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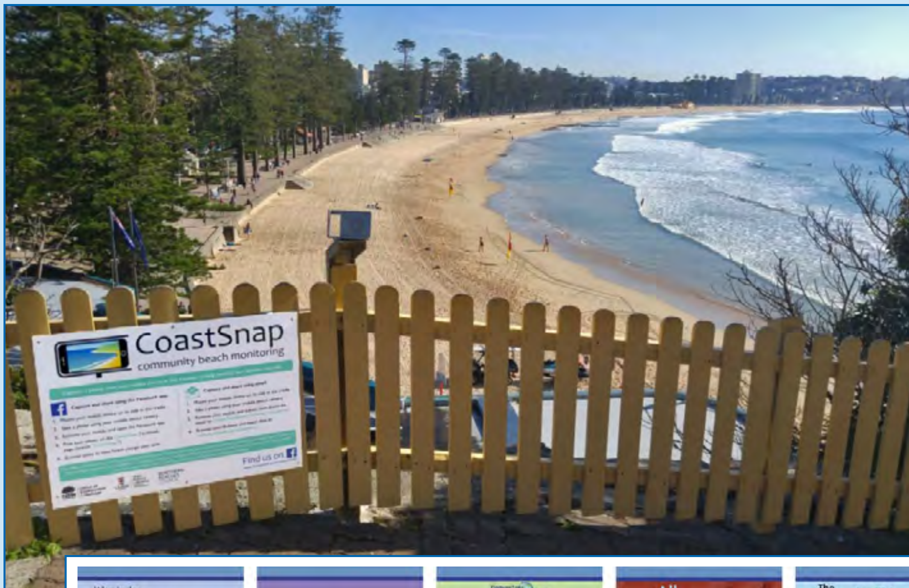
In The Trenches

THE NEWS MAGAZINE OF THE NATIONAL ASSOCIATION OF GEOSCIENCE TEACHERS



CITIZEN SCIENCE AND MORE!

In The Trenches

Editor in Chief: Redina Finch
Managing Editor: Lisa M. Graff

On the Cover, clockwise from top left: An example CoastSnap station at Narrabean Beach, Australia (see page 3). A middle school student learns basic Cert Program field techniques (see page 15). Students in the Junior Ocean Explorers program in the U.S. Virgin Islands (see page 28). A student in the GLOBE program learns about soil (see page 22). **Center:** UCAR SciEd offers books and learning activities geared toward grades K-4 (see page 19).

In The Trenches (ISSN 2372-1936) is a quarterly magazine of the National Association of Geoscience Teachers, a professional association that works to foster improvement in the teaching of the Earth Sciences at all levels of instruction, to emphasize the cultural significance of the Earth Sciences and to disseminate knowledge in this field to the general public.

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IN THIS ISSUE

JULY 2024 / VOL. 14, NO. 3

From the Editor

A Continued Exploration of Citizen Science and Changes Ahead for *In The Trenches*

Summer has gotten off to an interesting start so far. If you're located along the Mississippi River and its northern drainage basin, then you are no doubt a little (or a lot) wet. The Dakotas were under an extreme drought for the last few years and now there is widespread flooding. Last year the Mississippi River experienced low water levels for the second year in a row. In fact there was some concern that barges couldn't travel the river because it was so low. This year is very different.

This issue of *In The Trenches* continues the exploration of citizen science. CoastSnap encourages citizens to submit smartphone photos of beaches to help track soil erosion and coastline changes.

Universities have teamed up with professional archeologists to create the Virginia Archaeological Technician Certification program to train citizens on field techniques.

We have an overview of the University Corporation for Atmospheric Research (UCAR) Center for Science Education offerings, which focuses on K–12 learning and activities. Curriculum guides are available for content and field experiences.

The GLOBE Program is another amazing resource for citizen science and learning opportunities for K–12. Trained teachers – *you!* – guide students to conduct research.

As a way to increase STEM participation, the SEAS Islands Alliance explores pathway interventions at multiple levels in the U.S. Virgin Islands, Guam and Puerto Rico.

In addition to citizen science, we have an article on limitations created by classroom arrangement and how you can overcome these limitations. We've all taught in non-ideal classrooms before.

We also have a description of the 2024 Earth Education Rendezvous, which is going on July 15–19. This is an amazing opportunity to learn new things and interact with fellow earth educators.

In The Trenches started out as a quarterly printed publication, then transitioned to a quarterly online publication. The move to online allowed us to include active links to resources. It also gave authors more space to write about their incredible work. I'm very excited to tell you about a new transition! *ITT* will remain an online publication, but we will now publish articles as they come in, not on a quarterly schedule. This will allow articles to be more timely and for us to "see" you more often. We are also adding a discussion feature so that we can share our experiences better. The new *ITT* format will be live in September and I can't wait to "see" you there.

Have a wonderful rest of your summer!

— **Redina**

Heavy rains caused flooding and a large tree to float down the Mississippi River past the Burlington, Iowa, bridge. [Photo credit: Redina Finch]

CorpsCam CoastSnap: Engaging Students and Citizens in Monitoring Beaches

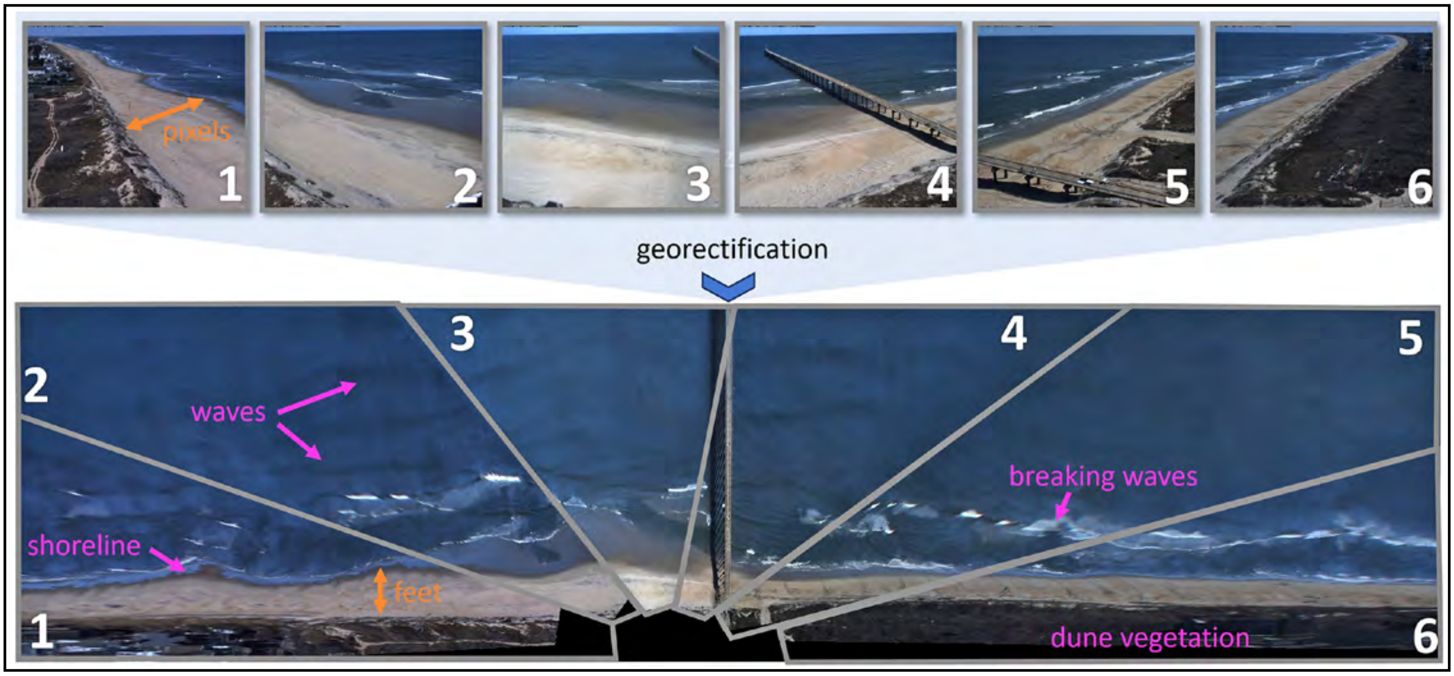

Figure 1: Example of georectification process. Orange annotations indicate beach width measured in pixels (in standard imagery, top row) versus feet (mapped/georectified imagery, bottom row). Pink annotations highlight mapped coastal features/processes visible by eye.

Our coastlines are crucial to society for a multitude of reasons, including the tourism draw that brings in millions of dollars of revenue, the habitat provided for many species, recreational opportunities, cultural resources, commercial fishing and beyond. Even more so, our coastlines serve as the first line of defense for critical infrastructure, businesses and homes from the powerful forces of the open ocean, so maintaining this resource-rich buffer zone is critical. The shoreline and sandbar positions are, therefore, important metrics for beach health and evolution. Yet, our coastlines are often quite variable in shape, width, sediment type and wave climate, and can evolve differently even over short spatial scales; for example, a hurricane may destroy dunes and severely flood an oceanfront property, but then a half mile down the road, homes are unscathed.

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For these reasons, monitoring our shorelines is essential as there is no "one size fits all" solution for protecting our coastlines. Engineering strategies such as beach nourishment require intensive design and numerical modeling, which typically requires real world field data. However, that real world data isn't always easy to obtain for a host of reasons, including the high costs associated with equipment and personnel, and hazards inherent to working in the coastal zone (e.g., large waves). Consequently, many coastal projects sites have very limited monitoring data in space and time, making the ultimate improvement of design strategies challenging. Ultimately, planners, managers, engineers and scientists need to make data-driven decisions in order to provide the best long-term coastal protection.

This is where citizen scientists, especially students, can fill a large void. Instead of deploying expensive equipment in harsh environments, the data can come from students. You might think that students or educators cannot afford expensive science instruments, right? You'd be surprised; found in nearly all the pockets or purses of teens (and older) are micro-computers with impressive-resolution cameras — cell phones! Cell phone camera resolutions have progressed to be sufficient enough to map shorelines and reveal other information about the coast using decades worth of technological progress in image processing. This article will explain how such technology can be applied to K–12 curriculum. Such lessons will not only benefit students with enhanced scientific reasoning and geospatial data access/analytic skills but also the community with high-valued data and participation.

History of Imagery in Coastal Science and Educational Outreach

In the 1980s, Oregon State University (OSU), in collaboration with the U.S. Army Corps of Engineers (USACE) Field Research Facility (FRF), first utilized video technology to quantitatively and autonomously measure shoreline change (Holman and Stanley, 2007). The fundamental process, still relevant today, is that a video camera can be set at a high vantage point to take imagery at regular intervals (i.e., hourly; examples top row, Figure 1). Such cameras are calibrated to find position, orientation and lens parameters. With such parameters, imagery can be georectified to provide maps or georectifications of the imagery (bottom image, Figure 1) with real world scale lengths (meters, feet versus pixels). Because nearshore processes have many optical signatures (shorelines are delineated via interface of blue water and brown sand, white foam indicates wave breaking, etc.), scientists can easily measure beach parameters quantitatively such as width, etc. This was a revolutionary method to remotely measure coastal environments, reducing need for in-situ (i.e., in place) instruments and increasing safety.

While cheaper than in-situ surveying, these imagining systems known as Argus still had relatively high initial costs. Image acquisition machines were scientific-grade quality and required subject matter expertise (graduate level coursework) to process data; most systems remained in higher education and research. However, in the 2010s, video technology and communications became much more ubiquitous and mainstream; video recording devices were cheaper and as portable as a cell phone. OSU and USACE Engineer Research and Development Center Coastal and Hydraulic Laboratory (ERDC-CHL) formed, along with other academics and agencies, the [Coastal Imaging Research Network] (CIRN) aimed at transitioning this technology to a wider audience (Palmsten and Brodie, 2022). CIRN provides biannual workshops and coding bootcamps along with a standardized software (MATLAB) curriculum for analyzing data from a stationary camera or unmanned aerial system (UAS). Such curriculum (Bruder and Brodie, 2020) is aimed for undergraduate and graduate students, however, it has successfully been run in summer high school programs with U.S. Geological Survey (USGS).

Despite advances in coastal imaging, there were still impediments for easy public adoption of the technology. Camera installations, data framework and calibrations still required a degree of professional IT involvement and resources. Leveraging the prolifera-

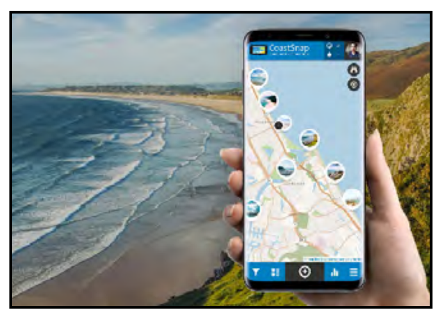


Figure 2: Example CoastSnap station at Narrabean Beach, Australia, hosted by University of New South Wales (UNSW). Right: Example of UNSW CoastSnap App. Images sourced from www.coastsnap.com (accessed March 2024).

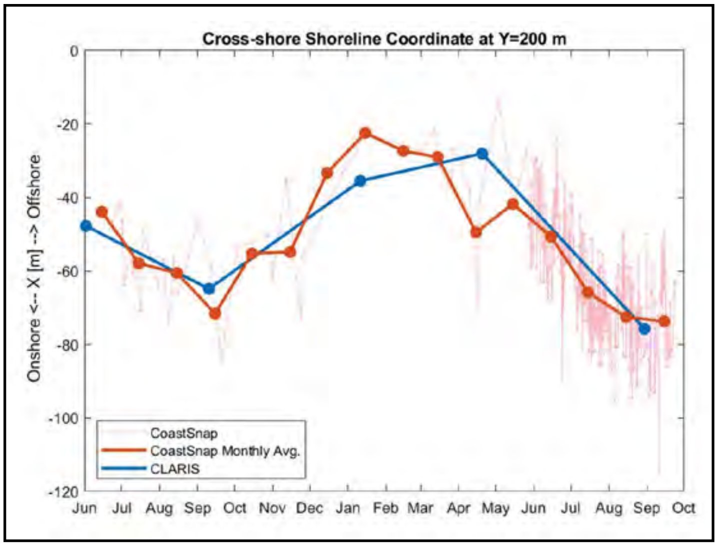


Figure 3: Example historical analysis of shoreline position (proxy for beach width/health) using CorpsCam CoastSnap data from 2021–2022 at Jennette's Pier Station. Blue line is surveyed ground truth where red lines are from CoastSnap clicked shorelines. (Conery et al., 2023)

tion of cell phones, and all the work put in decades prior for image processing, a team of scientists at the University of New South Wales (UNSW) in Australia created a novel citizen science program, CoastSnap, in 2017 (Harley and Kinsela, 2022). The community beach monitoring tool is low cost and requires a simple setup. Essentially, a cell phone camera mount is fabricated and installed overlooking a stretch of coastline (Figure 2) with simple signage that uses email submission or a QR code to migrate users to a photo capture and submission page. Once the images were catalogued by hand, they could be processed manually using novel processing software developed by Harley et al. (2019), eliminating the need for individual camera calibration and data IT (handled by cell phones and social media), the largest barriers to entry for K–12 purposes. This approach was evaluated for accuracy by several researchers (e.g., Harley et al., 2022; Conery et al., 2023) who showed it was a reliable quantitative tool for capturing shoreline change. Conery et al. (2023) showed CoastSnap produced similar shoreline trends when compared to other traditional, higher cost methods like mobile LiDAR (CLARIS) (Figure 3).

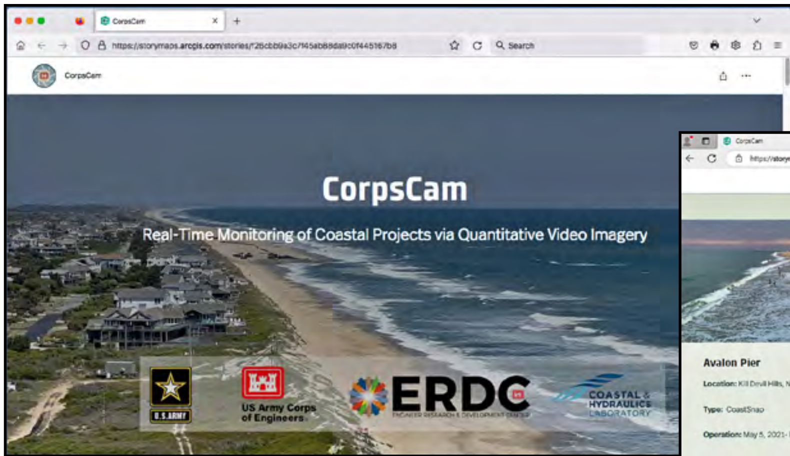
Other useful qualitative information can be gleaned as well including but not limited to: the number of beachgoers, vehicle traffic, vegetation coverage and changes, sedimentology (e.g., dark, heavy, metallic minerals), scarp formation (important for beach safety and trafficability), habitat changes (e.g., sea turtle nest) and storm impacts (e.g., dune collision). Due to its effectiveness, low cost and community involvement, the CoastSnap program has expanded to over 200 stations in over 20 countries on six continents, and now includes automatic data storage and cataloguing via a cell phone app, with or without an installed camera cradle (Harley et al., 2022). However, it still requires college/professional initial calibration and processing for georectified images that are processed manually via programming scripts/GUIs.

In 2019, the U.S. Army Corps of Engineers (USACE) and U.S. Army Engineer Research and Development Center (ERDC) partnered with the North Carolina Aquariums and installed the first U.S. CoastSnap station at Jennette's Pier in Nags Head, North Carolina. The partnership was particularly fruitful as citizen engagement, environmental conservation and outreach are critical tenets of the Jennette's Pier mission. Over the years, user submissions and engagement increased, with up to 15 images submitted daily in the summer, providing an abundance of data to adequately track the changes in shoreline position on hourly to annual scales.

In 2020s, USACE ERDC-CHL initiated its own quantitative coastal imaging data network to monitor coastlines of federal beach projects (CorpsCam, https://coastalimaging.erdc.dren.mil/CorpsCam). It is a data framework that securely ingests, processes, stores, and publicly disseminates georectified coastal imagery (needing no advanced processing) from a variety of imaging sources, one including CoastSnap. This article will explain the features of CorpsCam and CoastSnap and how it can be applied to K–12 curriculum. Such lessons will not only benefit students with enhanced scientific reasoning and geospatial data access/analytic skills but also the community with high-valued data and participation.

