the question: Do coquíes eat spiders?

This challenge is the first time students are required to answer a research question on their own using the data, as well as the metadata and background information. Providing them with a master dataset where they would have 14 variables to choose from in their first attempt at choosing the correct variables to answer a research question could be overwhelming. Instead, students are provided with a smaller dataset (Figure 11), where we still can challenge them and evaluate their ability to choose the correct variables, without having too many distractions that could set up the students for failure. When working with publicly available datasets – and not datasets that students collected themselves—researchers have pointed out the importance of students asking "who, how, when, where, and why" to ensure their understanding and proper treatment of the data (Rubin, 2021). In Data Jam, students are provided with datasets that are composed of at least two files: the CODAP file with the data, and a metadata file with an explanation of each of the variables and how they were measured. The metadata is both in the CODAP file and on a separate document, so students can access it however they feel more comfortable. Datasets on scientific topics that tend to be more complicated have a third file included: the background information document. The background information document has information on the topic studied in the dataset, as well as the research project and study design through which the data was collected. Providing teachers and students with these files all together gives them the tools needed for them to deeply explore the datasets, come up with proper questions and analyses and, when answering their questions, develop a reasoning statement that explains their answer. Datasets are created with different levels of complexity (from the derived and specifically aimed datasets, to the master datasets) to guide the students through their data science journey. The final goal is for the students to use the more complex master datasets when they are developing their Data Jam projects. All datasets are organized and publicly available through the Data Jam Webpage under Datasets (https://datajam.cloud/en/datasets).

Scientific Community of Practice

Data Jam is one of several outreach initiatives in the Luquillo LTER Schoolyard program. Our overarching goal for the Luquillo LTER Schoolyard program is to engage students as junior members of the Luquillo LTER community. Data Jam exemplifies the five hallmarks of this community of practice approach to science outreach (McGee et al., 2024). It supports identity development as a scientist by empowering students to investigate their own island and heritage, which is unusual for most educational programs that Puerto Rican students experience. The goals and research questions that Data Jam students undertake are shared in common with the Luquillo scientific community. The students can see that the scientific mentors are engaged in similar questions and see the pathways that can deepen their connection with the Luquillo LTER community. Students are using age-appropriate versions of the same Luquillo data and are engaging in age-appropriate Luquillo practices for analyzing the data and developing scientific arguments with an age-appropriate version of the scientific tools of the Luquillo community. Graphing tools are a staple of LTER research. Students are able to make connections between the graph representations and the meaning of those graphs for the question they are investigating.

The metadata and background documents provide a means for students to learn the scientific language of the Luquillo community. The development of the Data Jam projects for presentation to members of the Luquillo community at the symposium provides students an opportunity to apply the language they have learned. Through interactions with members of the community they have the opportunity to get feedback and refine their use of scientific language.

Data Jam fits within the overall learning sequence of the Luquillo LTER schoolyard program; Journey to El Yunque, a middle school science unit centered on the El Yunque Rainforest ecosystem, LTER DATA Jam, and Field Work Protocols, which provides hands-on experience with data collection protocols used by scientists at a student study site within the rainforest. In becoming members of a community, apprentices often learn the practices in the opposite order in which they conducted. In that context, students will complete the entire process of an investigation but focus on completing specific steps individually. In the Journey to El Yunque program, which precedes the opportunity to participate in Data Jam, students are provided with an investigation question, Luquillo long-term data and models about population dynamics and they are expected to develop a scientific explanation of how hurricanes directly and indirectly impact population dynamics (Easley et al., 2023; McGee & Zimmerman, 2016; McGee et al., 2018). In the case of Data Jam, students are provided with Luquillo long-term data and are given the opportunity to ask their own research question and analyze the data to develop a scientific explanation. With the Field Work Protocols, which comes after Data Jam, students are able to collect data and contribute to a long-term dataset of forest productivity in a plot near the Luquillo El Verde Field Station. Students can then ask their own research questions about tree biomass and analyze the long-term tree productivity data to develop a scientific explanation. As students develop their abilities with scientific practices, scientific tools, and scientific language, they are able to complete more steps in the inquiry process.

Conclusion

Providing explicit opportunities for all students to learn data science skills is foundational for broadening participation in STEM. The Data Jam model has been successfully implemented in a variety of classrooms and has great promise for broader application. Over the years, Data Jam has reached thousands of middle and high school students. The participating students have primarily been Puerto Rican from a range of socioeconomic contexts encompassing a broad range of urban, suburban and rural communities throughout the island of Puerto Rico. Students are able to engage in authentic investigations with Luquillo data about El Yunque, which increases their knowledge of and interest in studying the local environment. The combination of studying their local environment and connecting with practicing Luquillo scientists increases students' confidence in using data and increases their identity development and interest in pursuing a science major.

The professional development model is not only useful for supporting Data Jam, but also in any classroom where students are exploring publicly available datasets. Teachers' comments and recommendations highlight the importance of effective professional development and ongoing support throughout the Data Jam project implementation process. The positive feedback on the activities, the use of the CODAP platform, and interactions with mentors emphasizes the significant impact on students' skill development and understanding of the concepts. For the island of Puerto Rico, Data Jam is a powerful opportunity for engaging students in authentic science and inspiring a new generation of scientists.

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Andee Rubin is a mathematician, computer scientist, and learning scientist at TERC, an educational research and development non-profit, where she has been studying the growth of students' and teachers' reasoning about data for over 30 years, particularly as it is enabled by research-based tools for data education. She led the ViSOR (Visualizing Statistical Reasoning) project, which studied how middle and high school teachers used data visualization tools with their students. She has developed curriculum materials around data for students as young as 6, both in and out of school, as well as professional development materials for teachers and out-of-school facilitators. She was PI of the Data Clubs project, which developed three data modules for middle school students in informal contexts. She currently leads multiple projects creating materials to facilitate students' learning about data and doing research on students' successes and struggles as they explore large and complex datasets. She is committed to empowering all learners to use data to pursue social justice and serves as the "data diva" for the Data Jam project. She can be reached at andee_rubin@terc.edu.

Arctic Happenings: Global Impacts of the Melting Greenland Ice Sheet and Melting Sea Ice

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Satellite picture of the snowcap at the North Pole in summer. Photo credit: NASA

Abstract

In the Arctic region, global climate change is quickly transforming the environment. Melting of the Greenland ice sheet and loss of Arctic Ocean sea ice are two processes that have increased dramatically since the late 20th century. A four-part educational module focused on these two processes has been designed for upper middle school, high school and undergraduate students. Through this investigative module, students learn critical science skills as they collect, analyze and draw conclusions from data and engage with some of the most urgent environmental questions of our time. Finally, they are challenged to think about how these changes are affecting their lives and the lives of others around the globe. All the digital materials for this module are freely available online and include rich video and data resources plus step-by-step instructions.

Introduction

Global, near-surface, air temperatures have risen fast since the beginning of the 20th century, but the Arctic region stands out as one of the places with the most rapid increase. Arctic air temperatures are now 3.5°C higher than in the early 1900s (Richter-Menge, Overland, & Mathis, 2016), and have, together with other climate changes, transformed the Arctic environment. Two of the most note-worthy changes are the rapid loss of the Greenland ice sheet mass and the shrinking Arctic Ocean sea ice cover. September sea ice extent is 40% less today (2007-2010) than it was 20-30 years ago (Stroeve et al., 2012), and Greenland ice sheet mass balance has catapulted from a net zero between 1960 and 1991 to a decrease of -16±2.8 Gt water equivalent per year in the 1991-2015 period (van den Broeke et al., 2016). Both these changes may influence the global climate system in a variety of ways. Loss of the white reflective sea ice cover (high albedo) reveals a dark ocean (low albedo) that readily absorbs more solar radiation and subsequently warms the lower atmosphere. Through this process, sea ice loss has been connected to more persistent and extreme weather in the mid-latitudes (Overland et al., 2016). Greenland ice sheet mass loss, in turn, may influence marine environments (Arrigo, Dijken, Castelao, Luo, & Rennermalm, 2017) and raise global sea levels (Clark, Church, Gregory, & Payne, 2015). Already, Greenland ice sheet mass loss has contributed 0.59±0.16 mm (1992-2011) of the global mean sea level rise of 3.2±0.4 (1993-2012, derived from satellite altimetry) (Clark et al., 2015), which is about 18% of the total increase.

The net Greenland ice sheet mass loss is primarily the result of two processes, calving of icebergs where the ice sheet is in direct contact with the ocean, and surface mass balance. In the mid-20th century, snow adding to Greenland's surface mass balance was almost offset by surface melting running off to the ocean in the summer. However, this changed in the late 20th century when meltwater runoff surpassed snow accumulation and resulted in increasingly negative mass balance (van den Broeke et al., 2016). Thus, ice sheet meltwater runoff is a critical process to understanding Greenland ice sheet influence on global sea levels. Ice melting can be stimulated by above-freezing air temperatures (Hock, 2005) because they move in concert with the many of the actual forcings. Those forcings are a complex interaction of large-scale atmospheric circulation (Mcleod & Mote, 2016), meltwater refreezing (Machguth et al., 2016), ice sheet hydrology, and surface energy balance (Rennermalm et al., 2013) all influencing melting. For example, the darkening of the ice sheet surface, i.e. lowered albedo, which has been documented since the early 2000s (Stroeve, Box, Wang, Schaaf, & Barrett, 2013) has resulted in a greater uptake of solar radiation driving some of the increased contributions to global sea levels.

Building Awareness

These dramatic changes found in the Arctic should be alarming to people living everywhere on Earth. However, connecting people, including students, to a far-away location is sometimes difficult unless there is something meeting their interest at a location. For example, polar bears and penguins are the interest-grabbers for the polar regions; however, to sustain interest, a personal connection beyond polar bears and penguins is needed. In the case of students, this can be done by identifying climate phenomena that connects the lives of students to the Arctic, but also engages them in the climate mechanisms at work in the Arctic. For instance, students near a coastal location are interested in sea level rise; students living elsewhere are interested in climate system feedbacks related to surface warming and increased temperatures and stronger storms. Building off these connections, this multi-part module with four activities assists students with integrating numerous climate change factors, including those which will impact them during their lifetime.

Each activity within this 5-E (engage, explore, explain, elaborate, evaluate) module effectively blends disciplinary core ideas, science and engineering practices, and crosscutting concepts to assist learners with making sense of phenomena affecting their lives as prescribed by *A Framework for K-12 Science Education* (National Research Council, 2012). In addition, students develop their modeling, data analysis, and spatial

Table 1: Greenland Ice Sheet - From Warming Climate to Sea Level Rise Module Overview

Activity	Activity Question(s)	NGSS Components (Grades 6-8 & 9-12)	
1. My Burning Feet! (Engage)	Why do my feet burn more when walking barefoot on some surfaces and not others?	SEP:	Planning & Carrying Out Investigations
		DCI:	PS4.A & PS4.B
		CCC:	Patterns
2. From Burning Feet to the Greenland Ice Sheet: Examining model estimates of Greenland ice sheet mass loss, its drivers, and its impact on global sea levels (Explore & Explain)	What is causing the Greenland ice sheet to melt? How will this affect global sea level rise?	SEP:	Analyzing and Interpreting Data
		DCI:	ESS2.D
		CCC:	Cause & Effect
3. Should I Move Inland? What About Others Around the World - Should They Move to Higher Ground? (Elaborate)	How will sea level rise affect me, the people I know, and people around the world?	SEP:	Analyzing and Interpreting Data
		DCI:	ESS3.D
		CCC:	Cause & Effect
4. How Does Melting Arctic Ice (sea ice & ice sheets) Impact the Climate Where I live? (Evaluate)	Do both melting sea ice and melting ice sheet contribute to sea level rise? What are the connections to this melting on the weather and climate on the mid-latitudes or where I live? What evidence supports this claim?	SEP:	Engaging in Argument from Evidence
		DCI:	ESS2.A & ESS2.C
		CCC:	Cause & Effect & Stability & Change

skills as they create and analyze a model of the Greenland ice sheet using data from current research. Table 1 provides an overview of the activity sequence in this module and appropriate connections to the Next Generation Science Standards (NGSS, 2013). Visit the module website (https://arcticdata.io/catalog/view/doi%3A10.18739%2FA2TM7216N) to download teaching material and video resources.