CorpsCam CoastSnap Overview

CoastSnap is one component of the CorpsCam network, a data framework that securely ingests, processes, stores, and disseminates coastal imagery from a variety of imaging sources. There are three tiers of camera hardware available to USACE districts and researchers, scaling in cost, complexity, and measurement fidelity depending on project needs. Tier 1: Argus is an autonomous, custom, research-grade system that



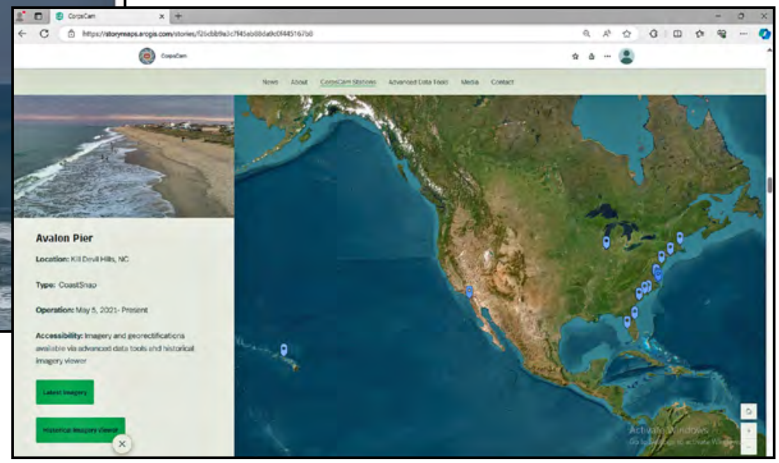


Figure 4: Example screenshots from CorpsCam website (https://coastalimaging.erdc.dren.mil/CorpsCam) with available stations and data products listed (accessed May 2024).

provides precise image capture and statistics ($20K); Tier 2: Trail-Cameras are autonomous, commercial, off-the-shelf systems with less precision ($5K). Tier 3: CoastSnap is the lowest tier with solely snapshots (<$1K). Each hardware tier is vetted to securely and automatically send hourly (Tiers 1+2) or citizen (CoastSnap) imagery via cellular transmission to the CorpsCam Data Framework on ERDC's RDE (Research Development Environment) Cloud Computing Environment (CCE). In the CCE, data is automatically processed into geospatial imagery (maps) with embedded metadata in common formats (geotiff, jpg). Imagery is publicly accessible via cloud object storage API or imagery viewers at https://coastalimaging.erdc.dren.mil/CorpsCam (Figure 4). Processing, file formats and accessibility are the same for all tiers, thus lesson plans discussed could also apply to other existing CorpsCam sites if a CoastSnap station is not nearby.

Installing a CorpsCam Tier 1 and Tier 2 site is prohibitive for most educational programs due to cost; however a CoastSnap installation is relatively inexpensive and minimal data storage and dissemination is of no cost. Thus, it is the only setup outlined here for a potential lesson plan.

Figure 5: Example of CoastSnap signage.

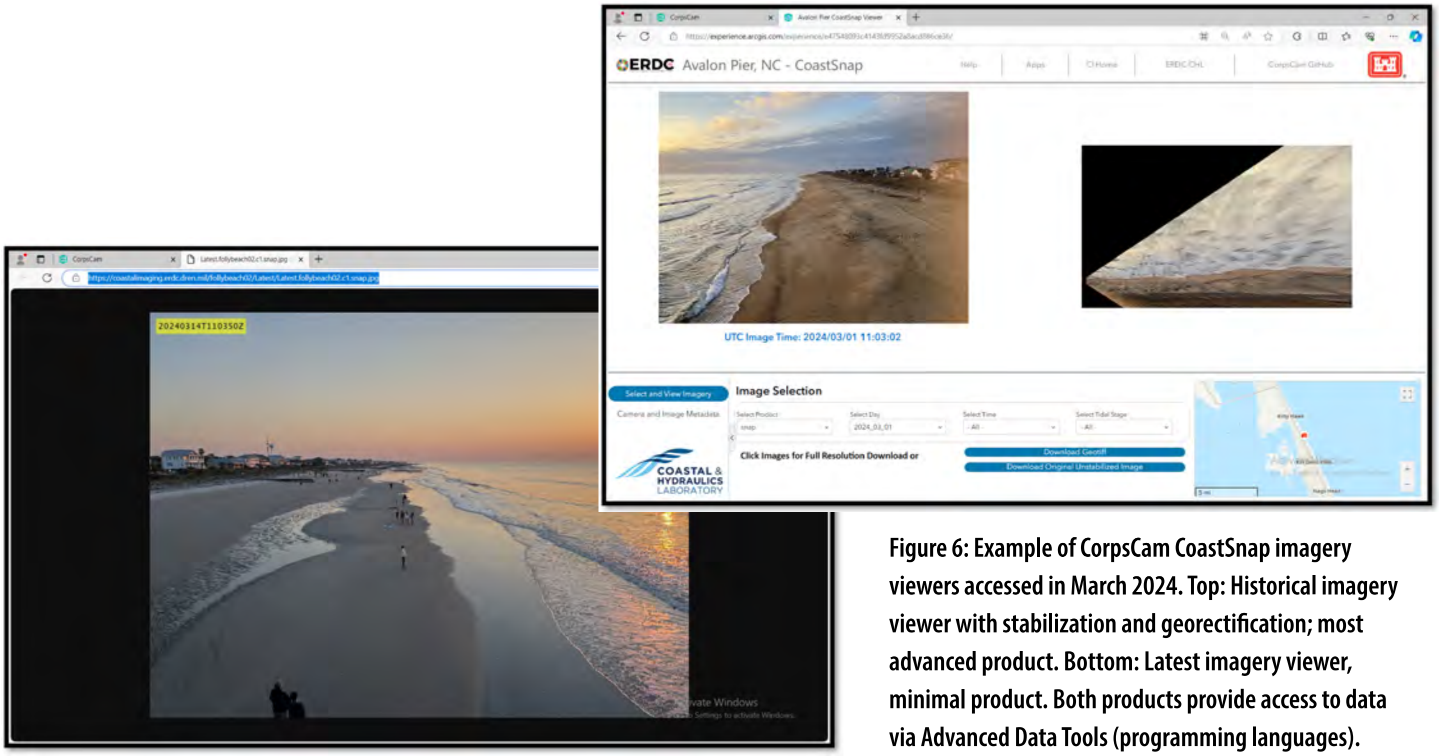


Figure 6: Example of CorpsCam CoastSnap imagery viewers accessed in March 2024. Top: Historical imagery viewer with stabilization and georectification; most advanced product. Bottom: Latest imagery viewer, minimal product. Both products provide access to data via Advanced Data Tools (programming languages).

CorpsCam CoastSnap operates similarly to regular CoastSnap, however, there is no mobile app to download or e-mail/social media post required. A user approaches a station, uses a cell phone to scan a QR code on an informational sign, and is prompted to take an image (Figure 5). The picture is then automatically uploaded and catalogued to the CorpsCam network and available on the website within an hour. If the site has been calibrated for rectification, the image is processed and georectifications are also available within an hour. The georectification workflow involves applying a Machine Learning (ML) algorithm to stabilize the imagery and rectification based on initial calibration. Most likely, a K–12 program would not be able to set up a site with calibration due to the cost of GPS equipment and advanced level of programming for ML and rectification. However, if a site is near a federal area of interest, USACE/ERDC could possibly facilitate installation/calibration or students could analyze data from an existing CorpsCam site.

Currently CorpsCam hosts 18 operational stations and four historical stations; six of the operational stations are CoastSnap sites. Depending on USACE district interest and funding at each location, there are different degrees of data products offered. Near real time and historical data is available via cloud storage API (application programming interface) for all locations; i.e., script programming to download data. Example codes in Python and MATLAB programming languages are available on the CorpsCam website and GitHub and are more applicable for high school students. All locations also have a "Latest Imagery" viewer linked on the website (Figure 6, bottom), while some have a linked historical viewer (Figure 6, top) where a user can click through time to observe shoreline evolution and download imagery, more applicable for younger students. High fidelity sites also provide georectifications or maps of the imagery (Figure 6, top); this is not offered at all sites due to additional effort and cost to calibrate/install sites with GPS equipment.

In the near future, CorpsCam will have historical viewers for all sites and increase CoastSnap sites featuring ML stabilization and georectification. The next section outlines Lesson Plans for K–12 education using existing data products freely available to the public.

Lesson Description

Two lessons are described below: 1) Installing a CorpsCam CoastSnap station and 2) Analyzing data from a CorpsCam station. Lessons could be applied for elementary, middle and high school students, depending on teacher involvement and computer resources of each class. Lesson descriptions below include modifications for respected age levels. These lessons align with Next Generation Science Standards *(Next Generation Science Standards: For States, By States, 2013):*

- Earth's Systems: Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind or vegetation (4-ESS2-1; https://www.nextgenscience.org/pe/4-ess2-1-earths-systems).
- Earth's Systems: Construct an explanation based on evidence for how geoscience processes have changed the Earth's surface at varying time and spatial scales. (MS-ESS2-2; https://www.nextgenscience.org/pe/ms-ess2-2-earths-systems).

Lesson 1

Installing a CorpsCam CoastSnap Station

If an educational program has access to a coastal environment, installing a CoastSnap station is a great opportunity for civic engagement, monitoring local coastal events, and potentially computer programming and geospatial mapping. Below are steps outlined to set up a CoastSnap station as part of the CorpsCam network, however, programs are encouraged to use the CoastSnap app if preferred with instructions at the CoastSnap website; this can allow educational programs to bypass creating a mount and contact with USACE/ERDC. Note, a downloaded app and free user account is required and automated georectification products are not available via this method.

- **Step 1: Identify a Potential Location.** Suitable CoastSnap locations have the following features: 1) view of coastal environment (wetland, lake, beach); 2) easily accessible and high foot traffic; 3) location to mount a stand and 4) if possible, elevation to provide a large field of view (i.e., a pier or elevated walkway). If grounds are situated on a coastal environment, students elementary through high school can tour school grounds to identify potential locations. If not, but in close proximity for field trips, students can tour these sites as well to identify potential locations.
- **Step 2: Reach out to Local Community for Installation Permission.** Before installation students can write letter(s)/e-mail to local authorities for installation permission with varying teacher involvement. Authorities could include school administrators, business owners or local governments. Students can outline A) Why monitoring a coast in important B) How CoastSnap works; C) Installation plans; and D) Where data will be accessed (CorpsCam website). Resources for such information can be found on the CorpsCam and CoastSnap websites as well as Conery et al. (2023) and Harley et al. (2019, 2022).
- **Step 3: Sign Construction and QR Code Generation.** Once permission is granted, students can help craft a sign to instruct users how to take an image. PowerPoint sign templates are available at the CorpsCam GitHub Site (https://github.com/erdc/CorpsCam) for students to modify. Full modification could be done by high school students whereas younger students would need teacher involvement. In addition, the sign must have a QR code to connect to the CorpsCam network. Students or teachers can reach out to the corresponding author to acquire a QR code to place on the sign; USACE/ERDC will also generate a "Latest Imagery" page and public data repository on the CorpsCam website. Also at this step, USACE/ERDC can evaluate if the site could be a candidate for advanced data products and involvement. Once sign design is complete, it can be printed at a local print shop or in house on waterproof material.
- **Step 4: Construct Mount and Install Sign.** Students/teachers can construct mounts similar to that seen in Figure 7 (left), depending on complexity. It is advised to get guidance or help from local maintenance staff at the location prior to construction and installation. Mounts on existing infrastructure such as handrails is typically simpler. The cradle and mount should be sturdy and immovable by general use. Signs should be placed nearby and in view. High school students could potentially design and construct the mount; younger students will need teacher involvement.
- **Step 5: Take Pictures!** Once the mount and sign are installed, students are welcome to scan the QR code and take images. Images will be publicly available on the CorpsCam website within an hour. Students can take images every day or assign a rotating responsibility to observe coastal change or even local flora and fauna. Potential analysis for varying ages is listed in Lesson 2.

Lesson 2

Analyzing CorpsCam CoastSnap Data

Once a CoastSnap station is installed, or an existing site is chosen for analysis, analyzing CoastSnap or CorpsCam data provides an opportunity for students to develop skills for generating/answering scientific questions, analyzing geospatial coastal data, accessing data from reputable online repositories, and understanding coastal change and phenomenon. Description of this lesson will be described in two parts: Data Access and Data Analysis, each segmented by age appropriateness.

Data Access: In CorpsCam lessons, students will learn a variety of methods to access scientific imagery and geospatial data on the Internet. To identify periods of interest, educators and high schoolers can access available tide, wave and meteorological data repositories with graphical user interfaces (GUIs) such as the NOAA National Buoy Data Center and NOAA Tides and Currents website referenced at the end of the article. CorpsCam data itself is accessed through a variety of methods and skill levels; most likely for elementary school level educators will have to access the data.

Programming Languages: All CorpsCam stations can be accessed via free Python programming language and Cloud services API or MATLAB programming; example code can be found on the CorpsCam Github page. This is appropriate for high schoolers and educators with computer programming experience.

Web Browser Access: All CorpsCam tier 1 and 2 imagery can be downloaded individually on any free web browser via the following pattern.

- **Standard Imagery**: https://coastalimaging.erdc.dren.mil/**Station Name**/Raw/Obliques/**ccamnumber/yyyy_mm_dd/yyyymmddTHHMMSSZ. Station Name.ccamnumber.**snap.jpg
- **Georectified Imagery:** https://coastalimaging.erdc.dren.mil/**Station Name**/Processed/Orthophotos/cxgeo/**yyyy_mm_dd/yyyymmddTHHMMSSZ. Station Name** cxgeo.snap.tif

Items **in bold** are to be changed. StationName and camnumber are provided on the CorpsCam website for each station (e.g., Figure 4, right panel); yyyy_mm_dd is the year, month and day; and HHMMSS is hour, minute and seconds in UTC time (+4 hours Eastern Standard Time). Middle to high school students can observe this pattern and attempt to construct web addresses of their own to download data. Note, this works with Tier 1 and Tier 2 stations since cameras autonomously capture at the top of the hour. However, it does not work well with CoastSnap since times are user defined and unknown without Python API.

Web Viewers Access: Some CorpsCam stations have historical imagery viewers that allow users to find imagery via a simple graphical user interface (GUI) (Figure 6; top). Users can click through time or filter by water level or time of day and download associated geotiffs and standard images. This allows for easy data comparison, identifying times with consistent environmental conditions such as water level and daylight. This method is appropriate for middle and high school students. Although historical viewers are only available for one CoastSnap station now, they will be a standard product for all stations in 2025.

In addition to a historical viewer, every site also has a "Latest Imagery" viewer which just provides the latest imagery and products. This can be easily bookmarked on a classroom computer where elementary through high school students can access it every day to get latest imagery.

Data Analysis: Once educators and students obtain a method to extract data, students can compare both standard and geospatial imagery. Elementary through high school students can qualitatively compare standard imagery to observe differences induced by coastal processes. Figure 7 shows two standard CoastSnap images at Avalon Pier, North Carolina, before (left) and after (right) large waves for an example discussion. Teachers can lead discussion with the following example questions, varying in complexity and age level.

- How are the images different?
- Which image has more people? Why do you think more people came on one day versus the other?
- Does it look like there is more beach to play on in one image versus the other?
- How does the water look different? Why do you think so?
- Which image looks like it has bigger waves?
- Do you think the images were taken at low tide or high tide?

Figure 7: Example pre- and post-storm analysis of Avalon Beach, North Carolina, from high waves on October 9–13, 2021, using standard imagery, applicable for Lesson 1 and Lesson 2. Left: October 8, 2021. Right: October 14, 2021, post-wave event. Notice the wrack line (deposited organic material) which indicates the highest point where water reached during the high waves.

- There are ways to tell how high the water had reached previously; can you see them?
- If we were to compare the water levels or shorelines, what would affect our estimate of change? Would it help to take images at the same tide level? Would it help to take images at the same point of the wave (running up beach versus running down)?
- If we take an image at high tide and compare an image at low tide, would the image overestimate or underestimate change? (Similarly, can ask if the wave is running up the beach vs running down.)
- Are there any differences in vegetation, sediment composition or hazards (e.g., beach scarps)?

High school students can perform more quantitative analysis using geospatial images. Currently only one CorpsCam CoastSnap station offers geospatial products automatically (Avalon Pier, North Carolina). However, more are planned and geospatial products are available for other existing tiers (Field Research Facility Duck, North Carolina; Lido Key, Florida; Lynnhaven Inlet, Virginia; Sunset Beach, Hawii; and New Smyrna Beach, Florida). Figure 7 demonstrates a potential exercise to measure shoreline change using geotiffs available from CorpsCam and Google Earth Pro (freely available geospatial software).

First, students can identify what periods of time they are interested in, change from a storm, tide or seasonality. They can refine dates and time via accessing tidal or meteorological information and downloading corresponding geotiffs as explained in Data Access section. Once two time periods are determined and geotiffs downloaded, students can drag and drop a single geotiff in geospatial software such as no-cost Google Earth as shown in Figure 8A. Then, using the Path tool, students can click a shoreline, the interface between the water and sand (Red line, Figure 8A). Visualization of the image and path then can be turned off and the process repeated for a second date and geotiff, naming the path with a different timestamp and representing it with a different color (green line, Figure 8B).

Visualizations of geotiffs can be turned off, leaving both shorelines visible (Figure 8C). There students can qualitatively observe areas of the beach that are wider and narrower, etc. Students can then identify a consistent point to measure the distance between the two lines using the measure tool (Figure 8D, yellow line). Students can then try to explain results as compared to their hypothesis. Did the beach grow or shrink? What factors do you think affected the shoreline position? For example, in Figure 8 (yellow line), data shows some sections of the beach are ~50 feet narrower likely due to wave-induced erosion. Figure 7 (right panel) shows the high waves reached the upper beach based on the presence of a distinct wrack line. A wrack line forms when waves or tide entrain organic material, then that debris is deposited on the beach at the position of the maximum water level. To perform an analysis of whether the beach eroded or

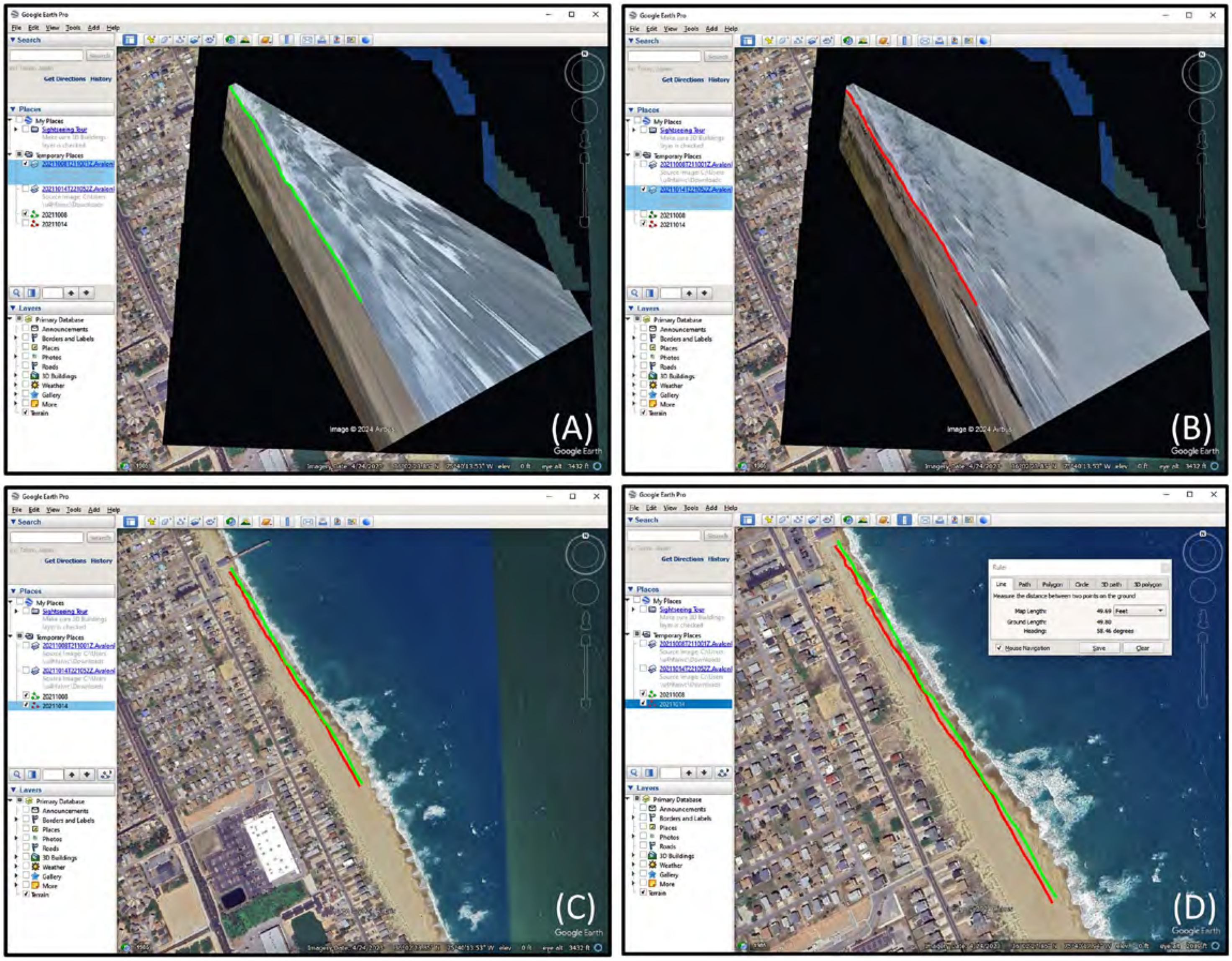


Figure 8: Example Post Storm Analysis of Avalon Beach, North Carolina, using georectified imagery, applicable for Lesson 2. A: Drawing the instantaneous shoreline using path tool on October 8, 2021, imagery; B: Drawing the instantaneous shoreline using path tool on October 14, 2021, imagery; C: Turning off imagery and examining qualitative differences, and D: Using the ruler tool to measure distance between shorelines (49 feet at this location).

accreted, images taken at similar tidal levels and wave conditions is needed in addition to more data points to increase confidence. Students can repeat these comparisons with the initial image to accomplish this, measure distances at a set location, and record time and distance in an Excel spreadsheet or programming language. Students can then reproduce trend plots (Figure 3, red lines) to show overall changes in time. More images reduce the noise of CoastSnap individual snapshots and allow students to make more robust conclusions of shoreline health. Additional analyses could examine how beach width changes seasonally or annually.

Conclusions

CorpsCam CoastSnap is not only a low-cost method for communities to monitor width/health of shorelines via crowd sourcing cell phone imagery, but also an educational opportunity for local schools and youth programs. Educational programs can leverage free existing data infrastructures (UNSW CoastSnap and CorpsCam CoastSnap) to create new CoastSnap stations or analyze existing stations for community benefit. Such activities not only benefit students with enhanced scientific reasoning and geospatial data access/analytic skills, but also the community with high-valued data and participation.

Students and citizens are encouraged to take pictures on daily walks and commutes, providing data points at a high frequency for robust shoreline/beach health monitoring. If connected with CorpsCam, imagery viewers can also be linked to existing community and school websites. The CorpsCam network is currently expanding with more stations and data products (automated shoreline detection and visualization, etc.); educators are encouraged to reach out to leverage this existing resource!

Resources

CorpsCam main page
https://coastalimaging.erdc.dren.mil/CorpsCam

CorpsCam GitHub
https://github.com/erdc/CorpsCam

CoastSnap main page
https://www.coastsnap.com

NOAA Water Level and Meteorological Data
https://tidesandcurrents.noaa.gov/

NOAA National Data Buoy Center
https://www.ndbc.noaa.gov/

Coastal Imaging Research Network (CIRN)Github and Social Media page

- https://github.com/Coastal-Imaging-Research-Network/
- https://www.linkedin.com/groups/12010767

Google Earth Pro
https://www.google.com/earth/about/versions/#download-pro

Acknowledgments

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Figure 9: An example of the CoastSnap map page – browse the map for reports all over the world.

Citizen Science Takes Archaeology Out of the Tower and Into the Trenches

Universities have a special responsibility for community problem solving, given their mission, resources, prestige, power and influence (Munck et al. 2019). By actively engaging in community-focused and citizen science education, higher education institutions can effectively utilize their vast resources — particularly their human resources of students, faculty and staff — and significantly contribute to improving the quality of life in America's communities. An example is seen in a Virginia-based citizen science program that has roots in academia, thrives on partnerships with federal, state and local government agencies and non-profit organizations, and is sustained by community members whose love of a field science has created a shift in its practice. By reframing archaeology as an endeavor undertaken by the public, the Virginia Archaeological Technician Certification program (Cert Program) challenges traditional partitions of knowledge generation, modeling the community-to-community principle of horizontal cooperation and reciprocity. This program has expanded the role of the university as a partner in an ongoing effort to support cultural identities, both past and present. Unique in its structure, the Cert Program brings archaeology to different audiences, reinforcing its critical position for understanding human responses to environmental change, while challenging archaeologists to better communicate the relevance of the discipline.

Social Capital and Community-to-Community: Civic Engagement in Archaeology

National Park Service Archaeologist Barbara Little has written extensively and persuasively about the engaged archaeologist who initiates or joins community projects which use archaeology to examine social issues or build trust among participants (2007). Drawing from "Better Together," the 2000 Saguaro Seminar on building social capital, Little (2007) brought the "C2C Principle" (communication from citizen to citizen or community to community) into archaeology. A discipline that has always generated public interest, archaeologists adhere to principles of ethics that underscore the obligation of connecting their work with the needs of contemporary communities, and especially descendant communities whose histories have been marginalized or not presented in any form.

However, this is easier said than done. Archeology is influenced by the overlapping and often-conflicting interests of various groups, and it is led by academics who maintain research programs. Under normal circumstances, these programs have the dual purpose of implementing anthropological research and educating students in the practice of the discipline. While noble in execution, academic field programs, by and large, may not reach the public in sustained ways, limit accepted participants, rely on students to pay for overall costs, and are constrained in geographic scope. While such an approach provides the opportunity for long-term, focused research and scaffolded training, it tends to restrict the practice of archaeology to a narrow audience (Sabloff 2008). Given that the very resource from which the discipline creates knowledge — the archaeological record — is held in the public trust, a community-to-community model of engagement is appropriate and necessary if we are to truly demonstrate the relevance of the study of the past for the present. The Cert Program provides a model for opening a historically academic practice to community partners, in the name of researching and conserving archaeological resources, while opening the doors of interpretation between professional and avocational.

The Certification Program

The Cert Program developed in the 1980s as a volunteer effort in Fairfax County, Virginia, where rampant development was impacting historic resources and trained archaeologists were needed to document sites. Members of a local chapter of the Archaeological Society of Virginia (ASV), one of the oldest avocational

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archaeological organizations in the U.S., requested training in the scientific study of buried resources, a task undertaken by the county archaeologist. The program, formally structured in 2000, operates on a statewide level and trains avocational archaeologists in the skills needed to reach the level of field and lab technician (Figure 1). The idea is simple: Trained volunteers who are knowledgeable of their communities are integral to research and conservation. Overseen by the ASV, the Council of Virginia Archaeologists (COVA), and the Virginia Department of Historic Resources (VDHR), the Cert Program is designed as a two-year program, but many students take longer to reach completion. They pay a one-time fee of $40 for administrative costs; no additional fees are charged. Requirements include:

- signing a code of ethics and maintaining annual membership in the ASV
- 60 hours of survey training
- 60 hours of excavation
- 60 hours of laboratory training
- 20 hours of direct public work at archaeological sites
- completing 12 topical lectures
- plowing through an extensive reading list
- recording archaeological sites with the VDHR
- maintaining a journal and program book that documents the learning process
- passing a lab practicum and final exam (https://virginiaarcheology.org/archeological_tech_cert_program/).

The program calls for a serious commitment on the part of students. As with many citizen science programs, the avocational community was eager to embrace it but professionals across the state were slow to get involved, some being skeptical of the abilities of those without a degree in the discipline. Once the ivory tower syndrome was overcome, both communities saw the logic in joining forces with the common interest of saving cultural resources and the stories they hold.

Figure 1: Logo for the Cert Program, highlighting partners COVA (Council of Virginia Archaeologists), ASV (Archeological Society of Virginia), and VDHR (Virginia Department of Historic Resources). [Image: Virginia Archaeological Technician Certification Program]

Currently, 40 professional archaeologists who are members of the COVA work with the program, which is directed by a professional archaeologist and a program graduate (Nash and Barber 2023).

Field and laboratory opportunities are ongoing throughout the year, including field schools around the state, along with survey and laboratory opportunities. Students are routinely queried concerning needs, and a committee comprised of avocational and professional archaeologists meets on an annual basis to redirect the program to those needs. Currently, 130 students, ranging in age from 20 to 85, are enrolled in the program. Each year, graduates are honored at the ASV Annual Meeting, where they receive a certification and engraved trowel, and their names are added to the list of graduates on the ASV web page. They remain on the contact list and are invited to participate in all program activities. The program has graduated 92 students over the past 20 years, and 70% of those graduates continue working with the program and many serve as mentors to current students. As a testament to their skills, professional archaeologists will request late-program students and graduates for field projects.

Certification and Citizen Science

The practice of citizen science is organized along a spectrum of participation and knowledge production, with the control of projects leveraged between researchers and volunteers (Schaefer and Kieslinger 2016). While there is general agreement that public engagement in scientific endeavors is the cornerstone of citizen science, the kinds of partnerships that frame research projects can vary from those that are controlled by researchers to those that are crowdsourced to the public. The Cert Program follows the approach outlined by Cavalier et al. (2020) that identifies citizen science as a collaboration through which the motivated public learns scientific methodology and works together with professional researchers. Nash (2024) identified this as “reciprocal archaeology,” which holds archaeologists accountable to their partners while creating research opportunities for learning and expanding access to the archaeological record. As a result, the Cert Program:

- Builds long-lasting relationships between students, teachers and archaeological practice
- Joins students and teacher to create a robust knowledge base
- Demonstrates the practice of archaeology as an ongoing learning experience
- Empowers students and encourages their involvement in program governance
- Increases advocacy for cultural heritage and descendant communities

Cert Program Partners and the Role of the University

The Cert Program works because, over the years, partnerships have been forged between federal, state and local government agencies, non-profits and universities — all of which offer support for projects. For example, archaeologists at George Washington's Mount Vernon created a long-term survey program for Cert Program students who are documenting a large cemetery of enslaved residents of the plantation. Staff members at Thomas Jefferson's Poplar Forest have undertaken significant studies of landscape and ornamental plantings with Cert Program students. The National Forest Service, through its Passport in Time program, has led Cert Program projects to identify historic mining towns in far western Virginia. These efforts were recognized in 2017 with the Virginia Archaeology Month poster, which promoted the learning focus of the Cert Program with the tag "A Classroom for All the Ages."

The current Virginia Archaeology Month poster can be found at: https://www.dhr.virginia.gov/state-archaeology/virginia-archaeology-month/

James Madison University (JMU), the higher education institution with the greatest investment in the Cert Program, has provided support for program development, field and laboratory work, and other research opportunities. At JMU, undergraduate students work together with Cert Program students. While many of the latter are familiar with field methodology, excavation forms and artifact typologies, the undergraduate students, many with little or no field work, develop an appreciation of their non-traditional co-workers. By the same token, Cert Program students lack knowledge of anthropological theory, in which the students are immersed, and which is important for the interpretation of discoveries. This multi-generational setting models life-long learning for the JMU students, who enjoy hearing about the partners' life experiences and come to appreciate the culture of volunteerism that surrounds the Cert Program. As most activities are open to the public, JMU students and Cert Program students can engage with members of local communities and learn history from their perspective.

The Cert Program has also made it possible for professional archaeologists to engage in a level of field and laboratory work not thought possible in the current economic climate due to the prohibitive cost of such work. The author directed a Cert Program field school at the White House Farm, where a stone house constructed in the late 1750s marks a location of early German settlement in Virginia's Shenandoah Valley. Forty-five volunteers, many of whom took vacation days from jobs, have worked almost 2,500 hours (valued at $79,500 using the Federal Volunteer Rate). A survey of the professional archaeologists who work with the Cert Program found that, on average, Cert Program students volunteer 25,000 hours/year, providing a cadre of well-trained archaeologists whose work has allowed new research questions to be considered (Barber and Nash 2023). In documenting over 500 archaeological sites in Virginia, Cert Program students are creating a legacy of work that will impact archaeological practice for years to come.

The Pedagogical Approach

Pedagogically, the instruction of archaeological skills is an archetype for active learning (Felder and Brent 2009) in which students are at the center of the learning process and partners in discovery and problem solving. Active learning can take many forms, including hands-on learning, problem-based learning, case studies and simulations (Burke and Smith 2007). In addition to the shift away from passive learning, the characteristic that truly distinguishes active learning from traditional pedagogies is the focus on student engagement resulting in independent, creative inquiry (Bain 2004). This strength has been most

Figure 2: Clockwise, from upper left, Certification students in laboratory, survey, excavation and public outreach activities. [Photos: Virginia Archaeological Technician Certification Program]

clearly articulated for pre-collegiate archaeology and programming for the public (Smardz and Smith 2000).

Archaeological skills like those taught to Cert Program students embody a tradition in which they “learn through an education of attention” (Ingold 2011:190). To borrow Høgseth’s identification of the transfer of knowledge through craft, archaeologists combine “knowing what” and “knowing how” (2012: 61) to create rich learning environments. Taxonomies of learning propose dimensions of knowledge that extend from concrete (factual) to abstract (metacognitive), the latter associated with higher order thinking skills (Fink 2013). Active learning in archaeology can move students along this continuum, requiring them to build on foundational knowledge to understand, apply, analyze, evaluate and ultimately create (hypothesize and design). This thinking about thinking or metacognition (Bain 2012) emerging from a variety of learning experiences and environments, positions archaeology students to develop the far transfer of knowledge (Ambrose et al. 2010) from one project to another, and across multiple citizen science programs. Rather than claim that archaeology teaches transferrable skills, archaeological learning based in active learning promotes a disposition of critical and synthetic thinking, requiring students to work across disciplines in different learning domains. Inherently interdisciplinary in approach, archaeologists draw from the earth and life sciences, the social sciences, and the humanities to develop evidence-based interpretations of sites and landscapes. Also, given that Cert Program students come from a variety of professions, including K–12 education, the knowledge and skills they bring to the field and laboratory enrich those learning settings. Children of parents in the program are invited to participate in field events, with middle school students excelling at the meticulous work required (Figure 3). Plans include the development of mini-field schools for K–12 teachers to provide enrichment for the science and history standards of learning.

Certification: Just in Time

Current estimates indicate that a full 21% of Virginia’s recorded cultural heritage resources are threatened by sea level rise and catastrophic storm surge (VDHR 2022). The VDHR, working with the Cert Program, has made the study of these resources, which include shipwrecks, inundated terrestrial sites, eroding shell middens, military fortifications, cemeteries, wharfs, fish weirs and waterman communities, a priority. Large field schools have been held at sites on the Eastern Shore of Virginia; in addition to Cert Program students, volunteers are solicited from the area and the field school is open for visitation daily. Local landowners with knowledge of sites being lost to inundation were approached by Cert Program students, who set up site visits. VDHR has partnered with JMU to test NOAA’s Digital Coast Sea Level Rise models and establish site vulnerabilities on the coast, in the Chesapeake Bay and on the western shore. Cert Program students piloted boats to get the students to inaccessible locations and assisted with GPS mapping of shorelines. The establishment of the Eastern Shore Chapter of the Archeological Society of Virginia provides a nexus for

Figure 3: Well-supervised middle school students can quickly learn basic field techniques. [Photo: Virginia Archaeological Technician Certification Program]

Cert Program students and other volunteers to bear witness to the loss of heritage as they triage sites for documentation (Nash 2022).

Conclusion

The university is an institution with a long memory and deep roots, an ideal body for building partnerships between researchers and the public. In the Virginia Archaeological Technician Certification Program, the university — along with government agencies and non-profit heritage organizations — has taken the role of partner, opening its doors to a new practice that recognizes the contributions of intentional communities, in this instance, avocational archaeologists, to the generation of knowledge and social capital. In archaeology, the networks of advocacy that emerge from citizen science efforts reinforce the derivation of avocational from its original meaning of guardian. By encouraging interactions between professors, university students and citizen scientists, the Cert Program profoundly impacts communities, a discipline and its practitioners.

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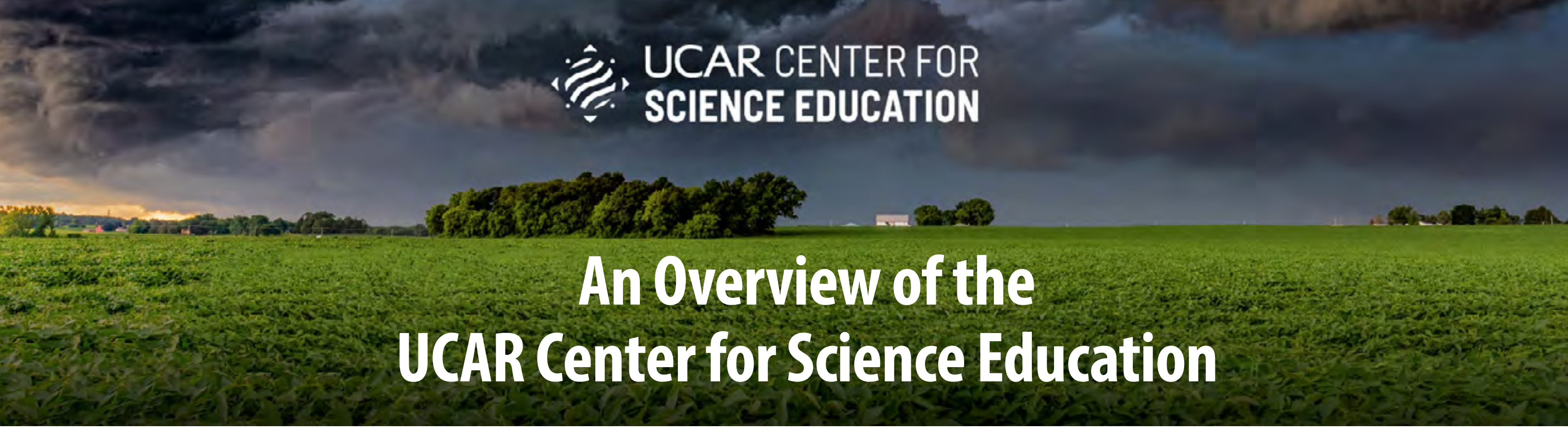

An Overview of the UCAR Center for Science Education

The UCAR Center for Science Education (UCAR SciEd), located in the foothills of Boulder, Colorado, serves the geoscience community by amplifying and complementing the work of the U.S. National Science Foundation National Center for Atmospheric Research (NSF NCAR) and the University Corporation for Atmospheric Research (UCAR) member universities. UCAR SciEd reaches audiences of K–12 educators, university faculty, students and the public through innovative educational programs and experiences. UCAR SciEd is dedicated to engaging all learners in exploring and understanding our changing world. Whether developing weather curricula that address Next Generation Science Standards (NGSS) or creating virtual field trips for students worldwide, UCAR SciEd offers free educational resources on weather, the atmosphere, climate, the Sun and space weather to support learning.