ACTIVITY 1: My Burning Feet!

To introduce students to the climate mechanisms at play in the Arctic, this “engage” activity about surface albedo connects student understanding of solar energy interactions with various surfaces in their location to solar energy interactions with the Greenland ice sheet. It opens with groups of students seeking to answer the question “Why do my feet burn more when walking barefoot on some surfaces and not others?” They create the protocol that employs easily obtainable infrared thermometers to collect the data; however, they need to be mindful of their data collection technique to ensure they collect quality data that can be compared across groups. Once the data has been collected and shared in the class, students seek patterns in the data, and ultimately define the term “albedo” and relate it their data. This activity ends with an interpretation of global images of surface albedo such as those found on the NASA Earth Observatory web site (see Figure 1 and earthobservatory.nasa.gov/) and a discussion about how and why albedo varies around the globe.

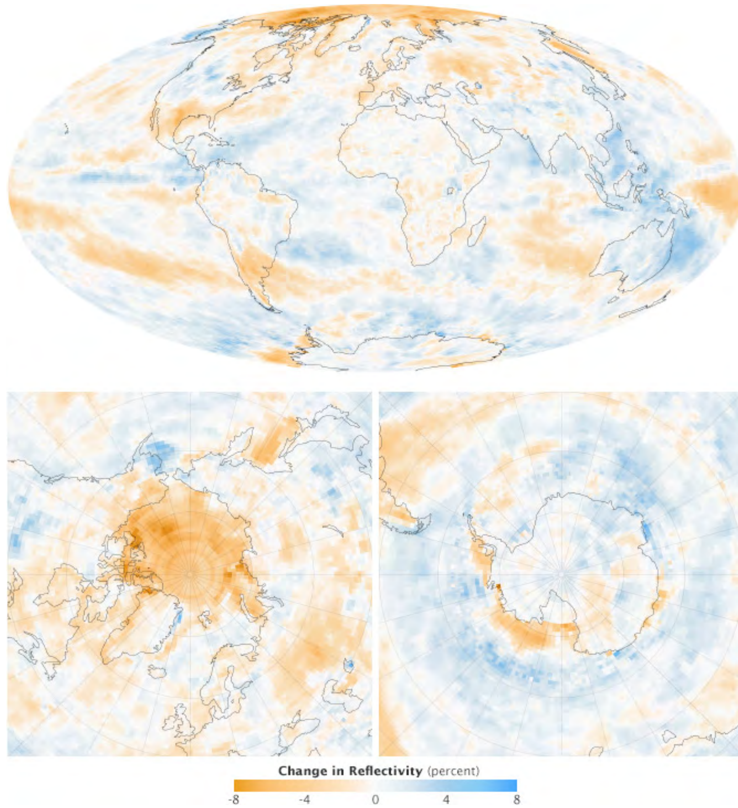

Figure 1. NASA Earth Observatory image by Robert Simmon based on data from CERES satellite. (https://earthobservatory.nasa.gov/images/84499/measuring-earths-albedo)

ACTIVITY 2: From Burning Feet to the Greenland Ice Sheet: Examining model estimates of Greenland ice sheet mass loss, its drivers, and its impacts on global sea levels

Over the next few class periods students explore Greenland ice sheet datasets using the public domain software, ImageJ (https://imagej.net/). With ImageJ, the user can model and analyze spatial data (see Figure 2).

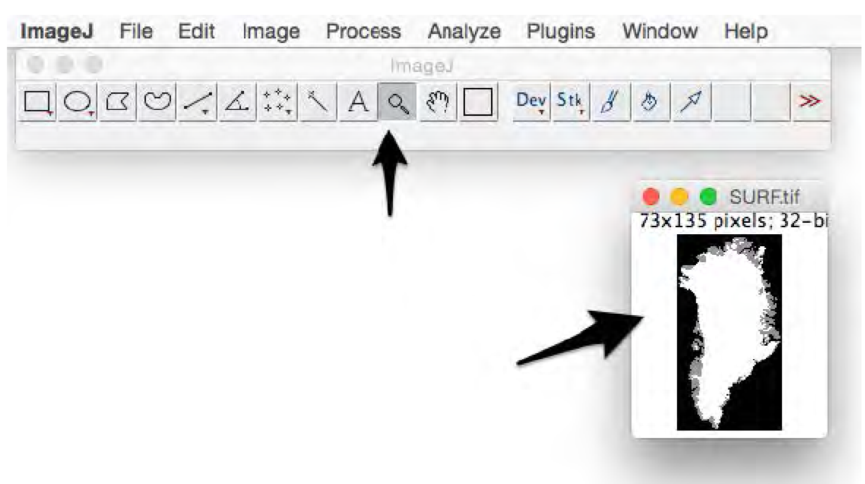

Figure 2. Screenshot of Image J software, and Greenland surface data. (Figure provided by the authors).

The students create and interpret models of spatial data to explain the connections between changing surface albedo and the surface hydrology of Greenland ice sheet. The activity contains all the necessary background information for students and the teacher, including the data, the metadata, definitions, and additional software needs (word processing and spreadsheet software). The data is taken from Modele Atmospherique Regional (MAR), a widely used regional climate model that simulates atmosphere-land mass and energy exchanges over Greenland (Fettweis, 2007; Fettweis et al., 2013). This activity uses MAR version 3.5.2 with boundary forcings from the global National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/ NCAR) reanalysis model. It should be noted that although MAR compares well with similar models, no model perfectly captures the true conditions (Fettweis et al., 2016). In fact, a complete understanding of the actual surface mass balance components are challenging since ground and satellite observations are sparse and has mostly started in the latter part of the 20th century (Rennermalm et al., 2013). Regardless, comparisons with MAR 3.5.2 and existing observations give confidence in using MAR, but it should be noted that it may over-estimate albedo in the melting zone and has a slight cold bias, particularly in the summer months. (Fettweis et al., 2016).

Step by step instructions and screenshots are included throughout the activity to assist students while they navigate the use of the software. The activity contains seven steps which begins with two steps that orient students to the software as they explore the types of surfaces and elevation on Greenland. Next, students import MAR data for albedo and above freezing temperatures and compare values across the ice sheet over time. They continue this effort by importing and assessing snowfall values over time.

Students then create transects, profiles, and animations to model changes in the data over time. Following this step, the data is imported into a spreadsheet program where students make scatterplots, add trendlines, and assess the resulting correlation coefficient. In the final step, they use the data from ImageJ to estimate sea level rise resulting from the melting of the ice sheet and compare it to the current projected values. They use the products of this activity to create an evidence-based argument for the melting ice and its resultant impact on global sea level rise. From the successful completion of this activity, students gain numerous scientific skills related to modeling, data analysis, and developing arguments from evidence.

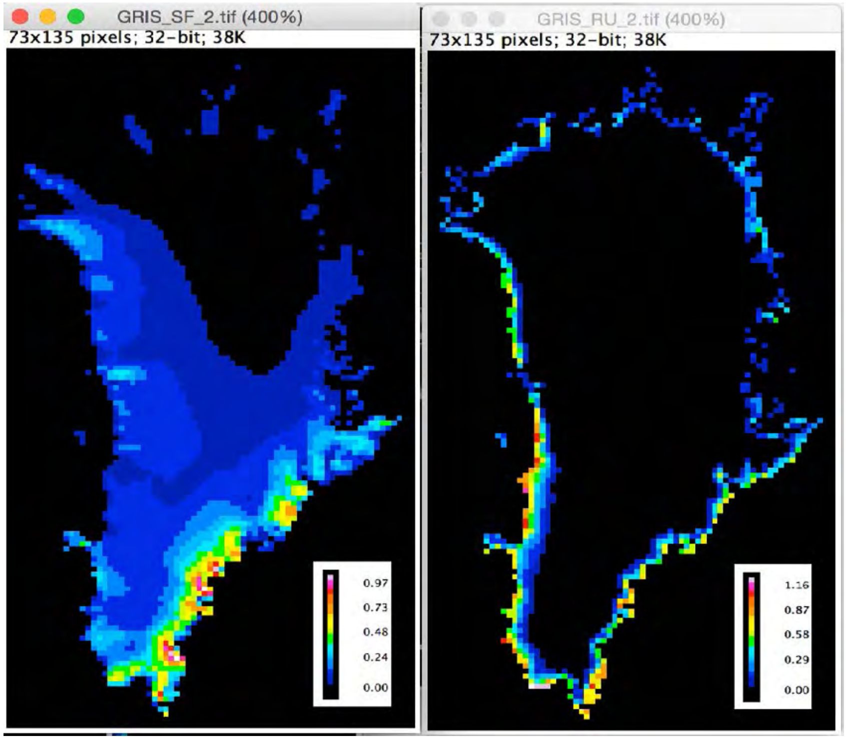

Figure 3. Screenshot of a comparison of snowfall (left) and runoff data (right). The color bars show the average annual water equivalent (2005-2016) of snowfall or runoff in units of km3/ year. (Figure provided by the authors).

ACTIVITY 3: Should I Move Inland? What About Others Around the World – Should They Move to Higher Ground?

Once students have made the connection between the melting Greenland ice sheet and global sea level rise, they elaborate on the impacts of sea level rise on coastal communities in the United States and around the world. After learning how to manipulate sea level rise mapping tools from the National Oceanic and Atmospheric Administration (NOAA), pairs of students use these tools to compare the impacts on the populations and infrastructure at various coastal locations around the United States. They create a report from the viewpoint of a federal government scientist and share their findings with the class. After all the presentations have been made, students discuss the variation in vulnerabilities found around the country. Identifying solutions for sea level rise is complicated since there are so many facets to the issue such as economic implications, social implications, and political implications. A class discussion organized around all the possible decision-making factors and possible solutions assists students with understanding how to address complicated issues. In the final component of this activity, students venture out of the boundaries of the United States to explore how sea level rise will impact our neighbors in different countries.

ACTIVITY 4: How Does Melting Arctic Ice (Sea Ice and Ice Sheets) Impact the Climate Where I live?

In this final activity of this module the focus shifts from the melting Greenland ice sheet to melting sea ice in the Arctic. Students apply what they learned from previous parts of this module to a new scenario as the teacher evaluates their understanding of the core ideas related to melting Arctic ice (sea ice and ice sheet). It opens with a demonstration designed to dispel the conception that melting sea ice will cause sea levels to rise. A clear glass is filled with ice and water and students are asked what will happen to the water level if the ice were to melt. After the ice melts, students recognize that the water level did not change, but are then challenged to identify the effects of melting Arctic sea ice. They brainstorm the cause-effect relationships between sea ice and our climate system while considering the associated climate feedbacks as sea ice dwindles, including the impacts on mid-latitude weather and climate. Next, pairs of students seek datasets such as those suggested in the activity to support their claims. These datasets may include raw data, graphs, images, animations, and models. To close the module, students report their findings to their classmates during a discussion on the complexity of the climate system that includes the far-reaching effects of melting sea ice and melting ice sheets.

From the Arctic to Our Backyards

Additional resources are available online to support this module, including an annotated PowerPoint presentation, videos and selected weblinks. The four high-quality videos were created to help students connect to the Arctic region and the people who collected the data in this module. Each video is about 3 minutes long and contains stunning footage from Greenland and introduces four scientists who explain their background and research methods. By completing this module students learn that what happens in the Arctic does not stay in the Arctic, and that we are all vulnerable to the changes occurring there. With scientific understanding of our climate system, they are better prepared to discuss measures to mitigate the effects of climate change as well as ways to adapt to the effects of climate change.

Acknowledgements

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From Satellites to Your Backyard

Dorian W. Janney,
NASA "Global Precipitation Measurement" (GPM) mission Education and Outreach Coordinator

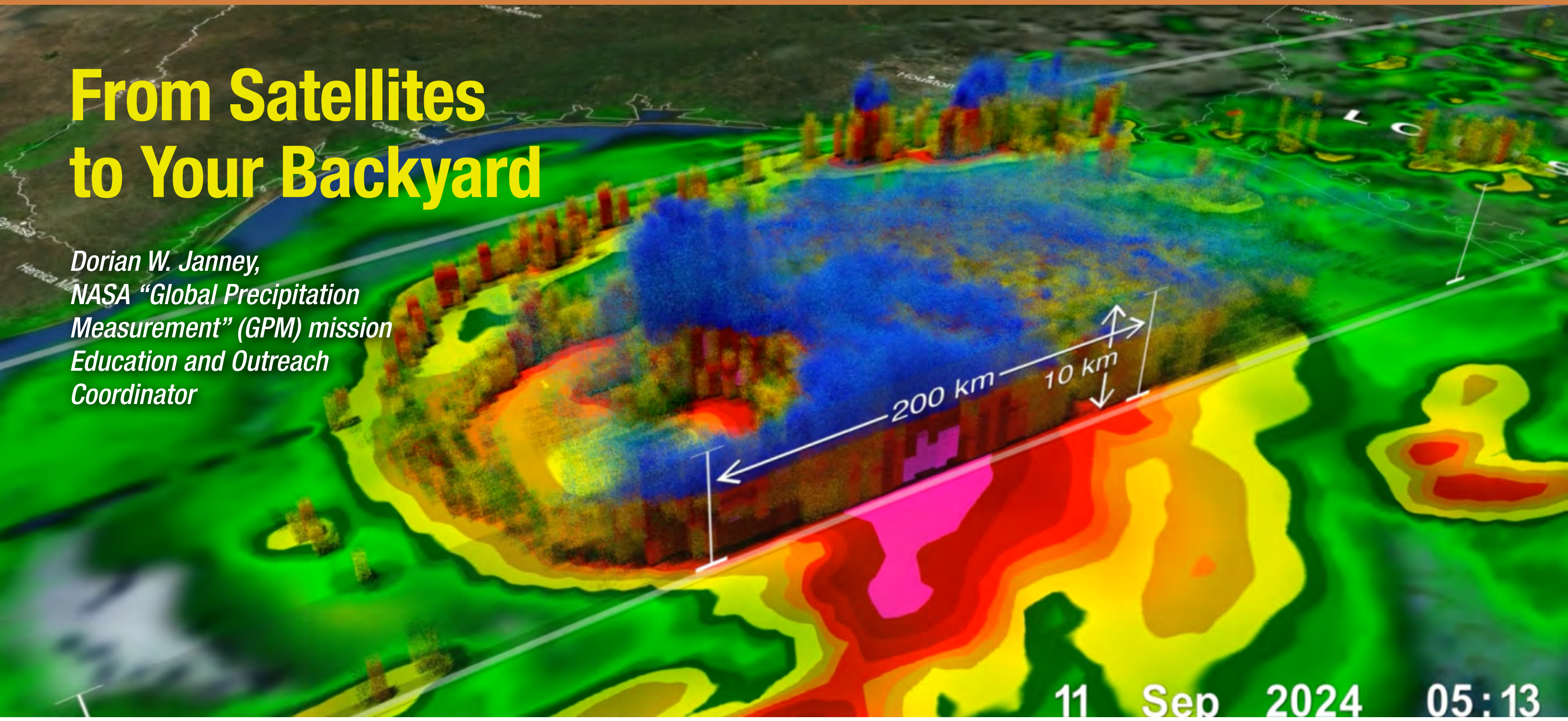


Image of Hurricane Francine from the GPM satellite. The hurricane made landfall on September 11, 2024 on the southern coast of Louisiana. Photo credit: NASA

NASA currently has two dozen Earth-observing satellite missions studying various aspects of Earth's system. NASA's Global Precipitation Measurement (GPM) mission is an international network of satellites that provides next-generation global observations of rain and snow.

Building upon the success of the Tropical Rainfall Measuring Mission (TRMM), which launched in 1997 and was in operation through 2015, GPM uses advanced instrumentation to measure how much precipitation is falling from the clouds to the ground for almost every location on Earth and it does this every thirty minutes.

We can now measure how much and what kinds of precipitation are falling as well as look back and see how much fell in almost any location on Earth for the past twenty-four years.

Educators can take advantage of a website that helps students understand how and why we measure

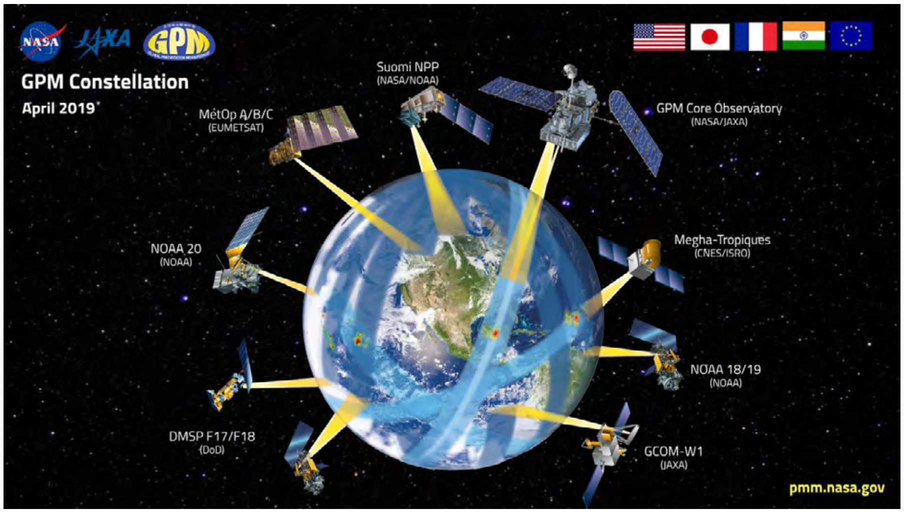
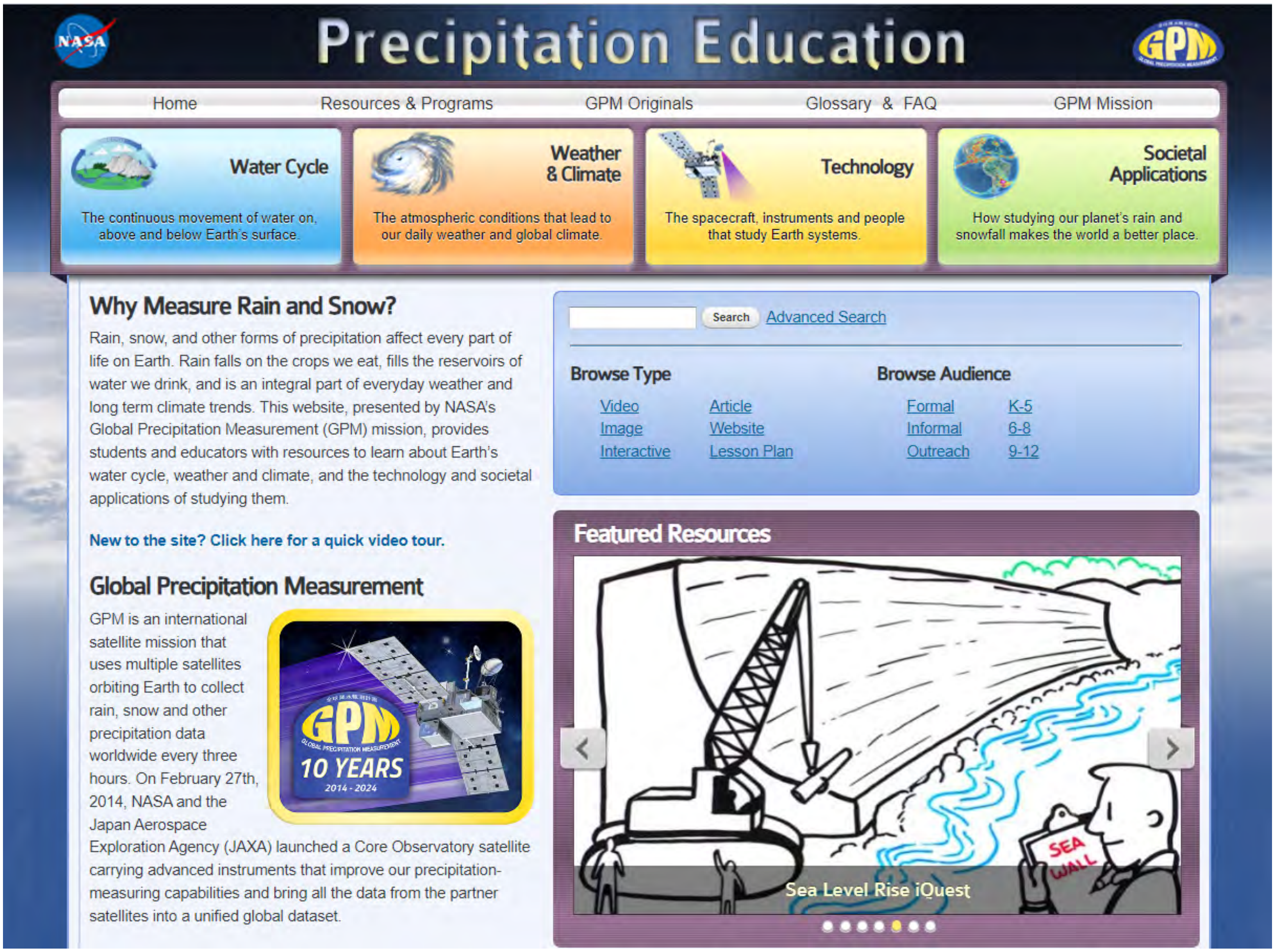


Figure 1. Diagram of the GPM satellite constellation as of early 2019. Credit: NASA GSFC



precipitation from space and how these data are being used to improve life around the globe. "[Precipitation Education]" is a collection of ready-to-go classroom materials aligned to Next Generation Science Standards (NGSS, 2013).

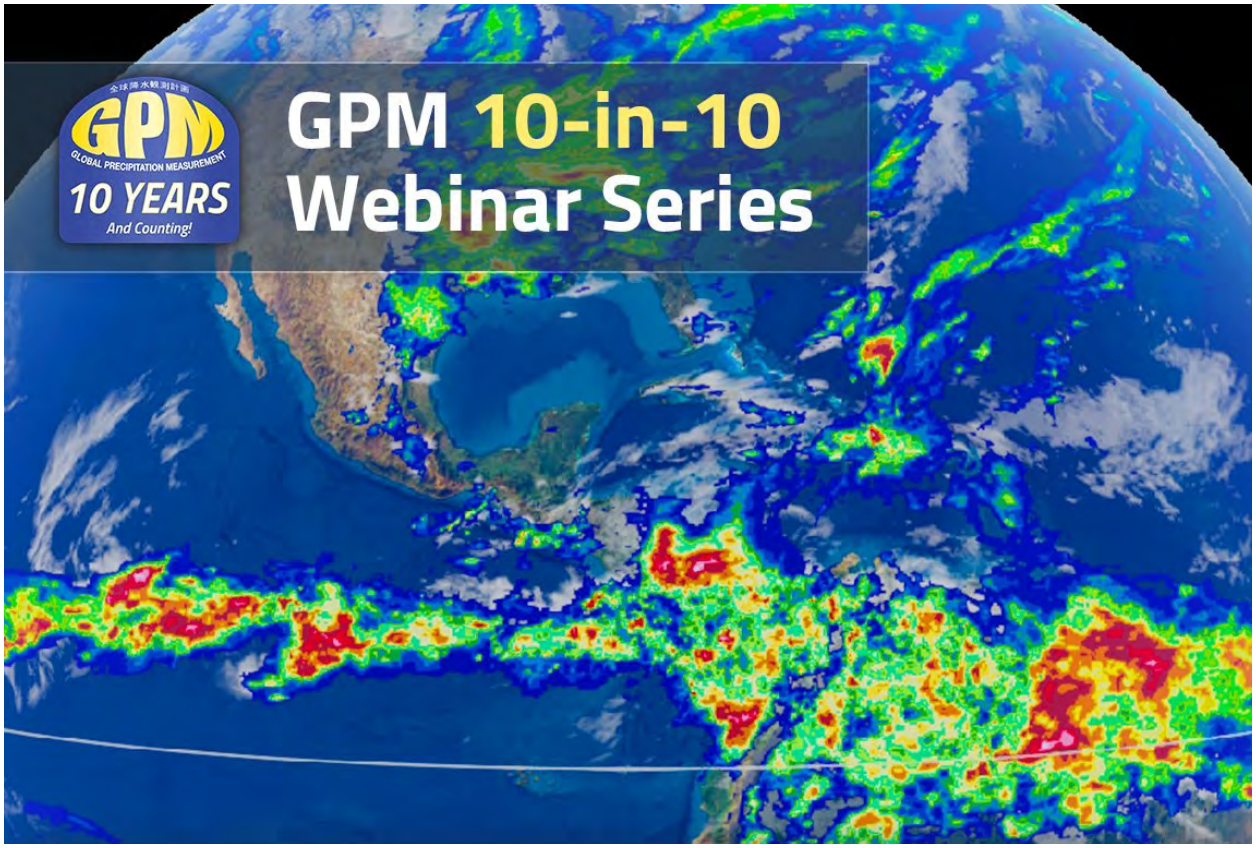
A video tour provides helpful information on how to search for content in four key themes: Water Cycle, Weather and Climate, Technology, and Societal Applications. Each theme includes lesson plans, videos, articles, interactives, WebQuests and more.