UCAR SciEd works directly with NSF NCAR to support the implementation of three broad goals:

- **Goal 1:** To inspire, engage and inform the public about the atmospheric and related science conducted by NSF NCAR and the university community.
- **Goal 2:** To entrain and prepare a highly skilled and diverse workforce in careers in the atmospheric and related sciences.
- **Goal 3:** To support the university community in educating students in the atmospheric and related sciences.

UCAR SciEd is comprised of staff with expertise in the atmospheric and related sciences and science education including scientists, informal educators and former K–12 teachers. The staff develops educational resources for K–12 classrooms and informal learning, exhibits used by school and public visitors at the NSF NCAR Mesa Lab Visitor Center, and undergraduate student and faculty mentoring programs.

UCAR SciEd is funded primarily through the U.S. National Science Foundation (NSF) and also receives funding through grants predominantly from the National Academies of Science, Engineering and Medicine; the National Aeronautics and Space Administration (NASA); and the National Oceanic and Atmospheric Administration (NOAA).

RESOURCES FOR EDUCATORS AND LEARNERS

Teaching Resources

UCAR SciEd Educational Designers have created over 120 classroom activities for grades K–12 that vary in length from about 45 minutes to multiple weeks. Each classroom activity addresses NGSS and covers an Earth System science topic. Classroom activities were created to support NSF NCAR, UCAR, and collaborating university scientific research, and were field tested in classrooms and with teachers. Many of the classroom activities also include strategies for inclusive and accessible teaching, which are in the teacher implementation guides. Examples of classroom activities include:

- Carbon Dioxide Sources and Sinks
- Dark Skies: Volcanic Contributions to Climate Change
- Infusing Science with the Arts
- Whirling, Swirling Air Pollution

UCAR SciEd has also developed multiple multiweek curriculum units. Each of these units was developed in conjunction with scientists, educational researchers and in-service classroom teachers. The curriculum units address NGSS and are freely available on UCAR SciEd's website.

DR. JULIE MALMBERG (malmberg@ucar.edu), Assistant Director of the UCAR Center for Science Education in Boulder, Colorado.

- GLOBE Weather is a five-week middle school science curriculum developed to address NGSS and is available in English, French and Spanish. In this curriculum unit funded by NASA, students explore weather phenomena to better understand weather at local, regional and global scales through a series of learning sequences and a culminating task. Students connect to GLOBE (Global Learning and Observations to Benefit the Environment) science protocols and have the opportunity to collect their own data and analyze weather data from around the world. GLOBE Weather is currently being updated to meet the needs of students with disabilities and share career pathways and opportunities in STEM for these students through funding from NSF.
- Hurricane Resilience is a 20-day environmental science high school curriculum for use in coastal locations where hurricanes are common. With support from NOAA, UCAR SciEd created this curriculum in collaboration with the NSF NCAR Mesoscale & Microscale Meteorology Laboratory and the South Louisiana Wetlands Discovery Center. With the curriculum, students make connections between the science of hurricanes, how they affect their community and region, and how we can plan for a more resilient future. Making local connections, students develop an understanding of 1) the risks that their community faces now and in the future due to hurricanes and tropical storms, 2) how sea level rise increases the risk, and 3) how our actions can help us be less vulnerable and more resilient. The curriculum unit aims to empower high school students to have a voice in resilience planning and understand the relationship between the science of hurricanes and the local impacts these storms have on people and places.
- Project Resilience is a 20-day high school curriculum developed by UCAR SciEd and the South Louisiana Wetlands Discovery Center with funding from the National Academies of Sciences, Engineering and Medicine. With the curriculum, students examine the environmental challenges facing communities along the Gulf of Mexico and learn about resilience planning. Project Resilience leads students through the development of a School Resilience Plan which contains student-designed projects to address one or more environmental challenges affecting their school campuses.

UCAR SciEd's Learning Zone is an online hub of short articles, games and simulations, thematic digital teaching boxes, images and videos to promote learning about the Earth System. Millions of users visit the Learning Zone each year. The resources cover various Earth System science topics including air quality, climate and water, clouds, El Niño, flash floods, the greenhouse effect, satellites, the Sun, tornadoes, weather forecasting and winter weather. Educators and caregivers can also find STEM at Home activities with detailed instructions, science background, and easy-to-find materials for learners to do outside of formal classrooms.

SkySci for Kids is an online space for our youngest users (geared for ages 4–10) that has child-friendly games, videos and science articles written for younger students. All of the resources feature an animated cast of characters including Jeff the Yeti, Snacks the skateboarding dog and Mindy the cloud nucleus.

Figure 1: Young learners can help Jeff the Yeti wear seasonally appropriate clothing in an online stamp game.

UCAR SciEd has also produced multiple resources to promote careers in STEM. This includes profiles of jobs in atmospheric and related sciences, a job shadow guide for students wanting to learn more about careers, and a series of interviews with experts in their fields. UCAR SciEd also hosts the NSF SOARS (Significant Opportunities in Atmospheric Research and Science) program, which is an undergraduate-to-graduate bridge program designed to broaden participation of historically underrepresented communities in the atmospheric and related sciences. During the summer, protégés come to Boulder and complete an original research project with a team of research, writing, computing and community mentors. By the end of the summer, each protégé prepares a scientific paper and presents their research at a colloquium. After starting in 1996, NSF SOARS has helped to launch the careers of hundreds of STEM professionals.

Figure 2: Each of the seven [Elementary GLOBE books] includes a story, learning activities and a teacher implementation guide.

Additional resources that UCAR SciEd has to offer include a suite of **Elementary GLOBE books** and learning activities geared toward grades K–4. These books follow the adventures of the GLOBE kids (Anita, Simon and Dennis) as they explore an aspect of the environment. Hands-on activities and coloring pages allow students to learn more about specific environmental topics. Each of the books is also translated into multiple languages. These books were created with the support of NASA, and *What's Up in the Atmosphere: Exploring Colors in the Sky* won the prestigious American Meteorological Society K–12 Battan Book Author's Award. The books, learning activities and teacher implementation guide are all available as free PDFs or eBooks with narration on the UCAR SciEd website, and physical, paper books can be printed on demand from Amazon.

With support from NASA, UCAR SciEd in collaboration with the Center for Astrophysics | Harvard-Smithsonian and NASA Langley is providing support and resources to a network of **Ozone Bioindicator Gardens.** Sharing resources that teach how to plant the bioindicator plant species as well as track them for signs of ground-level ozone damage, visitors to the gardens can learn how NASA's TEMPO satellite measures air pollution from space and how we can see signs of air pollution in the gardens by looking for tiny dark spots called "stippling" on the leaves.

Figure 3: An Ozone Garden in full bloom at the NSF NCAR Mesa Lab. [Photo credit: Danica Lombardozzi, NCAR]

With additional funding from NSF, UCAR SciEd partnered with the University of Colorado-Boulder and the Vail Valley Foundation to develop an innovative career readiness model, called **STEM Career Connections,** for both in- and out-of-school settings that will increase the knowledge of and interest in STEM and computing careers for middle school youth in rural, economically disadvantaged mountain communities. The team focused on these three components of the model: 1) a community partnership working together to support youth engagement in STEM and computing career pathways, 2) a STEM curriculum where youth use advanced sensor technologies to engage in science and engineering investigations, and 3) integrated career experiences that encourage youth to make personally relevant connections with local STEM and computing occupations. The STEM curriculum and a toolkit for partnership development are available online.

Multiple **comic books** developed by UCAR SciEd staff include a Zika Zine, which teaches about *Aedes* mosquitos and the Zika virus. The Zika Zine has been translated into 10 languages and is available as a free PDF download on the UCAR SciEd website. Developed with support from the U.S. Department of State, students can also create their own Zika Zines and learn how to draw scientifically accurate mosquitos. Students can also learn how the Argos-4 instrument on the General Atomics' Orbital Test Bed-3 satellite can track animals that are often hard to observe with the ***Follow Me!*** comic book. Available in English, French and Spanish, each downloadable PDF contains a teacher guide, student pages and other activity resources. With the comic book, students learn

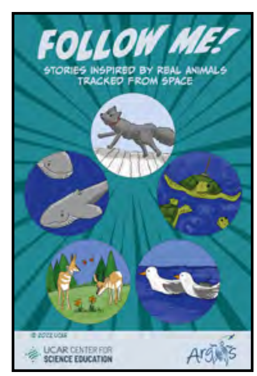

Figure 4: The *Follow Me!* comic book shares stories inspired by real animals tracked from space.

about tagged animals like arctic foxes, blue whales and pronghorn. Students can also learn about plastic pollution traveling in the ocean. Argos data collection is supported by NOAA and the French National Centre for Space Studies (CNES) as well as collaborations with the U.S. Space Force and General Atomics.

Exploring Atmospheric Dust and Climate is a collection of educational activities that can be used to engage the public around the topic of atmospheric dust and how it affects climate change. Learning the story of dust helps us better understand Earth's climate system and provides clues about how to mitigate current climate warming. The activities are designed for museums, science centers and outreach events, but can also be implemented in formal education settings from upper elementary through high school. The *Exploring Atmospheric Dust and Climate* activities were developed to support the NSF-funded research project *DUST PIRE: Dust stimulated draw-down of atmospheric* CO_2 *as a trigger for Northern Hemisphere Glaciation.* The project was a multi-year, international collaboration between scientists at universities and labs in the U.S. and China, each investigating a unique aspect of the connection between Earth's climate and atmospheric dust.

TEACHER PROFESSIONAL DEVELOPMENT

While UCAR SciEd has provided teacher professional development for decades as part of grant-funded projects, we are now also providing regular teacher professional development for frequently requested topics. This year, UCAR SciEd launched a series of 1-hour virtual, interactive webinars on climate science and solutions for grade K–12 educators. Educators in the local area are also invited to a series of in-person workshops hosted at the NSF NCAR Mesa Lab. Teachers can opt to receive graduate credit and hours toward their license renewals through a partnership with Colorado School of Mines. The current workshop topics are Climate Science Everywhere for grade K–5 educators and Teaching Climate Science and Solutions for grade 6–12 educators. You can sign up for future notifications on the Teacher Professional Development website.

IN-PERSON EXPERIENCES

For those who live near or visit Boulder, there are multiple opportunities to engage with UCAR SciEd in person. Entry to the NSF NCAR Mesa Lab Visitor Center is free and is open 363 days a year (it closes twice a year for maintenance), every day of the week for public walk-ins. The Visitor Center has three levels of indoor exhibits and a Weather Trail with outdoor exhibits. There is also an ozone garden at the front of the NSF NCAR Mesa Lab, which allows the public to see visible ozone damage in bioindicator species of plants during the growing season. Visitors can explore on their own or take part in free public tours provided three times a week.

At the **indoor exhibits,** visitors can touch a cloud, learn about chaos, steer a hurricane, explore climate and climate solutions, learn about Sun-Earth connections, and browse art galleries and many other exhibit spaces. The exhibits allow for a hands-on exploration of atmospheric and related science topics. To welcome as many people as possible to learn at and enjoy the Visitor Center, there are accessible bathrooms, a nursing room, wheelchair check-out, tactile interactives,

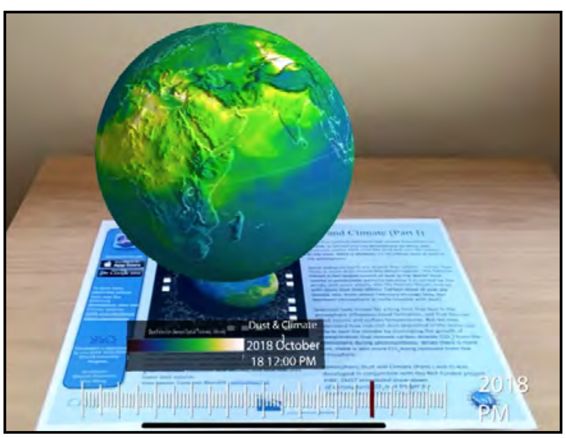

Figure 5 (left): Students and the public can explore atmospheric dust and climate with augmented reality by viewing datasets of atmospheric dust, chlorophyll, iron and nitrate in augmented reality by using the MeteoAR app (installed on a tablet or smartphone) and printable science sheets.

Figure 6 (right): Young learners explore the Sea of Clouds exhibit. [Photo credit: UCAR SciEd]

Figure 7: Young visitors listen to a story read by scientists at Super Science Saturday. [Photo credit: UCAR SciEd]

sensory guides, sensory tours for visitors who are blind or low-vision, social narratives and visual schedules for visitors with autism spectrum disorder, open captioning and interpreters.

Students in preK–12 classes, camps, clubs or homeschool groups can attend free **field trips** at the NSF NCAR Mesa Lab Visitor Center. Teachers can reserve a date and select from more than 10 field trip options including an extreme weather design challenge, weather and climate data explorations, learning about lightning or clouds, and discovering ways to be climate heroes. Students also get time in the hands-on exhibits and in the outdoor spaces.

Annually, thousands of visitors come to the NSF NCAR Mesa Lab for **Super Science Saturday**. This public science celebration is planned by UCAR SciEd and supported by Friends of the National Center and NSF NCAR and UCAR labs, programs and offices as well as local science and science education organizations. Super Science Saturday includes hands-on activities, science experts to answer questions, Wizards providing science demonstrations and weather balloon launches.

VIRTUAL EXPERIENCES

Learners and educators from around the world also have access to multiple virtual options to connect with UCAR SciEd. These include a series of award-winning virtual field trips, "Meet the Experts" webinars and Q&A sessions, and virtual tours of the NSF NCAR Mesa Lab and the NSF NCAR Research Aviation Facility. For virtual experiences with the NSF NCAR Mesa Lab and the NSF NCAR-Wyoming Supercomputing Center, visitors can take part in a 360° augmented reality tour.

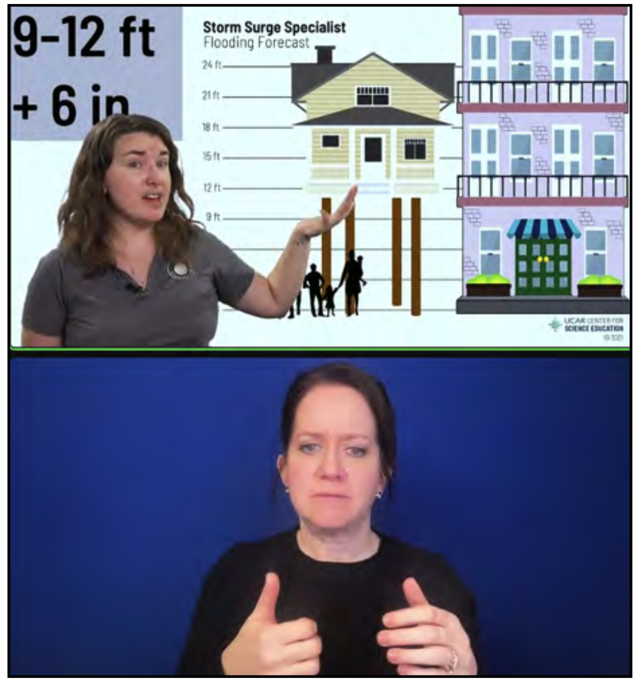

Figure 8: ASL interpretation of the virtual field trip Weather Wow: Hurricane Trackers. [Photo credit: UCAR SciEd]

Virtual field trips were developed by a team of experienced educators and piloted in multiple classrooms. Students worldwide can learn about hurricanes, including interpreting and communicating weather data and discussing how to prepare various audiences in Weather Wow: Hurricane Trackers (grades 3–6). For our younger audiences, the virtual field trip, Weather Wow: Up in the Air!, teaches students all about hot and cold air and cloud formation. UCAR SciEd educators have worked with interpreters for ASL for school groups taking part in these virtual field trips. To book a virtual field trip, visit https://scied.ucar.edu/visit/virtual-field-trips.

CONNECT WITH UCAR SciEd

UCAR SciEd has an active social media presence (@UCARSciEd on Facebook, Instagram and X (formerly known as Twitter) and @ncar_ucar_education on YouTube). We also have a newsletter with monthly themed classroom activities, articles and updates about our programs and events. Past newsletter themes have included Space Weather, Weather Forecasting, Wildfires and Hurricanes. Sign up and see archived issues of our newsletter here: https://scied.ucar.edu/newsletter. You can also email us at scied@ucar.edu.

All the resources shared in this article can be found on UCAR SciEd's website at https://scied.ucar.edu. We would love to hear from you!

Spark Your Students' Enthusiasm for Science with The GLOBE Program

When the New Hampshire-based GLOBE Soil Tent visited Mast Way Elementary School in Lee, New Hampshire, the educators could not have anticipated the jubilant cry from one first-grade student at the end of the day: "I want to be a soil scientist!" (Figure 1). The students were excited to learn about soil through hands-on activities and measurements using materials from The GLOBE Program. Ellen Ervin, the science specialist at Mast Way, reported: "They were able to examine a soil core, use the soil color profile book to identify layers, look through a microscope and record their observations. They learned what soil is made of and how soil in different habitats may look different."

What is GLOBE?

The Global Learning and Observations to Benefit the Environment Program (GLOBE) is an international science and education program that is sponsored by the National Aeronautics and Space Administration (NASA) and supported by the National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA) and the U.S. Department of State. GLOBE began on Earth Day in 1995 and is used by STEM professionals, educators, students and citizen scientists in more than 125 countries around the world. GLOBE's mission is "to increase awareness of individuals throughout the world about the global environment, contribute to increased scientific understanding of the Earth and support improved student achievement in science and mathematics."

GLOBE is implemented in the United States through GLOBE Partners at institutes of higher education, informal science centers, and other organizations that are affiliated with local schools. Formal and informal educators receive training on different data protocols (data collection methods) through GLOBE Partners or via eTraining.

When students collect data and conduct research, they contribute to our shared understanding of how the Earth functions. Students can also use GLOBE materials to explore the Earth system by downloading the data or visualizing it directly on the GLOBE website.

Ellen Ervin's students experienced one aspect of GLOBE: studying the pedosphere, or soils. GLOBE focuses on four spheres (atmosphere, biosphere, hydrosphere and pedosphere) and the Earth as a System. GLOBE provides data collection protocols, learning activities and resources for each sphere for use in pre–K through undergraduate classrooms.

GLOBE's protocols are developed by scientists and field tested in classrooms around the world. Adding new protocols is a well-designed, thorough process that ensures data are collected in a standardized way and results in research-quality data. Data collected are submitted to GLOBE's public database, which boasts over 250 million measurements from the past 30 years.