One of these lessons, From Satellites to Your Backyard, has directions for anyone to find the precipitation data for their "backyard" by simply entering their longitude and latitude and using one of NASA's free data portals. The lesson also has a Story Map that shows longitudinal seasonal precipitation data for many locations around the world and helps analyze this data to help "unpack" it. Real-world applications showing how TRMM and GPM data are being used to bring about positive change are highlighted in Societal Applications. Lessons include:

- Safe Drinking Water is Essential
- Science for a Hungry World: Growing Water Problems
- Satellite Data Empowers Farmers

The site includes video interviews with scientists who are using GPM's data to assist famers with reducing the amount of freshwater they are using and obtain low-cost insurance policies to guard against losing everything when there is too much or too little precipitation. Lessons plans entitled "Water for Wheaties?" that have been aligned to NGSS, include assessments and rubrics, as well as videos and PowerPoint slides. Finally, there are STEM interviews with end-users to have them describe how and why they went into their chosen careers.

To celebrate the tenth anniversary of the launch of the GPM Core Observatory, the GPM Outreach team has hosted a series of "10-in-10" webinars for the public. Each webinar includes a "Resource Packet" full of detailed information and educational resources.



About the Author

Dorian W. Janney has a passion for sharing the wonders of NASA's science and exploration with others across all age levels. For over three decades, she taught public school in both special and general education settings across all grade levels. She was an Einstein Fellow Finalist and achieved National Board Certification in Science Education, served on numerous education working groups, and wrote science curriculum for the country. She now serves as NASA's "Global Precipitation Measurement" (GPM) mission's Education and Outreach Coordinator, and she develops resources to help share the science, technology, and real-world applications of GPM with others. She is a Mentor GLOBE trainer, a member of the GLOBE Education Working Group, and supports the GLOBE field campaigns. Her most recent project is leading an effort to engage lifelong learners with The GLOBE Campaign's Citizen Science efforts. She can be reached at dorian.w.janney@nasa.gov.

Design Sprint: An Opportunity for Addressing Environmental Issues

Liz Martinez, Curriculum, Assessment, and Professional Development Consultant

A view of the Great Lakes from the NASA SeaWiFS satellite. Photo credit: NOAA

Abstract

A design sprint provides students with a unique opportunity to participate in a challenge that focuses on local and state environmental issues. In the shared example, student teams, which ranged from fifth grade through high school engaged in research and design thinking to create innovative responses and solutions to address their selected water challenge. Subject matter experts were available, both virtually and in person, for questions, conversations, and insights as teams worked. Students showcased their work at the end of the design sprint, a one-day event to experts and educator mentors. This strategy may provide a spring board for more opportunities so that students may interact with subject matter experts regarding a wide range of environmental issues.

Introduction

A design sprint challenges teams to identify a problem and solve it within a short amount of time, usually five days, through research, discussion, ideation, and prototyping. This framework supports flexibility allowing a sprint to be done as a multi-school, school, grade level, or class event. Time will dictate how much of the design process is completed and educators can develop a timeline for their needs and time constraints. In order to narrow the field of issues for the learners and teachers, it is helpful to develop a focused list of locally relevant topics. Categories should be selected based on local environmental issues, recent events, appropriate resources, and the availability of subject matter experts.

A design sprint connects learners to the local environment and community, which fosters greater ownership and engagement for students. Examining local problems may also assist the teacher in finding subject matter experts and volunteers to assist with the design sprint. Multiple standards and goals from a variety of disciplines are incorporated into this design challenge. This naturally lends itself to an interdisciplinary and/or team-teaching approach to the process if so desired.

Table 1: Potential Standards and Goals

Goals were identified from the United Nations Sustainable Development Goals, Essential Principles of Climate Literacy, the Next Generation Science Standards and the Common Core State Standards English Language Arts.

Source	Goal
United Nations Sustainable Development Goals https://sdgs.un.org/goals	Goal 6: Clean Water and Sanitation: Ensure availability and sustainable management of water for all Goal 13: Climate Action Goal 14: Life Below Water Goal 15: Life on Land
Essential Principles of Climate Literacy https://www.climate.gov/teaching/essential-principles-climate-literacy/essential-principles-climate-literacy	• Essential Principle 6: Human activities are impacting the climate system. • Essential Principle 7: Climate change will have consequences for the Earth system and human lives.
Next Generation Science Standards https://www.nextgenscience.org/	**Middle School** Earth and Human Activity: MS-ESS3-2, MS-ESS3-3, MS-ESS3-5 Engineering Design: MS-ETS1-1, MS-ETS1-2, MS-ETS1-4 Science and Engineering Practices: Analyzing and Interpreting Data, Constructing Explanations and Designing Solution **High School** Earth and Human Activity: HS-ESS3-1, HS-ESS3-4 Engineering and Design: HS-ETS1-1, HS-ETS1-2, MS-ETS1-3 Science and Engineering Practices: Analyzing and Interpreting Data, Constructing Explanations and Designing Solutions
Common Core State Standards English Language Arts https://www.thecorestandards.org/ELA-Literacy/	**Middle and High School Science & Technical Subjects** • Key Ideas and Details: CCSS.ELA-Literacy.CCRA.R.1, CCSS.ELA-Literacy.CCRA.R.2 • Craft and Structure: CCSS.ELA-Literacy.CCRA.R.4 • Integration of Knowledge and Ideas: CCSS.ELA-Literacy.CCRA.R.7, CCSS.ELA-Literacy.CCRA.R.8 **Speaking & Listening** • Comprehension and Collaboration: CCSS.ELA-Literacy.CCRA.SL.1, CCSS.ELA-Literacy.CCRA.SL.2 • Presentation of Knowledge and Ideas: CCSS.ELA-Literacy.CCRA.SL.4

Teams identify a local environmental problem, research the issue, and develop a plan of action or solution. In order to narrow the field of issues for the students, a focused list of locally relevant topics should be developed by the teacher. Categories and themes shown in Table 2 are based on local environmental issues, recent events, appropriate resources, and availability, of subject matter experts in the Great Lakes region.

Table 2: Sample Design Challenge Themes

Biodiversity	• Invasive species • Habitat loss
Water Quality	• Water conservation, usage, policy • Biological contaminants: Cryptosporidium, Campylobacteria, E. coli, Enterovirus, Giardia, Hepatitis A, Legionella, Norovirus, Rotavirus, Salmonella, Shigella • Drinking water infrastructure, water treatment • Fertilizer, pesticides, road salt from runoff • Harmful algal blooms • Industrial waste • Livestock – Animal feeding operations • Plastics, PCBs • Naturally occurring contaminants: arsenic, copper, lead, nitrate, radon • Sewage • Storm water • Waste disposal
Water Quantity	• Accessibility and supply • Availability • Flooding impacts • Increased demand: agriculture, housing, manufacturing, population • Scarcity and drought
Severe Weather	• Atmospheric rivers • Extreme heat • Fires • Floods • Hurricanes • Tornadoes
Rising global temperatures	• Crop productivity • Heating of ocean • Increased carbon dioxide in atmosphere • Respiratory illness • Sea level rising • Vector borne diseases: Lyme, West Nile, Zika
Sustainability	• Agriculture • Carbon sequestration • City planning: permits, codes, building materials • Erosion • Groundwater • Infrastructure to withstand increased threats: damns, dikes, flood plains, prairie restoration, • Loss of natural buffering areas

Depending on time constraints, research questions may be developed by the teacher for each of the themes. Note that an issue may seem geographically disconnected at first, but might have a local tie. For example, some areas along the northern Mississippi River contribute to harmful algal blooms in the Gulf due to fertilizer run-off. General themes might include biodiversity, water quality and quantity, severe weather, temperature, and sustainability.

Table 3. Teacher-Generated Research Questions

Algae	• Why are algae necessary for the biosphere? • How can uses of algae positively impact climate change or sustainability?
Algal Blooms, Pet Illnesses	• How does the Midwest contribute to harmful algal blooms in the Gulf of Mexico and how can we lessen the impact? • How to harmful algal blooms affect plants, animals (including pets), and humans? • What are potential solutions to reducing harmful algal bloom events?
Biodiversity/Invasive Animal or Plant Species	• How is climate change affecting the spread of invasive animal/plant species such as (specific local species)? • What are the impacts of invasive species such as (specific local species)? • What actions can be taken to control invasive species such as (specific local species)?
Marine Debris, Microplastics, Plastics	• What are the trends in the use of microplastics and what actions can be taken to reduce what ends up in the ocean? • Document the presence of marine debris in the Great Lakes and what communities can do to reduce the input.
Human Health Issues, Vector-borne Disease	• How is climate change affecting the incidence of vector-borne diseases? • What actions can be taken to reduce the incidences of vector-borne disease?
Nuisance Flooding, Weather Incidents, Shoreline Changes	• What are the impacts of local/state flooding events and what strategies are communities using to protect citizens and property? • Document how climate change may affect the incidences of severe weather. What actions should citizens take to prepare for the new climate future?

Otter Lake fog at Sleeping Bear Dunes National Lakeshore.

Photo credit: National Park Service

Sprint Implementation

A design sprint can be carried out over several days in class or an educator can choose to provide a one-day event in which the students have developed their research question and have been given a chance to investigate relevant data. The scope of the sprint may be within your class, within a school building or even multi-school. Next determine the length of the design sprint. Factors to take into consideration include team formation, idea selection, work time, and presentation options. How will solutions and prototypes be shared, evaluated, and displayed? A list of possible themes and research questions needs to be developed by the students. Decide if teams will be able to develop their own questions. Sample student-generated research questions are displayed in Table 4.

Table 4: Samples of Student-Developed Research Questions

• How do you think AI can help solve the issue of invasive species? • Do invasive species cause long term human health issues, if so what kind and what have we done in the past to prevent/stop them?
• What does marine debris encompass? Please provide categories or examples. • Is it possible to introduce catalysts that will re-polymerize microplastics so they can be combined into larger molecules that are easier to extract? • Are there any projects where algae or bacteria is being used to breakdown plastics or marine debris?
• In what ways does the algae benefit the ecosystem compared to what they take away? • How do algae compare to other marine/ aquatic plant life? • Could there be blooms of any other plant species that cause as much harm as algal blooms? • What is the main cause of algal blooms/ where is it most prevalent? • If algae is helpful to ecosystems, how does it also cause harm? • Could the impact of algae blooms extend as far as the Midwest and affect our drinking water supply?
• Once an aquatic system is thrown off-balance, can it fully recover, and how? • What types of laws or regulations have been put in place to regulate the use of fertilizers?

Teachers should guide the use of resources for the research phase. Although students at this level are capable of research, due to time constraints and often unfamiliarity with the types of needed resources, it is helpful to have options to share with teams. Many types of media provide a wide array of data regarding environmental issues. Government sources of information are particularly useful. This includes federal NOAA and NASA databases, USGS, USDA, and the U.S. Forest Service. State Departments of Natural Resources, local county offices and experts from extension services should be contacted for information and for being onsite mentors. In addition, local environmental agencies, community colleges, colleges and universities, colleagues, local meteorologists, professional organizations (NESTA, NSTA, your state science teaching chapter) are a few suggestions. Invite subject matter experts to participate in person, virtually, via email, or interviews.

Figure 1. Dennis Liu talks with a student about biodiversity and invasive species. Photo credit: Angela Rowley

Schedules, purpose and format of the sprint, and student generated questions should be shared with invited guests ahead of time. It is also helpful to have some questions developed yourself about information students may need but didn't cover in their questions. While planning the daily schedule for the sprint, consider how solutions and mitigation decisions will be shared. An idea for the final session is to divide teams into groups A and B. While group A teams present, group B teams move about and listen to group A team presentations. Reverse the roles so that group B teams are presenting and group A teams are listening.

Culminating Experience

Consider having a one-day experience for the students at the end of their design sprint. In one example, The Great Water Challenge was held at the Illinois Mathematics and Science Academy and centered around environmental issues of the Great Lakes. During registration for the project, student teams selected the question they wanted to investigate, subject matter experts they wished to hear, and submitted questions they wanted to ask each of the subject matter experts at the event. Teams were provided with resources to use for preliminary research prior to the event. Many student teams came prepared with extensive background knowledge about their chosen issue. This allowed them to focus on having final questions answered from the experts and to develop solutions and evidence to support their choice. All participants gathered in the auditorium where subject matter experts introduced themselves, briefly spoke about their jobs, and shared their areas of expertise. From there, teams moved to meet with the subject matter experts either in-person or virtually via Zoom, who presented additional background information regarding their topics and answered student questions.

Figure 2. Students engage with a virtual expert to learn more about their chosen topic.
Photo credit: Angela Rowley

Each team then began developing ideas to suggest ways to respond to their selected issue, as well as a presentation and materials for and poster session in the afternoon. The day wrapped up with awards that recognized creative efforts, scientific accuracy, and clarity of solutions.

Designing a day-long culminating challenge for multiple schools requires some additional preparation. Provide teams with resources to use for preliminary research prior to the event. Coming prepared with extensive background knowledge allows them to focus on having final questions answered by experts and to develop solutions and evidence to support their choice. Schedules for the day need to be customized for each school to meet with their subject matter experts of choice. Identification of and communication with experts is critical. Presentation materials, topics and questions from teams, schedules, and technical platforms need to be developed and shared. School and student permissions for participating and photographing, schedules, and other logistics for the day also need to be shared in advance. Consider beginning the day with all participants gathered in the same space for an introduction to the day and the guest experts. Divide into smaller areas where teams meet with their respective experts. Note, it may be appropriate for teams to divide up so they may attend multiple sessions. Allow planning time and presentation development time for the students.

Impact

The impact of the Great Water Challenge pilot is largely anecdotal in nature. Comments during the day were very positive from the students, the participating educators, and the subject matter experts. Responses are anecdotal in nature and some reflections are shared below and may be helpful in gaining support to implement the experience in your classroom or school.

- *"Our students thoroughly enjoyed the day. They have been talking about their idea to all of their teachers."* – Educator
- *"I didn't know that what we do here bothers the ocean."* – Student
- *"Why aren't there laws to stop that?"* – Student
- *"This is the best day of my life!"* – Student
- *"I met real scientists."* – Student
- *"Students were well prepared. They asked really good questions and had great ideas."* – Subject Matter Expert
- *"They are persistent."* – Subject Matter Expert
- *"It was refreshing – their perspective."* – Subject Matter Expert

A design challenge may provide a spring board for more opportunities for students to interact with subject matter experts regarding a wide range of environmental issues.

About the Author

Liz Martinez is a curriculum, assessment, and professional development consultant. Prior to this she was a curriculum and professional development specialist with the Center for Teaching and Learning at the Illinois Mathematics and Science Academy. In addition, she was a middle school science teacher for 29 years. Liz is a past president and secretary for the National Middle Level Teachers Association, and founding member of the Northern Illinois Science Educators. She has been a NOAA Climate/Planet Steward for many years and is appreciative of the support and opportunities they have provided over the years. She can be reached at lizlutter@gmail.com.

Using My NASA Data Literacy Cubes in a Co-Teaching Model

Angela Rizzi, Dr. Barbie Buckner, Michele Lewis, Sarah Creech, Rosalba Giarratano, and Maria Royle

Abstract

Two teachers, Michele Lewis and Sarah Creech, effectively implemented the Data Literacy Cubes from My NASA Data with students in a co-teaching model. They combined science and social studies content to provide their students a unique opportunity to learn about oil and gas deposits and landforms in Ohio. Post-test metrics showed statistically significant student growth.

Data Literacy Cubes

The Data Literacy Cubes found on the My NASA Data website offer a structured way to engage with real world Earth data and develop essential analytical and data literacy skills. These differentiated resources provide guided support for students to analyze and interpret NASA Earth data and visualizations. The Data Literacy Cubes are a hands-on tool that leads students through the process of exploring, analyzing, and interpreting NASA Earth science data in various formats using either the graph version, map version, or dataset version. Each version provides leveled questions addressing the same concepts. The questions guide students to think critically about the data, understand the underlying concepts, and draw meaningful conclusions. This enables students to use the same cube but answer different questions based on the data type and their language skills.

ENGAGE GLOBE Mission Earth

Michele Lewis and Sarah Creech from East Clinton Middle School in Sabina, Ohio learned about the Data Literacy Cubes when one participated in the ENGAGE (Earth, NASA, GLOBE, And Guided Explorations) GLOBE (Global Learning and Observations to Benefit the Environment) Mission Earth training. This 2023-2024 teacher cohort of in-service middle and high school educators participated in a year-long program that included virtual professional development and ongoing support from a NASA mentor.

Cohort participants incorporate The GLOBE Program to help students utilize observation skills, explore Earth science content, and practice science writing skills using pacing guides and lesson plans centered on outdoor environmental observations. The Data Literacy Cubes are presented to help students analyze their GLOBE data as well as related NASA satellite data. The sequence culminates in student writing that is considered for publication on the GLOBE website. The opportunity is supported by GLOBE Mission Earth, NASA Science Activation award No. NNX16AC54A and supports the Next Generation Science Standards (NGSS) released in 2013.

Next Generation Science Standards NGSS (2013)

Disciplinary Core Idea	• ESS2 Earth Materials and Systems
Science and Engineering Practices	• Asking and Defining Problems • Analyzing and Interpreting Data
Crosscutting Concepts	• Systems and system models • Cause and Effect • Patterns • Stability and Change

What's included in the Data Literacy Cubes?

Cube Template – There is a black-line master template for a cube. This template is used to construct a 3D cube for use with question sheets. Figure 1 shows the assembled cubes.

Figure 1: My NASA Data Literacy Cubes are used with maps, time-series graphs, and/or data tables.
Photo Credit: My NASA Data

Question Sheet Guide – The Graph version (specifically for line graphs), Map version and Dataset version are used with different types of data visualizations commonly used in Earth/environmental science classrooms. Each version has four leveled question sheets to facilitate differentiated instruction. They are leveled for both Lexile and WIDA English-language proficiencies. The levels are:

- **Novice** (Lexile Levels - 200-400) (WIDA proficiency level suggestions: 1.5-2.5)
  - Intended Audience: elementary students, struggling learners, ELL's, and students with specific accommodations.
- **Developing** (Lexile Levels - 210-400) (WIDA proficiency level suggestions: 1.9-2.5)
  - Intended Audience: elementary students, struggling learners, ELL's, and students with specific accommodations.
- **Proficient** (Lexile Levels - 410-600) (WIDA proficiency level suggestions: 2.5-4.5)
  - Intended Audience: students who require reading support, and those whose sentence and word phrase dimensions are more advanced.
- **Advanced** (Lexile Levels - 610-800) (WIDA proficiency level suggestions: 4.5-6)
  - Intended Audience: fluent English speakers, academically advanced learners, and abstract thinkers.

Keyword List – A list of keywords is included on various question sheets. It provides the teacher and learner with opportunities to document key vocabulary words that are incorporated in the data analysis prior to starting the activity. Some words have been included in the list, but space is provided for those who wish to add additional words that are important in the lesson. This provides language support to facilitate student understanding of the questions.

Task Card – The Task Cards provide roles for students while conducting the data analysis. This allows students to specialize in an area of data analysis and recording while contributing to the team. This is a great way to also include multilingual and other learners. Figure 2 shows a group of students with different roles.

Figure 2: Students worked in groups and had different tasks based on the task cards. Photo Credit: Sarah Melnek

Finding Data

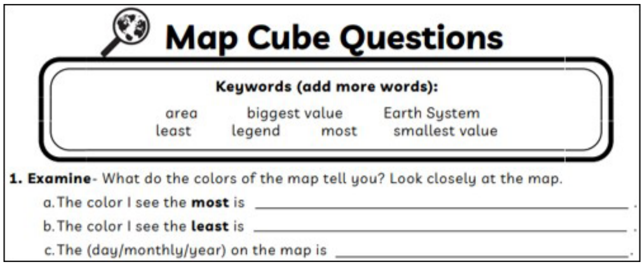
The resource can easily be adapted to various data sources such as maps, graphs, and datasets. Teachers interested in mapped data can use the My NASA Data Earth System Satellite Images. This set of images provides teachers and students opportunities to explore data and identify relationships between and among different components of the Earth system. They provide an opportunity for learners to visualize how different Earth system variables change over time, establish cause and effect relationships for a specific variable, identify patterns, or determine relationships among variables. There are six My NASA Data lesson plans which incorporate these images. The set consists of global images spanning one year for six different Earth science variables:

- Aerosols
- Cloud Cover
- Insolation (incoming solar radiation)
- Precipitation
- Surface Skin Temperature
- Vegetation

Teachers interested in using real-world NASA satellite data can use the My NASA Data visualization tool, the Earth System Data Explorer to generate line graphs, customized maps, and/or datasets. There are over sixty datasets, organized by Earth Systems Sphere. The Data Literacy Cubes were developed for use with this data, but the tool is versatile enough to easily be used with other Earth science graphs, maps, and/or datasets. Alternatively, teachers can use their own maps or data with the cubes.

Implementation

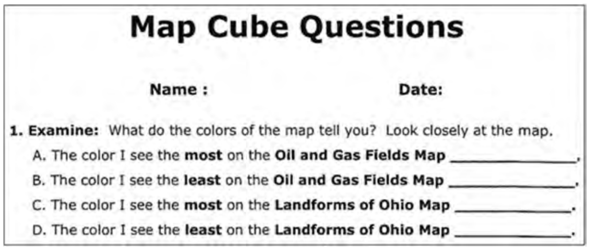
Michele Lewis and Sarah Creech teach in a rural Ohio school with 65% free and reduced lunch. The school has 271 students in grades 6-8. The implementation of this project involved the entire sixth grade of 76 students. The teachers recognized the flexibility of the cubes and modified questions for their lesson. They adapted the map question sheets to include the specific name of the maps they were using and kept the rest of the questions the same. Figure 3 shows some of the original Level 1 map questions and Figure 4 shows the modified questions.


Map Cube Questions

Keywords (add more words):
area, biggest value, Earth System, least, legend, most, smallest value

1. Examine- What do the colors of the map tell you? Look closely at the map.
   a. The color I see the **most** is ____.
   b. The color I see the **least** is ____.
   c. The (day/monthly/year) on the map is ____.