Figure 1: "I want to be a soil scientist!" [Photo credit: Dorr Elementary School via GLOBE website]

ALICIA CARLSON, HALEY WICKLEIN and JENNIFER BOURGEAULT, GLOBE U.S. Coordination Office (usglobeoffice@gmail.com)

For younger ages, **Elementary GLOBE** provides storybooks and associated learning activities to practice science skills and thinking. Storybooks include "The Scoop on Soil" (pedosphere), "Discoveries at Willow Creek" (hydrosphere) and "Do You Know That Clouds Have Names?" (atmosphere).

There are many ways educators can use GLOBE. And we're aware that it can be difficult to know where to begin! As one GLOBE Partner said at a recent workshop, "It can be a fire hose. Just find one place that's interesting to start and go from there."

GLOBE in Action

There are currently 11 pedosphere protocols, nine in the hydrosphere, seven in the biosphere and eight in the atmosphere. Here are two examples of how students used soil protocols in their research. Other student projects can be found using the Student Research Reports database.

- **Dorr Elementary School** — Some schools around Toledo, Ohio, have worked with U.S. GLOBE Partners to develop prairies on their school grounds. Students in grade 4 at Dorr Elementary asked the question, "How does the soil temperature in the school prairie compare to the soil temperature in the turf grass and the playground?" They collected soil temperature data at two depths (5 cm and 10 cm) at three locations and then compared their data. They found that the soil temperature was hottest at the playground at both depths, coolest in the turf grass at 5 cm, and coolest in the prairie at 10 cm. They discussed their conclusions (Figure 2) and gave recommendations to plant more native plants in their project report that was submitted to GLOBE's International Virtual Science Symposium *(described later in this article).*

Discussion: What Does This Mean?

- The playground is mostly gravel so it absorbs more heat, because there isn't much nutritious soil here. It is mostly gravel.
- The rocks absorb heat from the sun which makes it hotter on the top surface.
- We think the prairie had the coolest soil at 10 cm, because prairies keep the soil cool during the summer and warmer during the winter.
- This helps the plants grow better, because they need certain nutrients and temperatures.
- The prairie also has more animals, because there are more healthy plants.

Figure 2: Dorr Elementary School research project conclusions. [Source: The GLOBE Program]

Figure 3: Kingsburg High School students and teacher present their research. [Photo credit: GLOBE U.S. Coordination Office]

- **Kingsburg High School** — Three students in the Central Valley of California investigated soil and rainwater around their school and community to determine if pH was more alkaline than in other areas. (Their research built on the research of previous students at the school.) Particles of dust, pollen, and bacterial and fungal spores from nearby agriculture were found to contribute to high levels of particulate matter in the region, which resulted in alkaline rainwater. They presented their research (Figure 3) at a regional Student Research Symposium *(described later in this article).*

Earth as a System with Protocol Bundles

Another place to get started is through the Earth as a System protocol bundles. We know that the real world doesn't stick to these four spheres, so the GLOBE community developed bundles of protocols from the different spheres that can be used to answer student questions about a broad multidisciplinary topic. Not all of the protocols listed in each bundle need to be used; these are simply a way to show how protocols from different spheres can be used together. There may even be other protocols that can be incorporated that are not listed in the bundles. The purpose of these bundles is to provide educators with a starting point for making connections between the spheres through student research. Protocol bundles include relevant scientific information, example student research questions, case study examples, and resources from My NASA Data.

For example, the **Soils Protocol Bundle** uses protocols from all four of GLOBE's spheres (Figure 4).

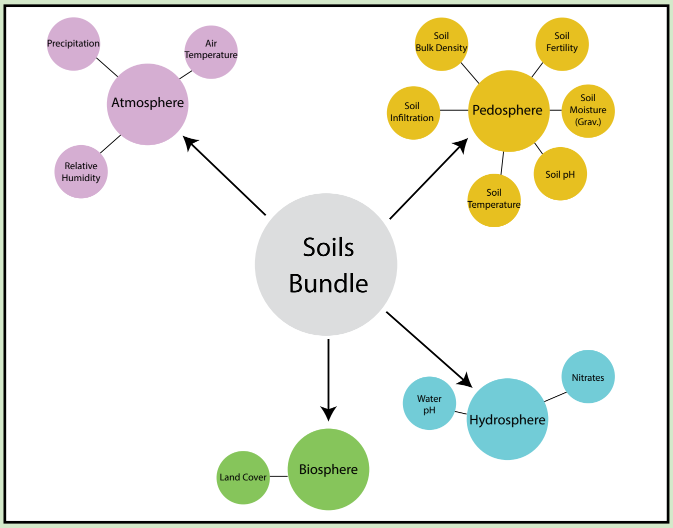

Figure 4: The Soils Protocol Bundle uses protocols from all four of GLOBE's spheres. [Source: The GLOBE Program]

The webpage for this bundle describes why each protocol is important in the study of soils. For example, students can collect air temperature measurements to understand evaporation of water from the soil. Determining the types of land cover can describe soil properties like soil moisture.

A student could use several of the protocols within the Soils Protocol Bundle to answer a question like "How does soil moisture vary for different land cover types?" or "How do high and low amounts of soil moisture influence air temperature and relative humidity?"

HOW TO "DO GLOBE"

Create an Account

The best way to get started using GLOBE resources is to create an account. This will allow you to be trained, either in-person or through eTraining, and will put you in contact with the GLOBE community. Browse to globe.gov and click on "Which GLOBE Account is Right for You" [Figure 5]. This takes you to a page

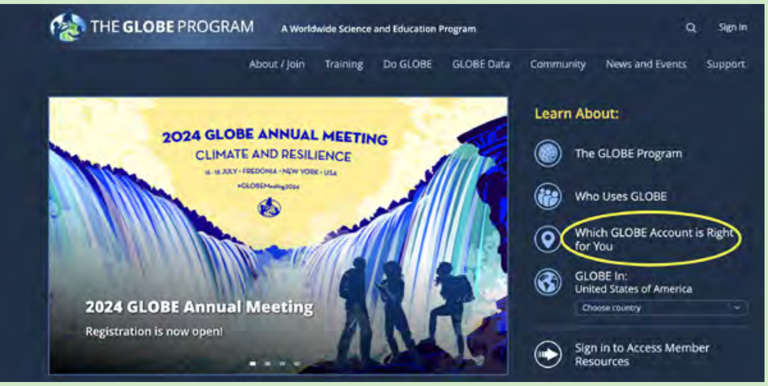

Figure 5: The GLOBE Program – Which GLOBE Account is Right for You.

with descriptions of typical users and account types. From there, click on "Create Your GLOBE Account" and follow the instructions. The teacher/formal educator account type requires additional training (below) and can create anonymous student accounts.

You can also create an account through the GLOBE Observer app available on Google Play and the Apple App Store. This limits your access to the few citizen science-focused measurements available through the app, but it can be a good way to get a feel for the program.

Become a Trained GLOBE Educator

Once you've created an educator account you'll need to go through protocol training to be able to upload data to GLOBE's public database. If there's a GLOBE Partner in your area that's providing an in-person training, we encourage you to go this route. Our GLOBE trainers go through a rigorous process to be able to train others in GLOBE protocols.

Alternatively, you can use GLOBE's eTraining resources. This requires completing at least three eTraining modules: Introduction to GLOBE, an introduction to a sphere of your choosing, and one protocol module in that sphere.

Once you are a trained GLOBE educator, you can start contributing your students' observations to the GLOBE website. Contributed data is available on the GLOBE website for use in classroom research projects around the world. Scientists also use the GLOBE data in research studies.

Become a GLOBE Observer

The GLOBE Observer app allows citizen scientists to contribute to four measurement areas: clouds, mosquito habitats, land cover and trees. In-app training walks users through the data collection protocols in the field. These measurements are tied to NASA satellite missions and the data are available to the public.

ACCESSING DATA

Whether or not you create an account and get trained, anyone can access GLOBE's public database. Go to globe.gov and click on "GLOBE Data" in the header menu. We recommend you access the GLOBE Tutorials on Data Access, Analysis and Reporting — they are much more detailed than what we can write here!

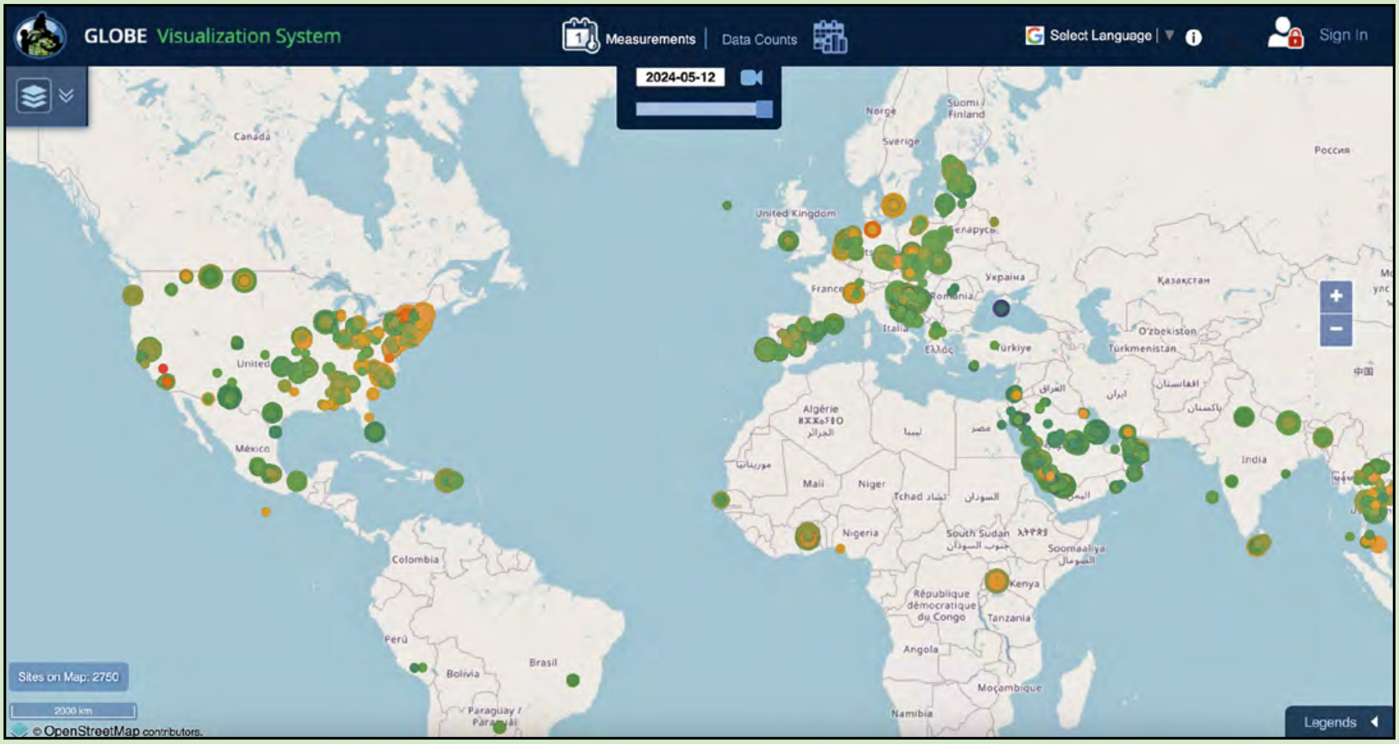

Figure 6: The GLOBE Visualization System.

Data are available by download through two different mechanisms.

- The **[Advanced Data Access Tool]** can be used to retrieve data by selecting from different search parameters, including protocol, country, date range, elevation range and more, and you can download a CSV file with your search results.
- The **[GLOBE Visualization System]** can be used to explore data on a world map and create graphs [Figure 6].

If you want to start with pre-chosen data sets that come as part of a lesson plan, My NASA Data has many options.

MY NASA DATA

Educators can access data using mini-lessons and other resources from My NASA Data. For example, students in grades 3 to 5 can use the "Soil Moisture Analysis" mini-lesson to look at a map to observe soil moisture anomalies. They are guided to observe the map and provide responses to prompts like "I see, I think, I wonder."

Middle- and high school-level students can use the My NASA Data mini-lesson "Hurricane Harvey's Effect on Soil Moisture" to analyze soil moisture quantities associated with the hurricane that hit south-eastern Texas in 2017. They are asked to compare soil moisture changes in the urban area of Houston to areas to the east and west.

GOING FURTHER

Once you've gotten the hang of using some of the basics of GLOBE, it's time to take the next step. Of course, there are many "next steps" available through GLOBE! Here are a few easy options.

Measurement Campaigns and IOPs

GLOBE and NASA often ask the GLOBE community to collect data to support satellite missions. These data requests are called Campaigns or Intensive Observation Periods (IOPs). Campaigns and IOPs can be global or regional and cover a vast array of topics. Some campaigns are ongoing, while IOPs are often a short duration.

One IOP is the Urban Heat Island Effect/Surface Temperature IOP coordinated by the U.S. GLOBE Partners at the University of Toledo, Ohio. By contributing to this IOP, students and educators are helping to answer the research question "How does surface cover affect surface temperature?" This is a very easy IOP to participate in; it requires collecting cloud measurements, air temperature and surface temperature using an infrared thermometer. Measurements are collected during the months of October, December and March.

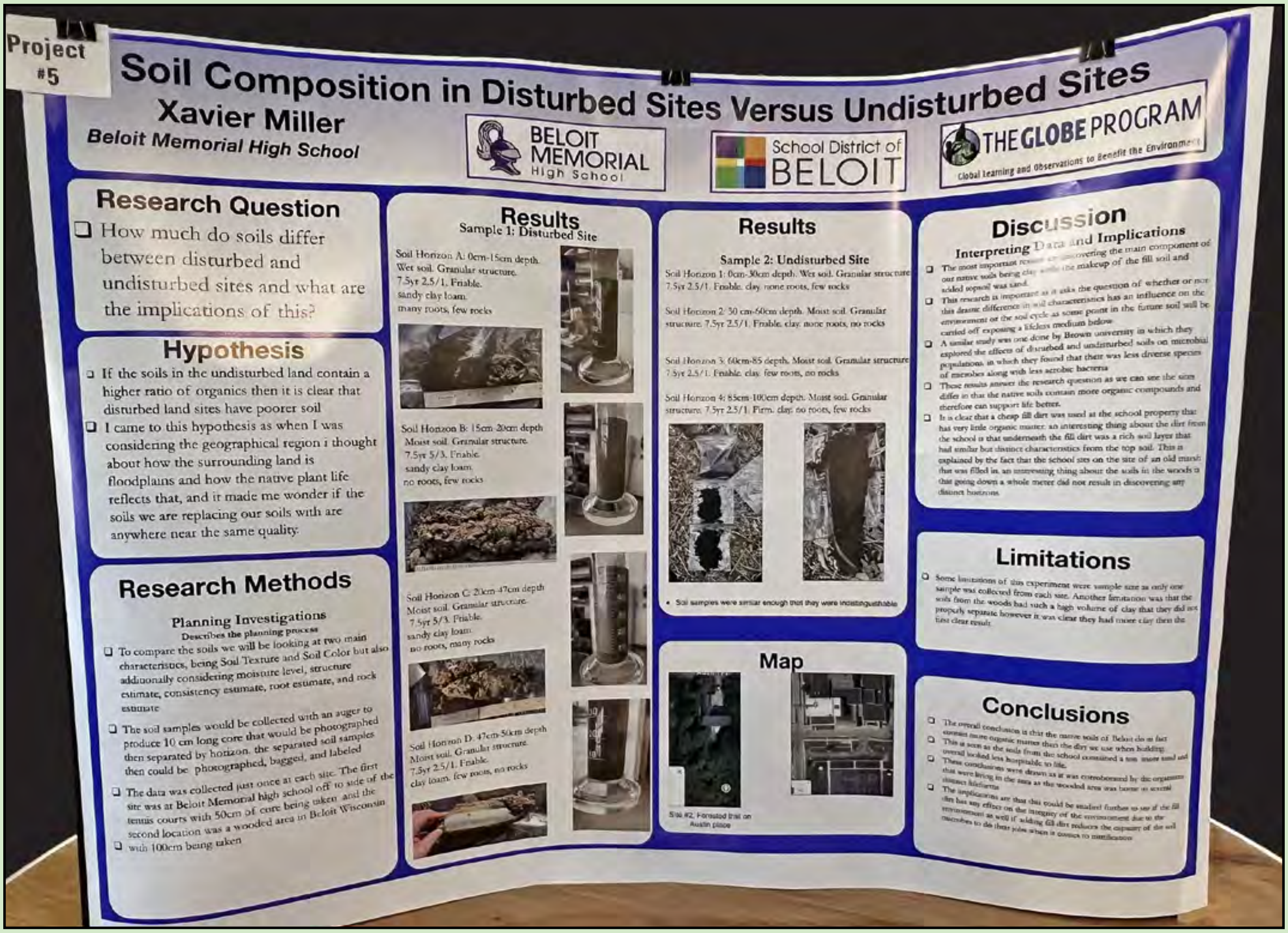

Figure 7: A sample GLOBE research scientific poster presentation. [Photo credit: Beloit Memorial High School via GLOBE U.S. Coordination Office]

Student Research Symposia

Each year, the GLOBE U.S. Coordination Office invites middle and high school students to attend regional Student Research Symposia (SRS) to highlight their GLOBE research. Students collect their own data or analyze data from GLOBE's database. They create scientific posters to present their research to their peers and STEM professionals at the regional SRS [Figure 7].

International Virtual Science Symposium

GLOBE also offers the International Virtual Science Symposium for students from all GLOBE countries to share their research. Students upload research reports that are judged by GLOBE scientists. Students who produce exemplary research are eligible for a stipend to attend GLOBE's annual meeting. In 2024, more than 280 reports were uploaded from 30 GLOBE countries, and more than 100 were eligible for the stipend.

BENEFITS OF GLOBE

Ellen Ervin told us about her GLOBE experience: "This was a powerful experience for our students because they got to work outside in the forest alongside soil scientists who were able to encourage them to be curious and to notice, wonder and learn about the soils right on their school grounds."

While we know that not all GLOBE students will become soil scientists, we want to help you spark enthusiasm like that first-grade student in New Hampshire. Using GLOBE can contribute to increased scientific understanding of the Earth, build excitement around careers in science, and open up collaboration opportunities with students and scientists around the world.

We hope this article has helped you learn a little more about The GLOBE Program and that you've found the "one thing" from the fire hose to get started with. The GLOBE community is always open to answering questions about getting started and sharing ideas. Reach out to us at usglobeoffice@gmail.com.

The SEAS Islands Alliance: Envisioning STEM Career Pathways as Braided Rivers to Support Island Students

Members of many historically marginalized populations remain underrepresented in the fields of science, technology, engineering and mathematics (STEM), despite significant efforts focused on recruitment and retention (McWhirter and Cinamon, 2021). This is especially true for the geosciences, which include earth, atmospheric and ocean sciences, despite more than 40 years of programming aimed at increasing racial and ethnic diversity of the field (Bernard and Cooperdock, 2018; Núñez et al., 2020). Individuals from island regions remain particularly underrepresented in the geosciences (Bohensky and Maru, 2011), even though island regions are strongly connected to the oceans that surround them and are among America's most racially diverse communities (U.S. Census, 2020). The lack of racial and ethnic diversity in the marine science workforce is concerning given the many challenges and opportunities facing coastal and island communities, including sea level rise and climate change impacts, changes in water quality and quantity, changes in fisheries and other natural resource management, and a growing "blue economy" of jobs related to ocean resources; the workforce must reflect the demographics of the communities they serve if it is to adequately serve their needs (Harris et al., 2022). There is also growing recognition of the importance of place-based perspectives and local knowledge in addressing societal and environmental issues (e.g., Koppes, 2022).

Interventions that engage students prior to college (e.g., DeFelice et al., 2014), during undergraduate (e.g., Houser et al., 2018) or during graduate school (Boger et al., 2014) have been successful in encouraging students from historically underrepresented identities to engage in STEM studies and careers. While persistence studies often focus on a "traditional" linear academic progression from pre-college to undergraduate to graduate programs, it is important to consider that individuals can enter the STEM field at different points of their careers and may leave the field and reenter throughout their lifetime (Gonzales and Terosky, 2020). Therefore, this paper utilizes a braided river framework (Batchelor et al., 2021), which offers an alternative to the "pipeline" analogy of STEM pathways, highlighting multiple entry points into the field and multiple ways to define persistence that are broader than the "traditional" path described above. From this perspective, this paper describes the NSF Eddie Bernice Johnson INCLUDES SEAS Islands Alliance (referred to hereafter as the SEAS Islands Alliance), an evidence-informed, multifaceted suite of interventions that engages individuals from multiple development points, offering several entry points into STEM with the goal of broadening participation in the geosciences. A review of the literature is presented at the end of this paper.

SEAS Islands Alliance: A Comprehensive Initiative

The SEAS Islands Alliance was designed to align existing marine and environmental science initiatives in three island locations to create a full pathway of educational opportunities that span from pre-college programming to workforce positions (i.e., full-time, on-island jobs). When the SEAS Islands Alliance began in 2019, three island "Hubs" led by the University of the Virgin Islands (UVI), the University of Guam (UOG) and the Universidad Interamericana de Puerto Rico

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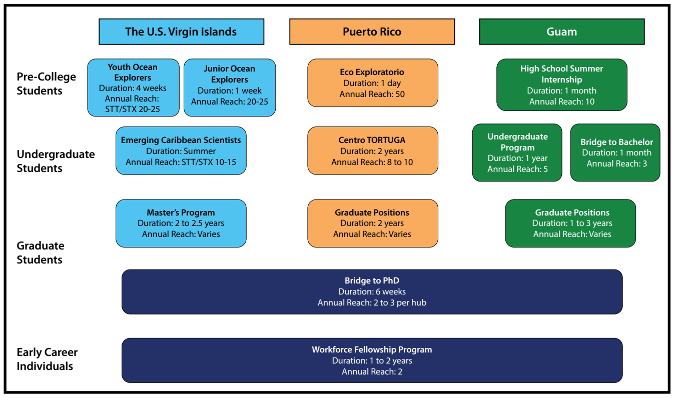

Figure 1: Overview of different interventions available to support STEM pathway, organized by time point offered.

(Inter)[1] each had existing initiatives that targeted some (but not all) educational levels. The Alliance allowed for the expansion of existing programming or the creation of new programming to fill gaps such that each Hub now includes a full pathway. These three hubs implement interventions across multiple developmental periods, from precollege through to the workforce. Individuals can progress through multiple interventions (e.g., pre-college and college) or they can enter at any other point in the pathway (e.g., workforce position only).

Interventions

Across the three Hubs, interventions capitalize on multi-tiered mentoring, engaging peer mentors, near-peer mentoring, and mentoring from faculty, professional staff and SEAS Islands Alliance leadership. Often, these mentors and students are from the same community, demonstrating that individuals from the community are and can become leaders in STEM fields. In addition to mentoring, experiential learning opportunities are provided, and students are able to demonstrate their expertise to peers, family members and their community in a variety of formal and informal ways. Aligned with the braided river analogy (Batchelor et al., 2021), participants might join at any point. For example, a participant might join as an undergraduate, then jump right into a workforce fellowship position, or leave for a few years and return as a workforce fellow. Alternatively, participants may join for the first time as a workforce fellow. The SEAS Islands Alliance recognizes that while the interventions each share many qualities, there are also island-specific approaches to implementation that are a function of relationships, capacity, culture and local needs.

Pre-College Engagement

To engage participants while still forming a sense of identity and interest in STEM, several interventions are available to middle- and/or high-school-aged students across the SEAS Islands Alliance.

The U.S. Virgin Islands. The Youth Ocean Explorers (YOE) program engages students in marine science activities for four weeks over the summer. This program runs five days a week for four weeks in the summer, and youth are engaged for six hours a day. Activities include hands-on research experiences and other activities with mentors on a number of topics (e.g., GPS, geosciences, snorkeling, drinking water safety and purification). Families are invited to attend field trips around the island over the summer, as well as the end-of-program graduation, where students present their research. Following the program, students and families are invited to participate in other marine science events during the school year (e.g., coastal cleanups, night snorkels). YOE is run by the Virgin Islands Marine Advisory Service (University of Puerto Rico Sea Grant's extension arm in the USVI), with support from Virgin Islands Established Program to Stimulate Competitive Research (VI EPSCoR). Students on St. Thomas and St. Croix are currently supported.

In addition to YOE, the U.S. Virgin Islands offers Junior Ocean Explorers (JOE). JOE serves youth between third and sixth grade. The structure and

Figure 2: Students in the Junior Ocean Explorers program learn to snorkel and identify nearshore organisms. [Photo credit: NSF SEAS Alliance U.S. Virgin Islands hub]

[1] When the Alliance began in 2019, the partnership was with Universidad Ana G. Méndez (UAGM); it transitioned to Inter in 2021

content are similar to YOE, although the activities have been adapted for the younger age. Originally, JOE was available all day for one week (five days).

Puerto Rico. Pre-college programming in Puerto Rico capitalizes on a partnership between the Alliance and EcoExploratorio, a science museum in Puerto Rico. This program offers a one-day interactive experience for youth to learn about several coastal ecosystems; many topics focus specifically on issues that directly impact Puerto Rico presented within that local context, such as hurricanes, earthquakes, bioluminescence and water quality. Additionally, students interact with a number of scientists who introduce themselves and discuss their area of research while engaging students in STEM experiments.

Guam. Each year, 10 high school students are engaged in a month-long summer internship, where they are in research labs with a SEAS Islands Alliance faculty research mentor and undergraduate fellows at the University of Guam. Faculty mentors are experts in a content area of interest to the students, and students engage in hands-on, place-based, science research aligned with that expertise. Students in this internship also attend a full-day Near Peer Seminar once a week. During these summer seminars, 20–30 grant participants from several grants engage in small and whole group discussions and activities on storytelling, the impact of research experiences on the evolution of self, and bridging science, culture and identity in science communication. The design for a rotating mix of small group members and activities exposes students to a variety of research projects while creating a sense of belonging that builds confidence and competence through ample speaking opportunities.

At the end of the program, a Science Symposium is held where interns present their research to judges from the science community. Winners of the Science Symposium advance to the final round of the Guam Island Wide Science Fair. Students who place in the Guam Island Wide Science Fair are funded to compete at the Annual International Science and Engineering Fair (ISEF) competition. The Science Symposium is attended by other interns, undergraduate fellows, faculty mentors and family members. Students receive a stipend for participating, and family members receive an incentive in the form of a gas card or grocery gift card when they sign in at the family orientation and Science Symposium.

Figure 3: Guam HS Summer participant Ryan Santos in Dr. Bastain Bentlage's lab working on his study titled Variation in Growth Rate Between Different Acropora Pulchra Populations Around Guam. [Photo credit: NSF SEAS Island Alliance Guam hub]

Undergraduate Engagement

As an Alliance, undergraduate students are supported in several ways, ensuring a variety of experiences such as mentoring, professional development and hands-on research opportunities.

The U.S. Virgin Islands. The Emerging Caribbean Scientists (ECS) Program is an umbrella program that coordinates on-island summer internships for undergraduate students enrolled at the University of the Virgin Islands (UVI). SEAS Islands Alliance students participating in the ECS program are matched with a paid summer internship with one of several organizations involved in marine biology and environmental science on-island (e.g., The Nature Conservancy, Department of Planning and Natural Resources, Ocean and Coastal Observing Virgin Islands, UVI STEM faculty). Within this internship, students engage in hands-on research or career experiences under the mentorship of organizational supervisors and USVI Hub mentors. A variety of experiences are deliberately solicited by Hub leadership each winter, to highlight that there are many different types of marine and environmental science jobs and that not all jobs/internships require fieldwork. Interns and mentors interview each other during the spring to ensure a successful match by identifying opportunities that align with the research and career interests of each student.

Once the program begins, interns engage in weekly professional development webinars and workshops, such as building resumes and writing for academic audiences. These workshops are led by

STEM faculty and other professionals, introducing students to other faculty in the field and allowing students to experience the many aspects of diversity within STEM, from the demographic identities of faculty and professionals to the disciplines represented and the methods used. As part of this experience, students typically present at one to two local conferences, keep an internship journal that has them reflect on the experience, and complete a debriefing report at the end of the internship. They also have the opportunity to present at national conferences such as the [National Diversity in STEM Conference] (NDiSTEM) or the [Coastal and Estuarine Research Federation] (CERF) Biennial Meeting. Students recruited for SEAS Islands Alliance internships vary from freshman to seniors; preference is given to first- or second-year undergraduates and/or Marine Biology majors. Students from St. Thomas, St. John and St. Croix are supported in this program.

Puerto Rico. The [Centro TORTUGA] (Tropical Oceanography Research Training for Undergraduate Academics; Olivo Delgado et al. *In Revision*) program engages undergraduate students formally for two years. Participants enroll in a geoscience seminar course where they are introduced to many foundational theories related to natural science. In addition to coursework and labs, this program provides experiential opportunities where students can learn why they need to learn so many difficult topics, such as chemistry, biology and math, and learn how to navigate the field of research/science. To provide these experiences, students attend several field trips during the program, especially during the first semester when the coursework is heaviest. Field trips are designed to introduce students to the ecosystems available on the island, including mangroves and coral reefs. Students also get to visit The University of Puerto Rico, which has the only graduate program in marine science on the island. Through these visits, Centro TORTUGA students (and sometimes their families) are introduced to graduate students who lead field trips that are designed to introduce students to individuals who work in the field of marine science, both inside and outside of the university, and demonstrate the different avenues by which they can engage in marine science work.

During their first summer, Centro TORTUGA students engage in a summer workshop organized and led by University of Maryland Center for Environmental Science (UMCES). During this time, students spend a full week in the field working on short-term projects at a bioluminescent lagoon, Laguna Grande, and hosted by [Para La Naturaleza], a local land trust, locally named "BioBays." This ecosystem is highly valued in Puerto Rico as a natural resource for eco-tourism. At the end of each workshop week, students present their work to their families and engage in a "hand-off" of the Laguna Grande monitoring program from the prior year's cohort of students. Fieldwork continues during the second year, when each student cohort manages the monitoring program, collecting and analyzing data that prepares them for presentations at scientific meetings.

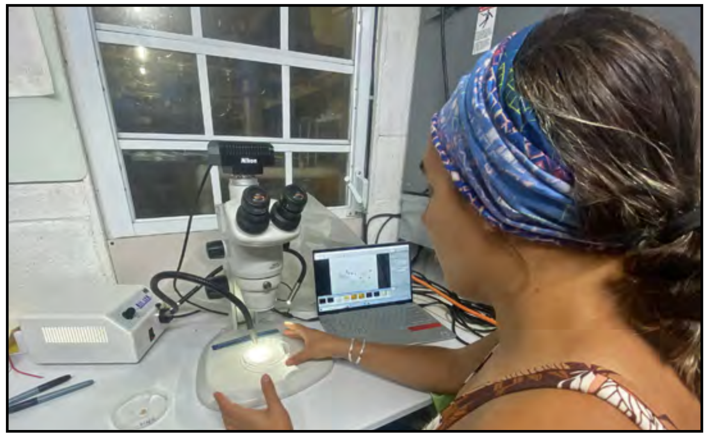

Figure 4: SEAS Workforce Fellow Delsabriana Gonzalez examines grooved brain coral, *Diploria labyrinthiformis,* larvae for successful fertilization for her placement with The Nature Conservancy on St. Croix. [Photo credit: NSF SEAS Alliance U.S. Virgin Islands hub]

The second year of the program also includes the only geoscience course offered at Inter, a short course co-taught with UMCES faculty that focuses on earthquakes and hurricanes. Topics focus on local issues, such as the plate tectonics that result in earthquake activity and the dynamics between ocean currents and atmospheric circulation that lead to hurricanes in the region. The program has also engaged a Puerto Rican anthropologist who speaks with students about Indigenous knowledge. As part of this experience, students present at two or three local conferences; parents and families are often invited to attend. They also have an opportunity to present at a national conference, such as the [Society for Advancement of Chicanos/Hispanics and Native Americans in Science] (SACNAS) or CERF. Twelve to thirteen students are recruited for this program annually.

Guam. On Guam, there are two initiatives available at the undergraduate level, including a year-long Undergraduate Fellowship Program and the summer

Bridge to Bachelor's Program. Five undergraduate fellows start their year-long program in January, where they spend at least 15 hours a week engaged in place-based research in a faculty research mentor's lab. During the academic semesters, fellows also engage in monthly Near Peer Seminars and, during the summer, they attend the weekly seminars. The seminars are designed to overtly connect their place-based research and its impact on their island, region and globally. Near Peer Seminars are also designed to bridge the research experience with the evolution of self. This is achieved by responding to reflection prompts such as, "how did the research experience impact how you see yourself as a scientist, a member of the community, a student…". Woven throughout the year, these seminars help develop student voice and culture in science communication. Undergraduate fellows also act as near-peer mentors to the high school student interns during their summer internship program. During the summer, the fellows spend at least 20 hours a week engaged in their research and Near Peer Seminars. Families (as identified by the participant) attend the orientation at the beginning of the program and are also invited to attend the final presentation. Fellows are supported to propose their work at a local conference, and toward the end of their programming present their research at national conferences such as the NDiSTEM or CERF.

The Bridge to Bachelor's (B2B) program is a 4–6-week summer program. The University of Guam is the only accredited 4-year university in the Micronesian region; students in the neighboring islands can only attend a community college. Within this program, students from community colleges are selected in March to join a research team on Guam in June. In April, the team holds a virtual meet and greet/orientation for the selected students, their families and their support team. The team supporting each B2B student includes an on-site mentor on their island, the Near Peer faculty mentor, the Near Peer undergraduate student(s) in their lab, and the research faculty mentor. In the orientation, B2B students and their on-site mentors are trained on how to collect data on their island which is then shipped to Guam. Once on Guam, B2B students work with the lab team to analyze the data and attend the weekly Near Peer Seminars. One summer Near Peer Seminar activity includes a guided tour of the campus and the different labs. This tour is led by the undergraduate fellows and benefits both the high school interns and B2B students. B2B students present their research at their end-of-program event and submit their research to a local and national conference. While on Guam, the B2B students reside in the dormitories and are also able to enjoy the island with weekend excursions to the malls, cultural events and beaches.

Graduate School Engagement

Across the islands, hubs provide funding to support graduate students as they engage in STEM learning and research.

The U.S. Virgin Islands. Students (number varying) are selected each year as SEAS Islands Alliance graduate fellows; these students join the University of the Virgin Islands Master of Science in Marine and Environmental Science (MMES) program as part of a cohort of around 12–18 students. UVI Graduate Fellows enroll in a two- to two-and-a-half-year master's program. In addition to coursework, students engage in a capstone research project that includes culturally relevant outreach events where they present information to the larger community. Graduate Fellows meet regularly with faculty mentors and members of the UVI Hub leadership team. Some students also mentor high-school and undergraduate students engaged over the summer as part of the YOE and ECS programs.

Puerto Rico. Graduate students who participate in the SEAS Islands Alliance through the graduate school program matriculate through the Marine Estuarine Environmental Sciences (MEES) Program at UMCES. The MEES program provides an interdisciplinary educational experience where students engage in foundational coursework as well as applied environmental science, including presentations and workshops with agencies and practitioners. Due to its inter-institutional status, students who engage in the MEES Program interact with faculty across multiple universities and research institutions across the state of Maryland. In addition to high-quality curriculum and coursework, students engage in hands-on experience conducting research and obtain several professional development opportunities that improve job skills, such as how to build a budget. Finally, graduate students act as role models for other individuals involved in the Alliance in both formal and informal capacities.

Guam. Guam also supports graduate fellows who, in addition to their graduate program load, work under the Guam Restoration of Watersheds (GROW) Initiative. The mission of GROW is to advance tools and technology that can be used by the community to reduce erosion in Guam's watersheds. Thus, the fellows' responsibilities include aiding in the management of seedlings at an on-campus nursery and aiding in planting over 6,000 seedlings per year. Additional responsibilities include supporting the maintenance (grass cutting, trail maintenance, tree clearing) of the GROW Ugum project site, leading community tours of the Ugum site, installing erosion control methods such as waddles and sediment socks, collecting location points using GPS to create maps, and researching how drones can be used to reseed the badlands of Guam. The graduate fellows also acts as mentors in Near Peer Seminars and serve as group leads during off-island conferences with undergraduate students. In addition to these tasks for GROW, fellows also take a lead role in hub and alliance activities such as chairing and speaking at conference panels and during annual events such as summits and alliance face-to-meetings.

Figure 5: University of the Virgin Islands undergraduate and graduate students Kayla Halliday and Kwami Alexander, Workforce Fellow Allison Holevoet, and SEAS mentor Allie Durdall prepare to measure a recovering mangrove forest in St. John. [Photo credit: NSF SEAS Alliance U.S. Virgin Islands hub]

Workforce Fellowships

As workforce fellows, individuals engage in paid positions in the geosciences with territorial partners that meet the needs of partners and the career goals and interests of the fellow. Within these roles, they get to experience life in the field of STEM, which for some includes fieldwork and research.

The U.S. Virgin Islands. In the U.S. Virgin Islands, one to two individuals are hired as workforce fellows each year and receive one to two years of funding to work in a field of interest. In addition to gaining professional, hands-on skills in their position, they also create individual development plans (referred to as Placement Agreements) to ensure professional development opportunities are identified early on. These students receive mentoring from their supervisors as well as the Hub leadership team. To date, workforce fellows have been placed in organizations such as the USVI Department of Planning and Natural Resources (DPNR), The Nature Conservancy, the Virgin Islands Marine Advisory Service (VIMAS), Virgin Islands EPSCoR and the University of the Virgin Islands. Fellows engage in hub meetings, contribute to cross-cutting workgroups, and engage with USVI hub interventions and students and Alliance-wide activities. They also participate in local and national conferences.