Figure 3: The original Level 1 map cube questions for item 1 have students examine the colors on the map. Other questions have students identify the meaning of the colors. Photo Credit: My NASA Data


Map Cube Questions

Name : Date:

1. **Examine:** What do the colors of the map tell you? Look closely at the map.
   A. The color I see the **most** on the **Oil and Gas Fields Map** ____.
   B. The color I see the **least** on the **Oil and Gas Fields Map** ____.
   C. The color I see the **most** on the **Landforms of Ohio Map** ____.
   D. The color I see the **least** on the **Landforms of Ohio Map** ____.

Figure 4: The modified Level 1 map cube questions for item 1. The questions were modified to include the names of the two maps. Photo Credit: Sarah Melnek

The teachers placed students into small groups and provided each group with Ohio maps and an overlay transparency of Ohio oil and gas fields as seen in Figure 5, an adapted map question sheet, and a data literacy cube.

The lesson was implemented with the student population described in Table 2.

Figure 5: Map of Landforms of Ohio with the overlay of the Oil and Gas Fields of Ohio.
Photo Credit: Sarah Melnek

The lesson focused on sixth grade science standards related to soil formation and natural resources. The target from the Ohio Learning Standards for Science. (Ohio Department of Education, 2018) included:

- 6.ESS.4: Soil is unconsolidated material that contains organic matter and weathered rock
- 6.ESS.5: Rocks, minerals and soils have common and practical usesIt also focused on sixth grade social studies standards for different types of maps and using different tools on a map.

Table 2: Breakdown of the sixth-grade students.

Out of 76 students, eleven are gifted, twenty have an IEP and six have a 504.

Sixth Grade Students	
Total	76
Gifted (Math or ELA)	11
IEP	20
504	6

The Ohio Learning Standards for Social Studies (Ohio Department of Education, 2019) targets were:

- Geography Spatial Thinking and Skills - Content Statement 3:
- Geographic tools can be used to gather, process and report information about people, places, and environments and Content Statement 5:
- Regions can be determined, classified, and compared using data related to various criteria including landform, climate, population, and cultural and economic characteristics

All students were administered the Pro-core pre-test and post-test to measure their progress according to the Ohio Learning Standards (Pro-Core, 2024). The results, as shown in Table 3, demonstrate gains in understanding following the lesson.

Table 3: Pre- and post-test data for students showing a statistically significant positive shift in the distribution of proficiency levels.

	Pre			Post		
Standard	Below Proficient	Proficient	Above Proficient	Below Proficient	Proficient	Above Proficient
Social Studies - Geo 3	86.84%	13.16%	0%	2.63%	22.37%	75.00%
Social Studies - Geo 5	75.00%	25.00%	0%	2.63%	9.21%	88.16%
Science - 6.ESS.4	88.16%	11.84%	0%	14.47%	7.89%	77.63%
Science - 6.ESS.5	81.58%	18.42%	0%	2.63%	28.95%	68.42%

A statistical analysis was conducted to assess the changes and evaluate their significance. The Chi-square test revealed a statistically significant and positive shift in the distribution of proficiency levels between the pre-test and post-test, with a p-value well below 0.05. This indicates that the observed improvements in proficiency levels are unlikely due to random change and are statistically significant.

The teachers successfully employed the following best practices included in the Ohio Teacher Evaluation Rubric 2.0 (Ohio Department of Education, 2020) and the Ohio Personalized Learning framework (Ohio Department of Education, 2023).

- **Multidisciplinary content** – Teachers integrated science and social studies, and students applied science learning to maps of Ohio.
- **Cultural relevance** – Teachers adapted the lesson to use Ohio data. Students engaged with maps of Ohio that they are familiar with to later apply the information other areas around the world.
- **Fun and engaging environment** – Teachers introduced the lesson by dressing up as frontiersmen as shown in Figure 6. They changed mid-lesson into construction workers for the ice age (L & C Ice Company). Costumes and reenactments hooked students into the activity from the beginning.

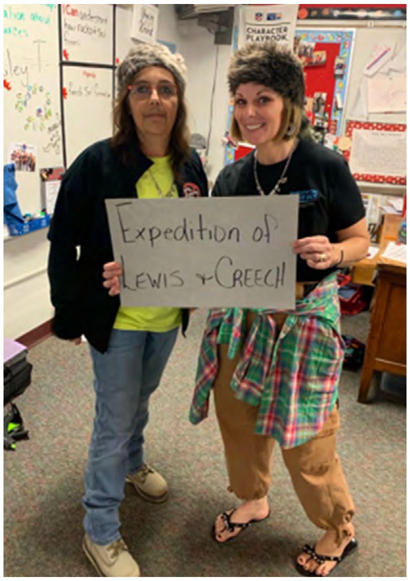


Figure 6: Lewis and Creech dressed up to make the lesson more engaging.

Photo Credit: Sarah Melnek

- **Data literacy** – Teachers analyzed and interpreted real data. Students were given a Pro-core pre-test over the standards prior to instruction. Students then took a Pro-core post-test following the activity. Teachers use Pro-core as one piece of high-quality student data.
- **Differentiated instruction** – Teachers worked to meet students' different learning styles and levels by using cooperative learning, auditory, visual, and kinesthetic skills. Students were grouped by learning style and mixed ability.

Conclusion

This lesson highlights the adaptability of the My NASA Data Literacy Cubes to many student populations. They provide scaffolded questions to analyze and interpret data yet are flexible enough to be incorporated into lessons with a variety of Earth science content. Additionally, the question sets are available in various formats and can be easily modified by teachers to fit their lessons. The differentiated questions support learners with different language abilities, and they are well suited to be used with diverse groups of students. The success of this lesson implementation also demonstrated that using authentic data with the differentiated Data Literacy Cubes can be leveraged to make cross-curricular lessons come alive. The statistically significant student growth shown in the post-test results suggests that using the Data Literacy Cubes enhances data literacy, encourages critical thinking, and engages interactive learning, all while supporting curriculum standards for all students.

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About the Authors

Angela Rizzi is the Task Lead for My NASA Data. She joined the team in 2018. She is a highly qualified teacher with certification in Middle School Math and Science and High School Earth Science. She taught for over 11 years and is also a seasoned GLOBE (Global Learning and Observations to Benefit the Environment) teacher. She effectively leveraged over 10 years of experience as an IT consultant to utilize technology in her classroom and draws on that experience in support of My NASA Data content and data visualization tools. Angela can be contacted at angela.rizzi@nasa.gov.

Dr. Barbie Buckner is a veteran STEM classroom teacher with a Doctorate in Mathematics Education. Her research interests include the impact of technology on student achievement and teacher behavior. In 2013-14, Buckner served as an Einstein Fellow at the National Science Foundation, where she collaborated on learning, learning environments, broadening participation, and workforce development. She has spent the last ten years as a NASA Education Specialist,

focusing on educator professional development. Barbie sees education as her calling and has dedicated her life to sharing her love for learning with everyone around her. Acknowledging that today's students will compete in a global economy, Barbie asserts, "It is imperative that today's students are prepared with consistent, rigorous, and relevant standards that produce more STEM majors, particularly women, to keep this great nation at the forefront of technology, innovation, and advancement." Barbie can be contacted at barbie.buckner@nasa.gov.

Michele Lewis is a 6th grade science teacher at East Clinton Middle School in Sabina, Ohio. She has been a science teacher for 10 years. She was the East Clinton Middle School Teacher of the Year in 2023 - 2024. She has served on the district Astro Pride Committee and Building Leadership Teams. Michele is the Advisor of the Science Club. Michelle can be contacted at michele.lewis@eastclinton.org.

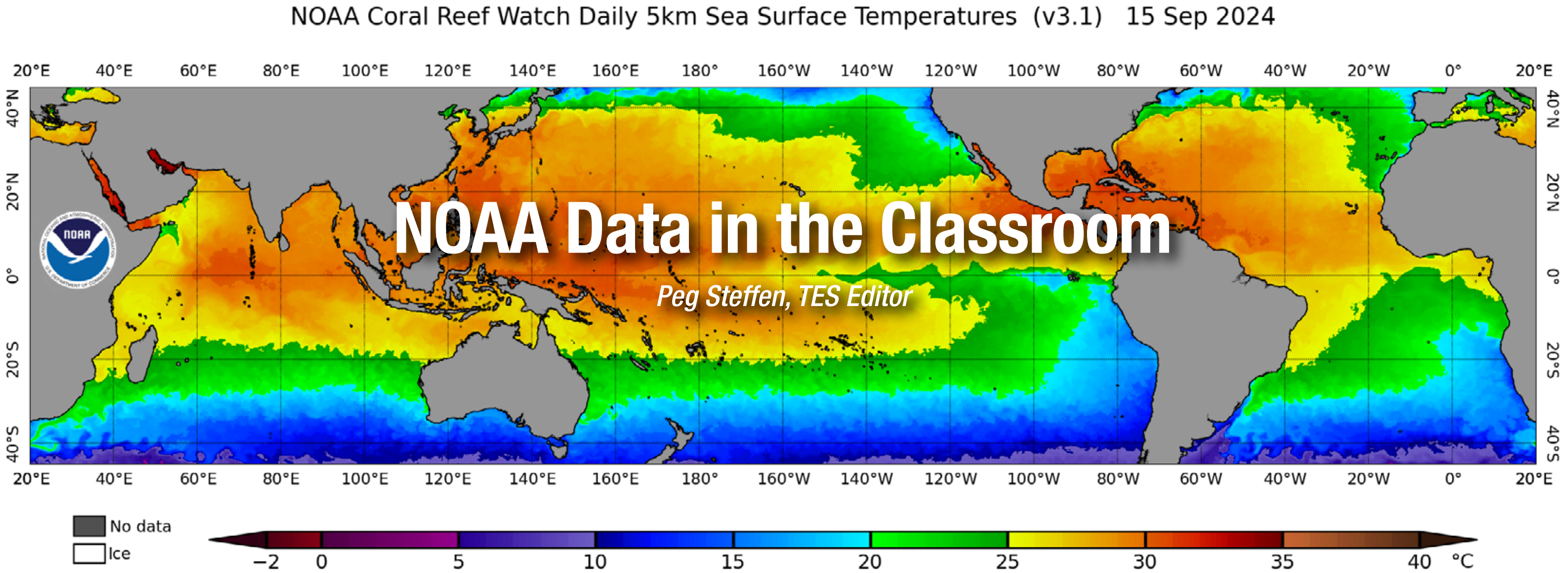
Sarah Creech is a 6th grade social studies teacher at East Clinton Middle School, a rural school district in Sabina, Ohio. She has taught 6th social studies in the same district for all of her 25 years in education. She earned a BS in elementary education from Wilmington College and a master's degree, "Masters in The Art of Teaching", from Marygrove College. She was teacher of the year for the 2004-2005 school year. Sarah serves on the middle school's building level PBIS Team (Positive Behavior Interventions and Supports), is a member of the Astro Pride Committee and is also the Student Council co-advisor for grades 6-8. Sarah can be contacted at sarah.creech@eastclinton.org.

Rosalba Giarratano is a dedicated leader in accessible science education, who engages diverse communities in GLOBE and other NASA programs. Currently, she leads the ENGAGE (Earth, NASA, GLOBE And Guided Explorations) GLOBE Mission Earth cohort, training and supporting teachers across the United States. Rosalba holds an undergraduate engineering degree, master's degrees in bilingual education and in information systems, and she is currently pursuing her doctorate degree instructional design and technology. She is certified as a professional in accessibility core competencies by the International Association of Accessibility Professionals, and she holds a New York State bilingual education certification as well. Rosalba's contributions to broaden student participation in STEM and to raise awareness of best accessibility practices in the workplace have earned her accolades, including the NASA Agency Honor Award—Diversity, Equity, and Inclusion Medal. Rosalba can be contacted at rosalba.n.giarratano@nasa.gov.

Maria Royle is a bilingual, dual-certified former educator in science and English to Speakers of Other Languages (ESOL) with over 18 years of teaching experience, as well as a GLOBE-trained teacher. She interned as an educator for My NASA Data in 2021 through NASA's internship program. Maria also has extensive experience in developing educational resources that focus on Universal Design for Learning, Diversity-Equity-Inclusion-Accessibility (DEIA), and 508 compliance. Maria can be contacted at mdr0303@gmail.com.