Puerto Rico. In Puerto Rico, fellows are placed with local partners, including Para La Naturaleza, the Department of Natural Resources (DRNA), the Jobos Bay National Estuarine Research Reserve, and EcoExploratorio. These positions vary in their work experience from research focused (DRNA, Jobos Bay), to non-profit contexts (EcoExploratorio, Para La Naturaleza). As a condition of their experience, fellows are also engaged as near-peer mentors for undergraduate participants and assist with the summer workshop. Workshop fellows have also contributed to cross-cutting workgroups, planning of SEAS Islands Alliance meetings, and in coordination of the high school programming with EcoExploratorio.

Guam. On Guam, the team partners closely with Guam Green Growth (G3), a comprehensive public-private partnership on Guam that includes 97 members from all sectors of society. Due to the existing relationship between the SEAS Islands Alliance and G3 initiatives, as well as the fact that G3 brings together so many partnering agencies, the workforce fellowship program on Guam typically places fellows in support of the G3 working group. These individuals work for G3 under the support of the SEAS Islands Alliance for one year, interacting with the leadership team at UoG as well as numerous partners involved in the working group. During this year, they are supervised by G3 staff in support of a professional position. Workforce Fellows also identify opportunities for professional development based on their goals and bring those requests to the G3 leadership team, ensuring tailored professional development opportunities. Following the workforce fellowship year, these individuals are either supported in permanent positions with G3, find a permanent position with another partnering agency, or decide to return to graduate school.

Figure 6: Guam's Bridge to Bachelor's summer participant Angel Santos from Saipan in Dr. Christopher Lobban's lab presenting his study titled Saipan Diatoms with Emphasis on Plagiotropis Regional Diversity. [Photo credit: NSF SEAS Island Alliance Guam hub]

Bridge to Graduate School Program

SEAS Islands Alliance participants have the opportunity to engage across hubs through working meetings and at national and Alliance meetings. Additionally, one intervention intentionally brings together students from all three Hub locations as they explore what a PhD program is like: the "Bridge to Graduate School Program."

The Bridge to Graduate School (Bridge) Program supports undergraduate or master's students from each of the three Hubs (typically six students annually, though the number varies). As a cohort, these students travel to an R-1 university where they engage in a six-week intensive summer internship experience to help students explore what it would be like to pursue a PhD. These students can experience research at a large R-1 institution while practicing skills and becoming familiar with campus resources that will contribute to their success. Students receive a stipend for attending. A matching system is used to place students in research labs of interest. Students often rotate through different research labs that work on topics related to their research interests for the first three weeks of the program. Then, students spend an additional three weeks working on a research project with the lab to which they were matched.

Students work on a research project with the support of their faculty mentor, postdoctoral students, and other graduate students working in the lab space. Students are also assigned a mentor at their home university; these mentors check in with students weekly through Zoom to offer support. All mentors that work with the student are trained prior to the activity.

In addition to engaging in research, students attend a number of workshops related to graduate school life, faculty expectations and study skills. Students also attend workshops and seminars led by leading researchers and practitioners in the field, where students are given the chance to learn more about the types of careers and the diversity of pathways to pursuing careers in marine science. At the end of the summer internship, students give a presentation of their research. For many students, this will be the first time they leave the island.

This program also typically includes a concluding week at UMCES where students have the opportunity to participate in a research cruise aboard the R/V Rachel Carson, network with additional faculty members and graduate students, and visit regional academic and non-academic partners to explore different career pathways with a particular focus on engagement with scientists underrepresented in geoscience. Science communication training is also integrated into this one-week portion of the program.

The Bridge to Graduate School Program has been the most varied of the interventions during the years; the program went virtual during COVID and experienced other shifts, such as a change in leadership and university partner (on U.S. Mainland). The description above includes the elements that remain fairly consistent across the years. Those main components include collaboration across alliance hubs, networking with a variety of researchers and faculty, workshops around themes such as doctoral application and program expectations, and advanced research exposure and engagement. However, this intervention is currently being redesigned.

Follow-up Survey

Since the SEAS Islands Alliance developed in 2019 through Spring 2023, the Alliance engaged 291 individuals, though that number includes 37 participants who have engaged in more than one intervention or the same intervention more than once (See Table 1 for numbers by interventions). In Spring 2022 and then again in Spring 2023, former participants from these programs were emailed a survey that requested information on their current involvement in STEM. Of the 291 SEAS Islands Alliance participants, 197 of them received the survey in either or both years; 109 participants (37%) responded to the survey at least once. Results from this survey indicate that 89% of respondents were still engaged in the STEM pathway; 91 respondents (83%) were still engaged in the marine science pathway in some capacity at the time of the survey, whereas another six (6%) were somewhere else in the STEM pathway. Only 12 respondents (11%) reported no longer being engaged in the STEM pathway.

TABLE 1

Number of participants engaged by each intervention through Spring 2023

	U.S. Virgin Islands	Guam	Puerto Rico	Total
Precollege	120	19	50	189
Undergraduates	30	29	38	97
Bridge to Ph.D.	10	9	5	24
Graduate Students	5	2	1	8
Workforce Fellows	4	2	6	12
Total	169	61	100	**330**

Note. This count includes duplicates when individuals engaged in more than one intervention offered by the SEAS Islands Alliance.

DISCUSSION

Numerous interventions have been designed with the effort of broadening participation in the geoscience field. Researchers examining these interventions offer advice on strategies that might be most effective in supporting individuals from historically underrepresented communities, such as including family engagement techniques (Bruno et al., 2011), hands-on research experiences (Pfeifer et al., 2021), place-based pedagogy (Weissmann et al., 2019), and partnerships that bring students to four-year institutions (Gamage et al., 2021); many of these are in use by the Alliance.

The majority of participants engaged in our interventions persisted. However, it is also important to highlight that not everyone did. Sometimes this was due to contextual factors. For example, some students needed to get non-STEM jobs right after their undergraduate degree to help support their families and could not attend graduate school right away, though they planned to return to the field eventually. We also had students engage in an intervention and realize that the STEM field was not for them. We count those as victories as well! Following the braided river framework (Batchelor et al., 2021), it is imperative that the unique journeys of participants are not only accounted for in the design of the intervention, but that the insights and self-knowledge they gain in these programs are supported and celebrated at the scale of individual participation.

CONCLUSIONS

Increasing representation within the geosciences requires the recruitment and retention of individuals from historically marginalized and underrepresented populations. To support these individuals in meaningful ways, programs must reach individuals at different points of their development in life. Developing interventions that consider the “braided river” and can lead individuals to STEM careers is an important step toward broadening access. In this paper, we outline multiple strategies that have been used to engage students from island communities. However, it is important to note that much of the success of these programs came as programs adapted to the expressed needs of the students they reached. Therefore, while this information is meant to be helpful to anyone looking to develop informal and formal STEM learning contexts within their community, it is essential to ensure that the voice of those participants is central to program development.

REVIEW OF LITERATURE

Interventions to Address Inequality Within the STEM Field

In addition to the need for structural changes within the STEM field (McWhirter and Cinamon, 2021), interventions that aim to increase STEM interest and competence have demonstrated some promise in broadening access for individuals from historically underrepresented populations (Wolfe and Riggs, 2017). For example, interventions that engage underrepresented high school students in research experiences have been found to improve student sense of identity within science (DeFelice et al., 2014). Carrick et al. (2016) documented that 55% of high school students who engaged in a two-week summer program entered college as a STEM major, 20% of whom majored in geoscience. In addition to supporting students who are in middle school (Sherman-Morris et al., 2017) and high school (Carrick et al., 2016), interventions have also been found to improve participation within the geoscience pathway for undergraduate (Bingham et al., 2003; Blake et al., 2013; Houser et al., 2018) and graduate students (Boger et al., 2014; Stassun et al., 2010). These interventions utilize several different strategies, including family engagement (Bruno et al., 2011), hands-on research experiences (Pfeifer et al., 2021), place-based pedagogy (Weissmann et al., 2019), and partnerships that bring students to four-year institutions (Gamage et al., 2021).

STEM Pathways as a Braided River

Interventions targeting varying age groups and using various strategies have found success in promoting STEM pathways; this finding highlights that individuals access the STEM pathway at different points in time. Although STEM workforce development has historically been discussed as a "pipeline," where individuals enter the STEM field at specific (usually academic) points and follow a linear path that leads them into a STEM career, this is not true for many individuals (Gonzales and Terosky, 2020; Reider et al., 2016). Not only is this analogy often inaccurate, but some researchers also argue that this framing can perpetuate inequality within the geosciences (Batchelor et al., 2021). Instead, Batchelor and colleagues (2021) present the "braided river" analogy, which better represents the "broad range of interdisciplinary and innovative opportunities that STEM professions now offer across a wide range of industries, nonprofits and other organizations" (p. 1). This framework accounts for entry points into the STEM pathway that occur at various time points and through multiple mechanisms, the opportunity for individuals to change directions and pacing after entering the pathway, the possibility of exit and re-entry, and the fact that successful STEM engagement and persistence can look different for different individuals. Additionally, the braided river framework highlights the importance of creating inclusive and supportive environments to allow scientists from different backgrounds and identities to feel a sense of belonging.

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Beyond Lectures and Lone Desks: Learning Assistants and Active Learning in Undergraduate Earth Science Classrooms

Active learning is crucial to the success of many college science classrooms. At the University of Montana (UM), active learning is encouraged and supported through the Learning Assistant (LA) program. The LA program allows students who have successfully completed a course to return to the same course in future semesters and help facilitate discussion and collaboration between students. Using this approach has made active learning more accessible to professors who want to teach with this method, especially in high-enrollment classes. Different classrooms at UM offer various levels of flexibility for student interaction based on the classroom seating arrangement, and variability in these setups may affect the quality of learning for students. Here we take advantage of the diversity of classroom assignments for a single faculty member's lower division Earth Sciences courses over the 2023–24 academic year to conduct an informal investigation led by a team of undergraduate LAs.

Active Learning

Classrooms across the United States have been moving away from the traditional lecture approach to teaching in favor of a more active approach. Active learning has been shown to improve equity in college science classes, for example, Freeman (2013) found that active learning decreases the fail rate for students in STEM classes and increases student exam performance by about 6%. Students across the board have been performing so much better in active learning classrooms (ALC), that a decade ago, Freeman (2013) suggested the best course of action could be to fully convert college classes to active learning and begin asking what types of active learning are the most effective, rather than if they are effective at all. Converting a class into an active learning format can be challenging for professors (e.g., Stains et al., 2018), especially in high-enrollment courses, which is where LAs may help.

Learning Assistants

At the University of Montana, LAs from a variety of different content areas meet weekly to participate in a seminar led by the director of the program. Discussions in this seminar are focused on pedagogical strategies that foster an increase in collaboration among students and between students and the professor/LA in courses.

Students in this course use the observations, photos and surveys they document during their class to ask questions and share ideas with other LAs in the seminar. LAs are able to help students in their STEM classes, but their focus is not necessarily on being a content expert. LAs do more than just aid students in their understanding of material, they are there to provide real-time in situ social support using three techniques: appraisal, emotional and informational support (Hernandez 2021). LAs are often seen by students as more approachable than the professor because they recently completed the course and are in a similar stage of their education. Because of this relationship, LAs not only aid with course content, but encourage students to engage with the class and the material. Having one LA present in a class doubles the availability of someone to answer questions and guide problem solving during active learning tasks. Adding two LAs triples it, and so on. The availability of LAs as classroom facilitators can really become a key factor in a professor's ability to convert to an active style of teaching. LAs have been helping facilitate active learning in various lower division geoscience classrooms at the University of Montana since 2022.

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Figure 1: Students participating in various activities in the observed classes. A and B show students in ERTH 101 working on an earthquake probability forecast problem. C and E show students in GEO 224 testing wave speed hypotheses and collaborating on a unit synthesis jigsaw presentation, respectively. D shows students in ERTH 103 testing groundwater contamination hypotheses. [Photo credits: A – Natalie Bursztyn, B – Natalie Bursztyn, C – Trevor Wilson, D – Andy Kemmis, E – Natalie Bursztyn]

Classroom Geography

Classroom setup is another key factor that can determine a lot about the way a professor teaches their classes. Classroom setup involves both the layout of the classroom and the tools that may be available in a given classroom. Park and Choi (2014) note that in a traditional lecture classroom there is a "golden area" and "shadow zone" for students. In a traditional lecture course, the golden area is located in the front and center of the classroom, as it is associated with more eye contact with the professor and an increased ability to focus in class, while the shadow zone is the area in the back and on the sides of the classroom. Students with higher GPAs tend to want to sit in the golden area (Park and Choi 2014). The ALC facilitates increasing the golden area and decreasing the shadow zone through peer interaction and instructor movement about the room. As a result of these factors, the ALC does not favor students based on GPA as the traditional classroom tends to, thus it may create more equity in the classroom (Park and Choi 2014). ALC classroom layouts also encourage instructors to use more student-centered teaching. Rands and Gansemer-Topf (2017) explain that knowledge mobility increases in active learning classrooms that have a more flexible arrangement such as moveable tables and chairs. Furthermore, these flexible arrangement classrooms may also encourage professors to use more active learning in their instructional approach (Stains et al., 2018).

WHEN LIFE GIVES YOU MULTIPLE CLASSROOM ASSIGNMENTS, MAKE IT AN EXPERIMENT

In this investigation we observed four different rooms and how the layout in each may be affecting student learning in an active learning class with learning assistants.

The Classes

General Science: Physics and Geosciences (GEO 224) is a 5-credit, integrated lecture-lab physics and geoscience course for students pursuing application to the teacher education program and choosing to compress their physical science course requirements. This course has been pilot testing the new TIDeS (Teaching with Investigation and Design in Science) curriculum that is all active-learning based (Figure 1C, 1E). In the fall of 2023, it had 39 students enrolled and was set up to meet twice a week in 3 hour 20 minute sections.

Earth Systems Science 101 (ERTH 101) is a lecture-based course that has been designed to include active learning and daily in-class activities (Figure 1A, 1B), many modified after InTeGrate materials. In fall 2023, the section observed had 52 students. In spring 2024, the section observed had 67 students enrolled. In both semesters the class met twice a week for 80 minutes.

Earth Systems Science 103 (ERTH 103) is the lab counterpart to ERTH 101. The labs are designed to be a set of hands-on, project-based learning activities (Figure 1D). The observed section had 25 students enrolled and met once a week for 1 hour and 50 minutes. This course was facilitated by a teaching assistant (TA).

The Classrooms

The classroom for GEO 224 was located in the Phyllis J. Washington College of Education building which was remodeled in 2009. This classroom is equipped with multiple big screens throughout the room, table groups of four, outlets near the tables, rolling chairs and tables, and whiteboards on multiple walls (Figure 2). This classroom mirrors the active learning classrooms (ALC) described by Park and Choi (2014).

ERTH101 (fall semester) took place in Stone Hall, which was built in 1936. This auditorium-style classroom (Figure 3) features stationary seats with small flip-up desks in rows and columns and one big screen at the front of the classroom. This setup is similar to the Korean traditional classrooms depicted by Park and Choi (2014).

ERTH101 (spring semester) took place in the Social Science building, room 356. This building was originally built in 1921 and an addition was added in 1955. The classroom we observed was renovated in the summer of 2023. This classroom has six rows of alternating rotating and rigid chairs with one long table at the back with independent chairs (Figure 4). A lecture-style setup allows students to move around more freely than the Stone Hall classroom because students can work with those behind or in front of them with ease.

ERTH103 was held in the Clapp building which was constructed in 1971, this classroom has long immovable benches in rows with five chairs per bench (Figure 5). This learning space can be described as somewhere in between the Social Sciences classroom and the Education classroom. Students are set up all facing the front with stationary tables, but the chairs can be moved and students can turn to face peers behind them.

OBSERVATIONS

Observations were made in each of the courses by the LAs assigned to them. ERTH 101 had one LA in the fall and two in the spring. ERTH 103 had one LA and GEO 224 had two. As part of the program, LAs in each section took note of student behavior, engagement

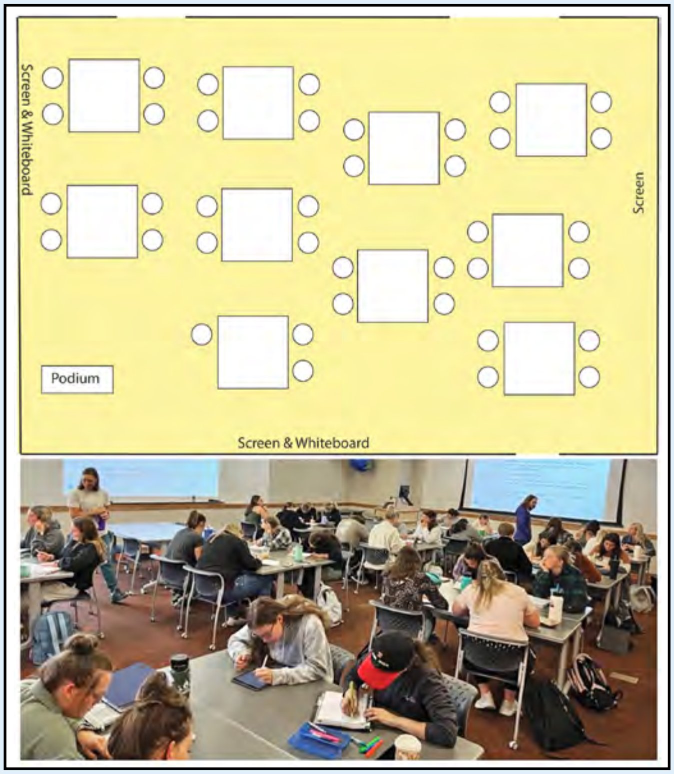

Figure 2: The classroom layout (schematic above and photo below) in the Education building for the GEO 224 course. As a result of the classroom layout and the active learning approach, the "golden area" exists everywhere in this classroom. [Photo credit: Trevor Wilson]

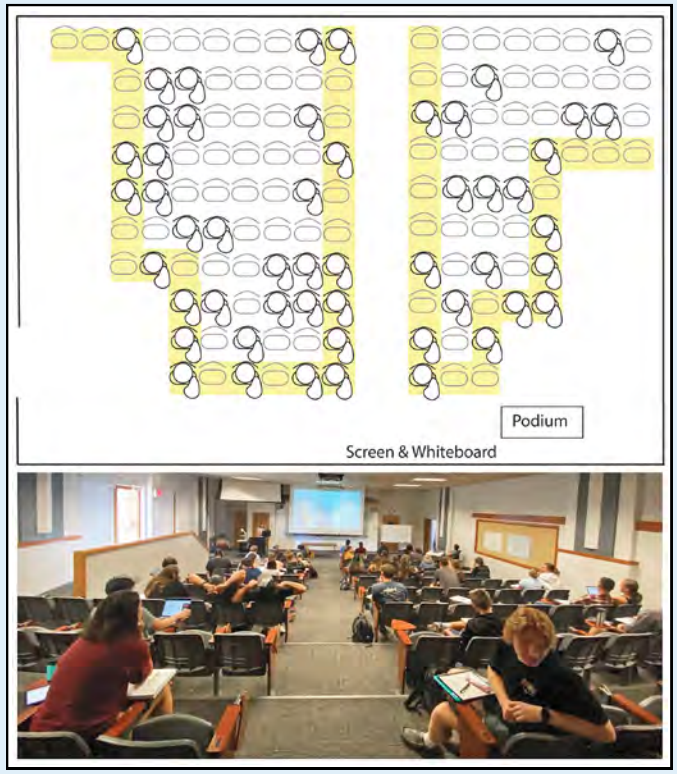

Figure 3: The classroom layout (schematic above and photo below) in Stone Hall for the fall section of the ERTH 101 course. Though a traditional lecture hall, due to the active learning approach, the "golden area" during in-class activities is highlighted, existing only along the accessible perimeter and aisle. [Photo credit: Isla Hargreaves]

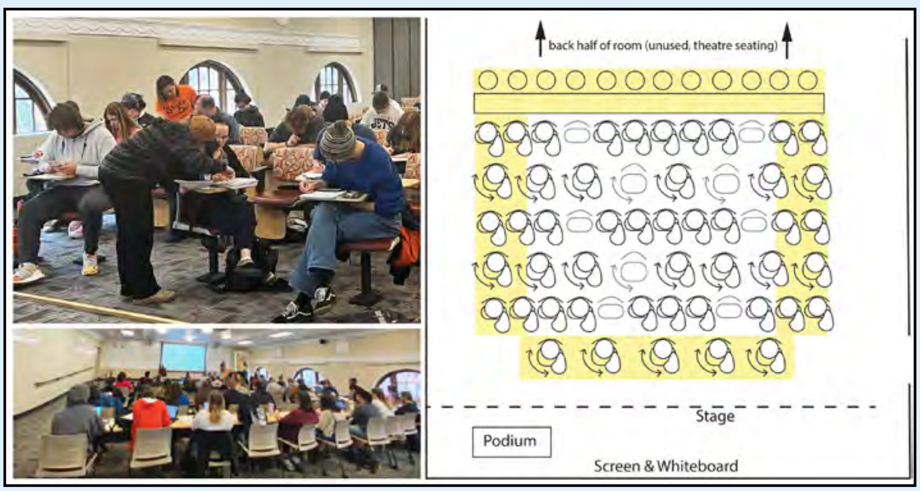

Figure 4: The classroom layout (photos left and schematic right) in the Social Sciences building for the spring section of the ERTH 101 course. A modernized traditional lecture hall with some swiveling seats, the "golden area" during in-class activities is highlighted, existing around the perimeter, but with more depth into the interior due to seat rotation. [Photo credits: Top: Brandy Reinhardt, Bottom: Nicole Cornell]

Figure 5: The classroom layout (photo left and schematic right) in the Clapp building for the ERTH 103 course. During activities students can face either direction and cluster within rows, but affixed tables still limit the "golden area" (highlighted) to the front and entrance-side edge of the space. [Photo credit: Grace Suden]

and interaction with each other and with the LAs, and were also required to survey their classes to gather feedback.