NOAA Data in the Classroom

Peg Steffen, TES Editor



NOAA Coral Reef Watch Daily 5 km Sea Surface Tamperatures 15 Sept. 2024

NOAA possesses an array of observing systems that monitor oceanic, atmospheric, and terrestrial parameters that can be used to teach STEM principles & concepts. Using historical and real-time scientific data offers exciting classroom teaching opportunities to study the processes and interactions of planet Earth with an emphasis on observing, understanding, and predicting global environmental changes. Data-rich resources are available for project-based and problem-based learning investigations in the physical, earth and biological sciences, providing pathways for students to become informed planetary citizens.

Data in the Classroom brings together NOAA data, education resources and technology to help support teachers and educators around the world develop a fundamental understanding of the systems of the natural world, the relationships and interactions between the living and non-living environment, and the ability to understand and use scientific evidence to make informed decision regarding environmental issues. Scientific concepts of interactive Earth systems including ocean and climate literacy principles are important foundations to NOAA's work.

Data in the Classroom is a series of 5 online curriculum modules that integrate tools for accessing NOAA data. Modules include:

- **Investigating El Niño**, (Grades 6-12): How does NOAA track changes in sea surface temperature over space and time and how does El Niño affect phytoplankton & species distribution in the eastern Pacific Ocean?
- **Investigating Sea Level,** (Grades 6-12): How do scientists monitor sea levels in order to determine the effect of sea level changes on coastal communities?
- **Investigating Coral Bleaching,** (Grades 6-12): How can NOAA data (ocean surface temperature, coral bleaching hotspots, and accumulated heat stress) be used to understand and monitor coral bleaching events in the world's oceans?
- **Monitoring Estuarine Water Quality**, (Grades 6-8): How can water quality parameters (nutrients, temperature, salinity, pH, dissolved oxygen) and an interactive graphing tool be used to understand the effect of water quality on estuarine organisms?
- **Understanding Ocean and Coastal Acidification**, (Grades 9-12): What are the relationships between carbon dioxide, ocean pH and aragonite saturation state and how can ocean conditions support the growth and survival of shell-building marine life, both now and in the future?

In addition to providing a virtual platform with data tools and simulations, the lessons allow students to interact with the content through multiple modalities. Each module contains five scaled levels of interaction: Entry, Adoption, Adaptation, Interactivity, and Invention. (Figure 1) Entry and Adoption levels are teacher driven but are important first steps when learning something new.

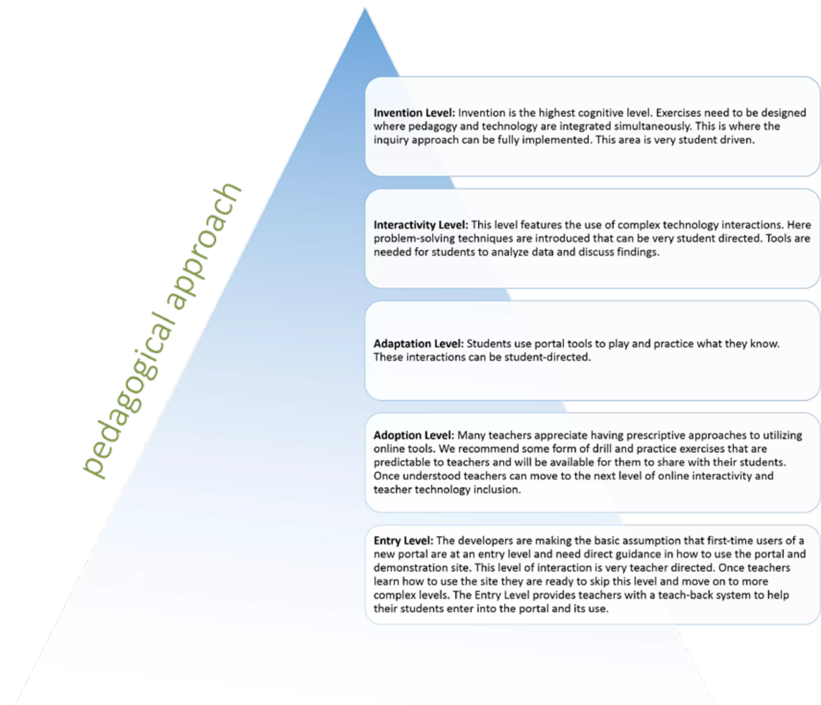


Figure 1. The levels of adaptation through invention are more student directed and open up opportunities to design lessons featuring student driven inquiry.

Each module is built with the same structure and sets of resources, including online data visualizations and activities for students, and user-friendly tools for accessing and exploring NOAA data. A Teacher Guide provides background information, detailed instructions on the use of the data tools and suggestions for guiding students through the exploration of real-world data. Story Maps contain a series of five web-based lessons (Levels 1-5) that provide a stepped entry into a series of authentic data investigations that increase in complexity and student-directedness. Each Story Map also contains a 'Get Data' tab that provides direct access to all data tools within the module.

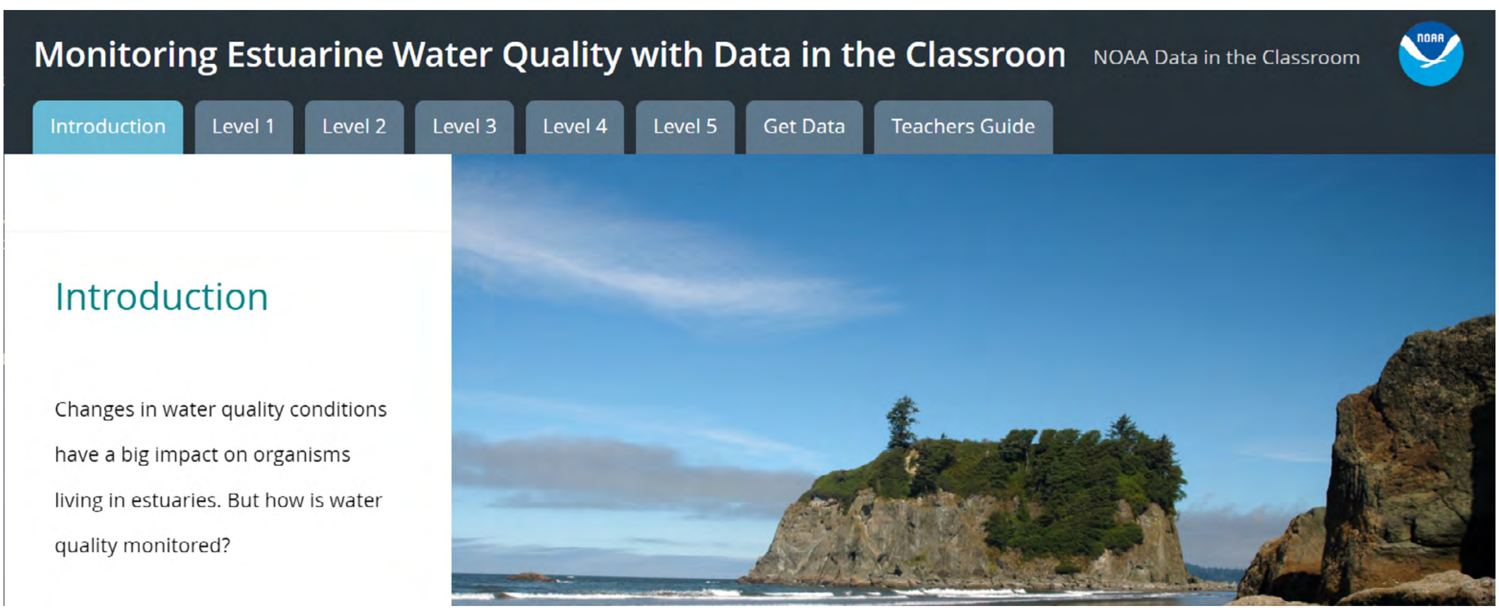
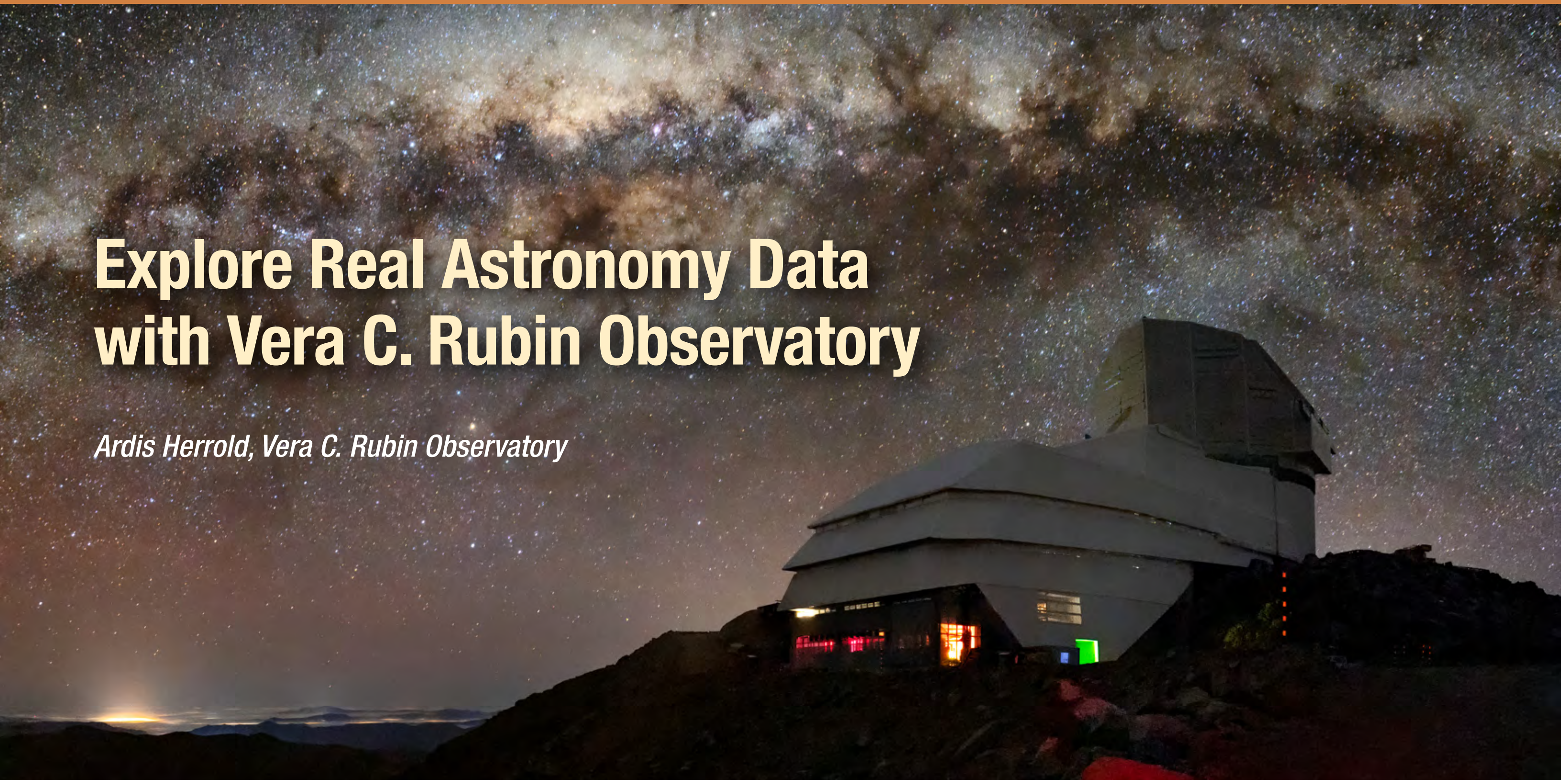


Figure 2. Monitoring Estuarine Water Quality offers lessons at five different levels, beginning with basic graph interpretation (Levels 1 & 2) and building towards activities that challenge students to ask questions and develop their own data investigations (Levels 4 & 5).