As a result of the observations, differences in student behavior in classes were identified. Some of the most significant variations we saw across classrooms were the students' ability to get started on an activity, their willingness to listen to instructions, and their cooperation with their peers, LAs and professors.

Getting Started on Activities

In some classrooms, students launched into each activity, while in others, students struggled to get started. Students in GEO 224 started the activities as early as they could, some even ignored instructions to begin. These students appear to be excited to start engaging in active learning with their peers. Students in both the fall and spring sections of ERTH 101 struggled more with getting started on activities. Often it seemed that these students who were struggling to get started were not understanding the content of the lecture, so they could not answer the questions that were part of the activity. Students who sat in groups with their peers in ERTH 101 spring were more likely to get started faster than those who preferred to work individually. In ERTH 103, students initially struggled to get started on activities, however, those that worked with other students gained more independence throughout the semester. Students in this class who insisted on working alone all semester needed more help from the LA and TAs than others, whereas students in groups discussed questions that kept them on track without additional guidance. Overall, students in the ALC were quicker to start activities than those in the traditional classrooms or the lab classroom.

Listening to Instructions

Students in some classes were more likely to listen to instructions than students in other classes. In GEO 224, students struggled to pay attention to instructions. Often these instructions were presented to them at the beginning of class, and they tended to start focusing when they were able to do the activity. This classroom had more distractions than the other classrooms. With students facing each other, multiple screens to look at, and table groups close together, there were more opportunities for students to not pay attention if they were not interested in what was being presented. In ERTH 101 in the fall and spring and in ERTH 103, students appeared to pay more attention to instructions. Because they were all in stationary desks, all facing the front of the room, turning around and talking to a neighbor would be more obvious than it was in the GEO 224 classroom.

Collaboration Between Peers

Collaboration between peers varied between different styles of classrooms. Students in GEO 224 were often observed engaging with each other and the activities that they were asked to complete. They enjoyed activities that fostered interaction, like the jigsaw activities where they shared information with their respective groups (Figures 1 and 2). A lot of cooperation between peers was noted in this course and there were no mentions of students working on the assignments on their own. In fact, collaboration between students is strongly encouraged in this course, with lab exercises and discussion questions being collaborative processes by design. Furthermore, because students are sitting next to and facing each other in this class, giving or receiving help from classmates is more natural than if they had to move around to face each other. It is also important to note that in this class, activities like the jigsaws require students to work in at least two different groups in order to complete the assignment. Knowledge was able to move around the classroom as students collaborated with their peers, an observation consistent with the literature (e.g., Rands and Gansemer-Topf, 2017; Park and Choi, 2014).

Students in classes where the seats do not face toward each other, like those in ERTH 101 fall and ERTH 103, experienced less cooperation. Some students in these classes struggled to join groups to discuss the activities. Because they were not forced into groups by geography of the classroom, especially in ERTH 101 fall where there were a lot of extra empty seats (Figure 3), some students may have felt hesitant to approach other students and work with them. The students who worked on their own were often more confused about the class content. In ERTH 103 in particular, students who worked alone consistently needed more content-related help in order for them to reach the same level of understanding as those working in groups. In ERTH 101 spring, there was more collaboration than in the fall semester. Students who collaborated tended to understand the topics at hand and asked more meaningful questions to the LAs. The rotating chairs allowed students to discuss problems with their peers more easily.

Cooperation with LAs and Professor

Certain seating geographies lead to more LA and professor interaction with a wider range of students. In GEO 224, there are walkways between each group of students that are wide enough for the LAs and professor to approach each student from each group (Figure 2). In this way, the shadow zone of the classroom shrinks. Students are all able to get the same amount of attention as their peers, creating a golden zone that spans the entire classroom. In ERTH 103, students who were seated in the front, side and back of the classroom were in the active-learning golden zone and were more easily accessible for the LAs and TAs to work with. In classrooms like those of ERTH 101 fall and spring, there are certain students that LAs may physically struggle to stand near and offer support, limiting them to work on their own as well as limiting the questions they may ask. Students who sit in the center of these rooms are harder to reach, creating a physical shadow zone where the LAs and professor cannot discuss content with those students due to lack of direct access (Figures 3 and 4). LAs noted that they felt like "sharks circling the room" when they were unable to move in between rows of students.

Learning Assistant Survey

During the LA seminar course that all LAs participated in, they were asked to create and disseminate a survey for the students in the course for which they were an LA to get feedback for themselves and for the professor. The Earth Science LAs that participated in these observations decided to ask students a series of the same questions to see how their responses compared across classes. The first of these was, "My LA encourages me to interact with my peers." Across all observed courses, 80% or greater of students agreed or strongly agreed with this statement. LAs are able to help students connect with their peers when discussing content, a finding in agreement with Talbot et al. (2015). The next statement given was, "The in-class activities helped me learn and understand the content better." Across all observed courses, 90% of students agreed or strongly agreed with this statement. Students appreciated that in-class activities allow them to practice their knowledge of the course material as they learn it, a finding in agreement with Rutledge et al. (2015). When students were asked what aspects of the class encouraged peer interaction, "classroom arrangement" was an option provided to see if the students in our observed classes noticed being impacted by the layout of the rooms. Figure 6 shows the survey results for this question; students in the fall semester of ERTH 101 were by far the least likely to respond with "classroom arrangement" as a facilitator for peer interaction. The immovable front-facing furniture in the large classroom where students are not forced to sit near each other did not benefit their learning. Students in GEO 224 and ERTH 101 (spring) with swiveling seats and ERTH 103 with moveable chairs were all similarly likely to respond with this choice, with a substantially greater likelihood than students in ERTH 101 (fall). These students were all able to face each other, discuss with nearby tables, and had easier access to LAs and the professor.

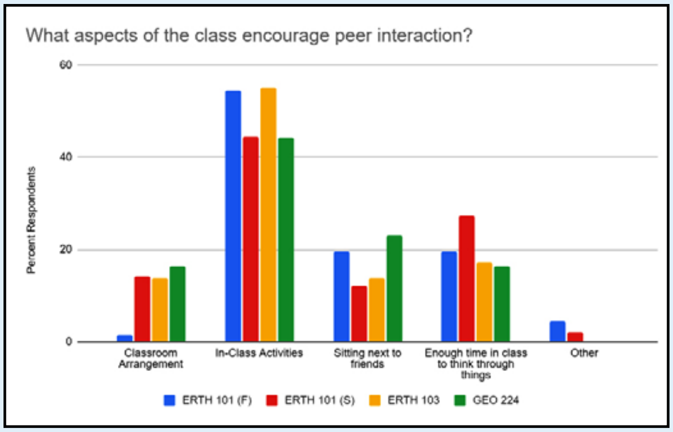

Figure 6: Data from one common question on the LA survey shows that the aspect of class that encourages peer interaction that varied the most between classes was classroom arrangement.

KEY TAKEAWAYS

The scheduling of introductory Earth Sciences courses in a diversity of buildings on the University of Montana campus during 2023–24 academic year afforded us a great opportunity to document observations from LAs with the intent of investigating the impact of classroom geography on our active learning classes. Our key takeaways from this informal experiment are as follows:

1. Accessible walkways between tables/seats increases the "golden zone" of the classroom and

fosters interaction between the professors/LAs and students.
2. Classroom geography changes what kind of active-learning activities are available for a teacher to implement (e.g., the jigsaw posters worked on by GEO 224 students; Figure 1).
3. Students who don't work together, often due to classroom geography, are less receptive to LA interactions (even when LAs climb over seats to try to reach them).
4. Students are more inclined to work together when they are seated at tables where they face each other.
5. Students who worked together and/or faced each other were more successful than those who sat and/or worked alone.

Our study, carried out in real classrooms on the University of Montana campus, agrees with the findings predicted in the literature (e.g., Hernandez et al., 2021; Stains et al., 2018; Rands and Gansemer-Topf, 2017; Freeman et al., 2014). However, to be able to experience the effect of classroom geography in similar-subject introductory active-learning classes supported by LAs, all taught by the same professor within the same academic year, makes the impact that much greater.

So, how can we apply these takeaways when we are assigned a less-than-ideal classroom layout? In a lecture hall that has capacity substantially greater than students in attendance, we can manipulate available seating space to maximize "golden areas" in a couple of different ways, such as blocking off the back half of the room as was done for ERTH 101 in the spring semester. Other suggestions include marking the difficult-to- reach middle section as off limits or designating seating rows with every third row off limits (i.e., two rows of students, one row empty) to create a pathway for the instructor and/or LAs as well as structure students to be more able to collaborate even in rigid seats. In the spring section of ERTH 101, LAs were "seating police" who politely and gently ushered students away from the off-limits area at the back of the classroom at the beginning of every class until the seating routine had been established. Creating a work-around for fixed tables and stadium seating that facilitates students to interact with each other and collaborate makes a big impact in the success of implementing active learning in the classroom. However, it is LAs that seem to make the biggest impact! Our nimble LAs sometimes worked acrobatics to access self-isolating students in the lecture hall, and by reaching them, instantly became a peer to interact and collaborate with for active learning.

Finally, the addition of LAs in these classrooms seemed to substantially increase both the "active" and the "learning" parts of the active learning curriculum in several notable ways. First, the addition of a single LA halved the number of students per instructor in the classroom (e.g., 1:70 became 1:35), the addition of two LAs further improved the student-to-teacher ratio. Acting as seating police, LAs facilitated active learning by mitigating instances of lone students in the lecture halls. The "lone desk" issue was also mitigated by LAs scrambling across tight lecture seating to access inaccessible, self-isolated students. As peers to those currently taking the course as well as former students in the course, LAs can empathize with the challenges some struggle with. It seemed more likely that students would admit to not knowing what to do to LAs rather than the professor, so by LAs being empathetic peers and thus more approachable, more lost students were found and set on the right track. Finally, through all these interactions, LAs modeled critical thinking and discourse as learning strategies within the active learning curriculum.

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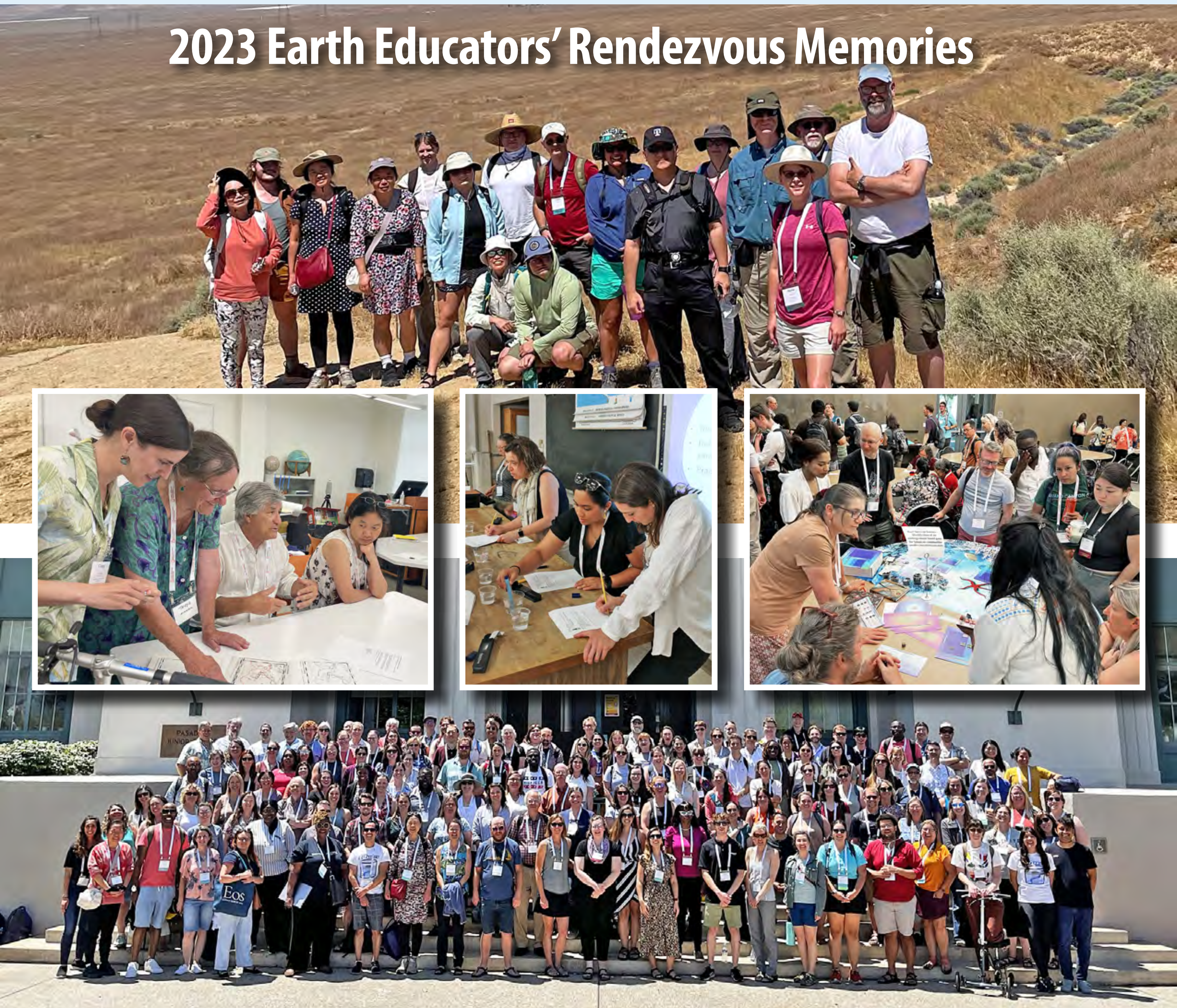
2023 Earth Educators' Rendezvous Memories



Earth Educators' Rendezvous 2024 Temple University, Philadelphia

The Earth Educators' Rendezvous is celebrating 10 years of its unique blend of workshops, plenaries, teaching demonstrations, contributed program presentations and community conversations in 2024. We hope that you'll be joining us at Temple University in Philadelphia, Pennsylvania, July 15–19, for what is sure to be an exciting week of connecting as a community of Earth educators!

Following the Sunday field trip to the Wissahickon Valley Park and the Jean & Ric Edelman Fossil Quarry, the week will kick off with an Opening Reception on Sunday evening, where we'll also introduce one of the week's themes — eARTh ("art" in Earth). This year, there will be various ways to engage with Earth science art, including an exhibition of Earth art open throughout the week and opportunities to create your own Earth art to take with you and to contribute to community projects.

In addition to the morning multi-day workshops, each afternoon will be full of a variety of programming options. Over the lunch break on Monday, there is the opportunity to learn more about NSF proposals. On Tuesday and Thursday, there is an option to visit the Temple University Cognitive Sciences fMRI lab. Some days will offer mini-workshops, providing a time to dig deeper into particular topics, encompassing attracting and supporting students, student learning, preparing students for the workforce, assessment, teaching resources and more. Roundtable discussions will also be held, allowing for more informal discussions and the opportunity for peer-to-peer interaction and networking. The share-a-thon, teaching demonstrations, posters and oral sessions highlight the exciting work being done and resources that have been developed by the community.

Plenary speakers feature hot topics in earth education. During the Tuesday plenary, geologist and education researcher Anita Marshall will share her expertise and experiences in the geosciences, specifically related to field accessibility. The Thursday plenary, led by learning sciences expert Monica Ko, will focus on the future role of AI in teaching and learning.

The Wednesday panel discussion and forum will focus on disruptions in education, including opportunities that arise from them. The community will come together to discuss disruptions such as navigating DEI landscapes, shifting enrollment and departmental change, emerging technologies and more.

Evenings provide a great time for social events with colleagues. In addition, being in Philadelphia provides an opportunity for participants to check out various exciting museums and more. If you can stay an extra day, the post-Rendezvous field trip on Saturday features the Ambler Field Station, which offers a unique opportunity to see urban research and teaching of environmental monitoring.

After this year, EER will move to a biennial meeting, with the next meeting planned for 2026. In the interim, be on the lookout for expanded programming from NAGT. You can share more about what you would like this programming to look like at the EER!

We hope to see you in Philly!

EER 2024 co-conveners and NAGT support staff:

ANDREA BAIR, Delta College

BARBRA SOBHANI, Colorado Space Grant Consortium (COSGC)

LYNSEY LeMAY, Virginia Peninsula Community College

MONICA BRUCKNER, Science Education Resource Center, Carleton College

Program link: https://serc.carleton.edu/earth_rendezvous/2024/program/index.html