The luminous Milky Way stretches across the sky behind the silhouette of Rubin Observatory. Photo credit: Rubin Observatory/NSF/AURA/B. Quint

Abstract

The Education and Public Outreach (EPO) Team at Vera C. Rubin Observatory (formerly the Large Synoptic Survey Telescope, LSST) offers free classroom investigations that make it simple for students to work with authentic data while learning some of the commonly taught topics in an astronomy unit or course. All investigations are designed to support the Next Generation Science Standards (NGSS, 2013), and require no additional materials other than internet access. The investigations and website are available in English and Spanish.

Background

Vera C. Rubin Observatory is currently under construction in Chile and is scheduled to begin operations in late 2025. Using the world's largest camera, it will conduct a ten-year survey by imaging the entire sky visible from its location every 3-4 nights. Each image spans almost ten square degrees (about the area of 45 full moons) and has a resolution of about 3.2 gigapixels. The large size and high resolution of these images, combined with frequent visits to each area of the sky, will make it easier than ever before to spot objects that change in brightness, such as supernovae, or objects that move across the sky, such as asteroids and comets. Over the ten-year survey, images will be combined to produce very deep views that will lead to countless discoveries and help to answer some of the biggest questions in astronomy.

Rubin Observatory brings the power of real data and interactive learning to educators and students around the world through a suite of free online investigations. Each investigation explores common astronomical topics taught in advanced middle school, high school, and college "Astronomy 101" courses, and can be used in asynchronous or face-to-face settings.

Accessing and using authentic data has historically required using specialized query routines, installing and learning special software, or downloading data, which requires additional time, permissions and computing power. But Rubin Observatory has made it simple. All of the tools for data analysis are contained in the

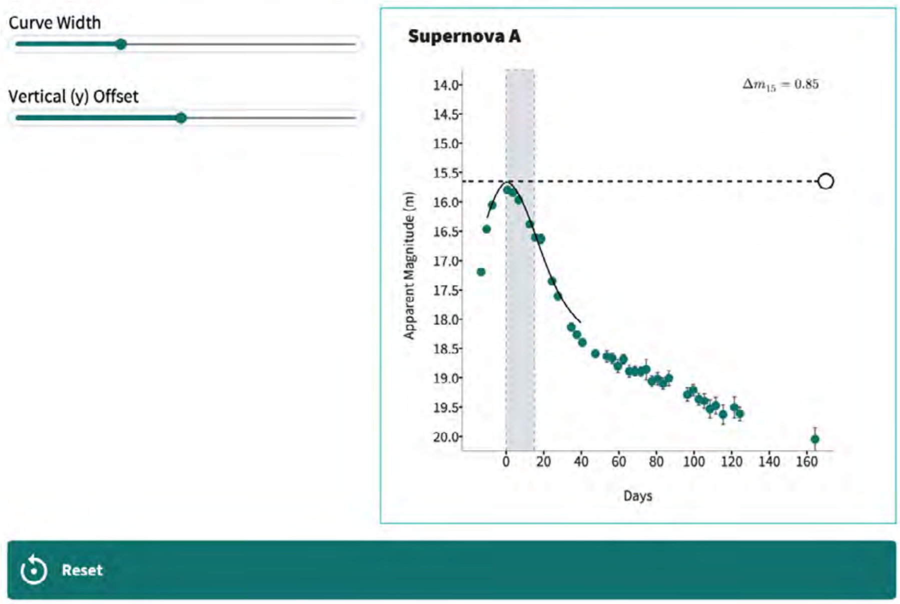


Figure 1. An interactive tool for fitting a supernova light curve. Photo credit: Rubin Observatory

investigation, so no downloads or additional software are required. Teachers and students need only to access to the internet using a Chromebook, desktop, or laptop computer. (Full functionality might not be achieved using a phone or tablet, check on your device to be sure.) Currently, all data are from other observatories or surveys, but Rubin data will be swapped in as soon as it is available.

These investigations are not online worksheets, but are interactive web applications that contain intuitive tools and rich data visualizations. The science methodologies parallel those that professional scientists use to evaluate data. Students can apply them to interpret their own unique dataset. The emphasis is on improving data literacy and applying science practices to extract key concepts, as opposed to focusing on content recall.

Instructional Design

Investigations incorporate multiple supports to ensure that all students can achieve mastery learning, drawing on best practices from the Universal Design for Learning (Meyer et al, 2014) and Integrating Differentiated Instruction + Understanding by Design (Tomlinson and McTighe, 2006). Special tools have been developed for low vision users that enable them to interrogate and fit curves to data.

The interactive nature of each investigation builds engagement as students learn the essential concepts for each lesson and decide how to interpret data. The cloud-based format allows for self- pacing, reviewing, and saving work. Progress bars and congratulatory breaks appear as the lesson progresses. Where possible, guided practice and feedback are provided before introducing a new or unique data set. An embedded glossary provides simple definitions for science vocabulary in context with learning.

Sequenced tasks and questions build a progression of the concepts necessary for students to make sense of the big ideas of each investigation. In addition to providing a scaffolded learning approach, some questions are added for the purpose of confronting misconceptions and helping students to reflect on and reassess their conceptual models.

The approach to numerical literacy emphasizes evaluating computational and data relationships rather than focusing on doing arithmetic. To achieve this, equations come with embedded calculators to do the number-crunching. This affords more time to concentrate on conceptual learning, and builds confidence in students who may feel that they cannot "do science" because of their math skills. Multiple modalities for learning include text, numerical relationships, computational and spatial data visualizations, graphics, and animations. Students can express learning through open-ended questions, image creation, and sketches. Collaborative work is encouraged through opportunities for interactive formative assessment and peer discussions. Each investigation includes some questions or tasks to solicit student input from their unique ideas and perspectives, which helps to build relevance and inclusion (O'Donnell et al, 2021, Bell & Bang, 2015).

Using Evidence to Support Your Ideas

It might be tempting to imagine that Earth is the center of the Universe if you don't consider the perspective of observers in other galaxies.

Often breakthroughs in understanding, such as there being no center to the Universe, come as a result of challenging the popular theories or beliefs of the time.

26. Describe a time when you (or someone you know) had an idea or opinion that went against what is commonly accepted by most people. What evidence did you use to try to convince others to consider your idea or opinion?

Adding new evidence can change commonly-held opinions or ideas. Credit: Rubin Observatory

Figure 2. An example of a question designed to invite discussion from students' perspectives.
Photo credit: Rubin Observatory

Supplemental Materials for Investigations

Investigations are designed as individual lessons that can be flexibly incorporated into any learning sequence. Accompanying materials include a phenomenon, teacher guide, a short science video, speaker slides, and a variety of assessments. All components are designed for three-dimensional student-driven learning and assessment, providing support for the Next Generation Science Standards. The online application can be completed in two hours or less, but the lesson can be customized and extended depending on which additional components are used.

Comprehensive teacher guides contain information on the NGSS standards, prerequisites, and learning outcomes, as well as notes about the data and scientific processes used. Four sections may be especially useful if you are new to teaching astronomy:

- Background and Teacher Notes contain an overview of the topic, and links to the free OpenStax Astronomy textbook.
- Common Student Questions highlight typical student questions with (teacher) answers.
- Common Student Ideas address preconceptions, misconceptions, incomplete learning, and learning confusions, along with suggestions to redirect students toward building a conceptual model that achieves the learning outcomes.

The phenomenon included in each investigation may be used as an engagement piece and as a way to assess and direct student learning. Each phenomenon has a lesson-specific driving question that can be used as the focus for a driving question board or other methods of formative assessment, and a summative section which may be used to revisit the phenomenon at the conclusion of the investigation.

Three types of assessments are provided for each investigation: A pre/post-test, formative assessments, and a summative assessment. All may be downloaded for use in learning management systems and classrooms. The pre/post-test is a short multiple-choice test that emphasizes interpreting data. Formative assessment questions are correlated to checkpoints in the investigation where a teacher may pause to check for understanding and implement redirects. The summative assessment is designed with open-ended questions and comes with a scoring rubric. All assessments have answer keys with three-dimensional learning components identified that support the Next Generation Science Standards. (Stromholt, S. et al, 2017).

Beyond the core components listed above, there are additional resources available on the general Rubin Observatory website such as slideshows, images, and general information about the observatory. A series of short animated videos are available in English and Spanish to help introduce students to the observatory and some of the science it will pursue. Rubin Voices are short profiles of Rubin scientists and staff that feature diversity, personal interest facts, and short audio files of each person's voice as part of their story. "Make Your Own Rubin Voices Trading Card" encourages students to visualize themselves in a STEAM career, and comes with a teacher guide

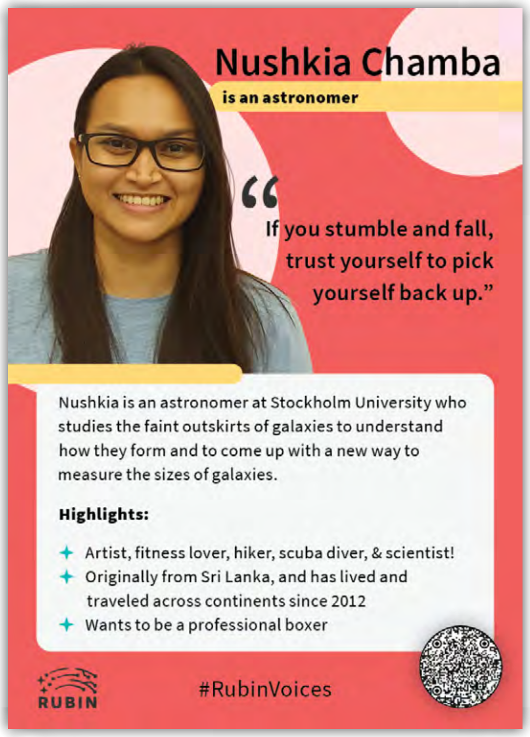


Figure 3. A Rubin Voices trading card. Photo credit: Rubin Observatory

How to Get Started

Visit rubinobservatory.org/education to check out all seven investigations. Surveying the Solar System, Expanding Universe, Exploding Stars and Coloring the Universe are available in English and Spanish.

You may also use beta versions of Hazardous Asteroids, Exploring the Observable Universe, and the newest addition, Stellar Safari. These investigations are still undergoing some revisions, so are not yet available in Spanish.

In order to access the assessments and answer keys for any investigation, you must first create a free teacher account. You will be prompted to do so when you try to view any assessment.

Discuss implementation, share ideas and ask questions of other educators and the Rubin education team by joining the Rubin Observatory Educators community of practice. It exists in two forms: a Facebook group and an email discussion list. To join the Facebook group, simply agree to the group rules. To join the email discussion list, send a message to education@lsst.org.

Figure 4. Free investigations available for use now at rubinobservatory.org/education.
Photo credit: Rubin Observatory/NSF/AURA

More educator-tested material to supplement your astronomy units may be found at the Center for Astronomy Education, which contains classroom resources such as instructional strategies, lecture slides and tutorials, and question banks.

Conclusion

The first six investigations designed by the Rubin Education and Public Outreach Team have been tested by more than 4800 teachers and students from over 30 countries and are reported to work effectively in typical classroom and online contexts considering available resources, time constraints, and the common learning challenges of students. Beyond that, teachers and students alike express enthusiasm for the interactive design, flexible use, and open-ended nature. In the words of one teacher, “It’s focused more on the real work people are actually doing. It’s very supportive of inquiry – nothing says you should know the answers, nor that it’s beyond your reach. This is the data that folks are working on in astronomy and we are wanting to see what you find out. They (students) can discover without feeling threatened.”

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Collaborators

It takes a team effort to produce quality educational resources. Education and Public Outreach Team members **Kristen Metzger** and **Justine Schaen** reviewed this article. José Pinto designed investigation graphics and has led efforts for most of our short videos. **Stephanie Deppe** created the Rubin Voices section of the website. Developers **Blake Mason** and **Alexandra Goff** created the interactive widgets and online applications. Data scientist **Clare Higgs** contributed astronomical expertise in acquiring and preparing data to be used in the investigations.

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