Letter from the President ........................................ 2
What is in a Logo .................................................. 3
25 Years Ago in TES ............................................. 4
NESTA Nuggets: Teaching Topographic Maps and
Topographic Profiles ............................................. 5
Using Block Coding to model GPS motion, land
deformation, and earthquake risk ............................ 11
Tsunami Stories: Connecting Indigenous Tsunami
Oral Histories with Current Tsunami Scientific
Understanding and Safety ..................................... 16
Using Drones to Teach Modern Earth Science .......... 19
Advertising in TES .............................................. 25
NESTA Membership Dues Structure ..................... 25
Manuscript Guidelines ......................................... 26
Letter from the President

By John-Henry Cottrell, NESTA President 2022-2024

Reading over these wonderful articles in this Spring 2022 issue of *The Earth Scientist* brings to mind how closely it relates to teaching students post-COVID and the current conversations within NESTA as an organization. Articles regarding classroom advancement in the 21st Century: creating GPS datasets for computing Earthquake risks and tectonic movements, or the use of drones to collect images to teach observation skills to pull scientific data. On the flipside, using ancestral oral histories to understand tsunami safety measures and their history. The new mixed with the old. As learning changes while we advance into the 21st Century, it is important to not lose connection with our past that serves as a foundation to ground us.

One positive attribute teaching online to 180 high school students during COVID, it allowed me to make many technological advances I’d always promised to do in the “next school year,” and master them. However, one of the most difficult aspects of teaching post-COVID, taking this new found technological mastery and applying to the “tested and true,” in-person curriculum I had perfected over the years. There is a special place in my heart for labs created in the 70s, searching out books and retired teachers for “new” old ideas. Those labs have a depth mixed with mechanical sense that seems lost over time, a quality that current labs can’t seem to match; often the labs students enjoy most. Then again, building block codes to investigate GPS velocities and the rate of land deformation, how awesome is that? Flying drones requires understanding FAA codes and live data collection, how do you compete with that? So now I am stuck. All these cool new things, vs the “old faithfuls.” Maybe I’ll just have to have the same students two years in a row, for there is so much I want to do in the classroom. One thing is for sure, I will prepare my students for the technological world ahead of them, while also giving a dose of those good ol’ hands-on labs, it’s all about balance. At a minimum, it keeps teaching exciting.

NESTA has also advanced in the last two years with a restructuring, and will continue in this new direction over the next two years. The question: “What makes a useful Teacher’s association in the 21st Century surrounded with social media and free access online?” Answering that question will give a strong direction, ensuring NESTA is a community of Earth System Science teachers, for decades to come. However, it is important that we stay true to our roots, and rightfully honor those who came before us.

Which also poses, how can we best support the new teacher today with their cutting-edge expectations, while also honoring our Legacy members, those that have or will soon retire? Both sets of members are equally important, though due to time and place in life, can offer different strengths. The young with new ideas and fresh excitement. The seasoned with sage advice, measured experience and more time to offer assistance. After all, there is something that ties us all together, regardless of age or place in life… our Passion for the Earth System Sciences. NESTA is about bringing together those passionate for the Earth and creating one Community to help and assist each other. Just as our articles in this journal issue, the new mixed with the old… it is there that we find balance.

One Earth. Our Future.

John-Henry Cottrell
NESTA President (2022-2024)
What is in a Logo?  
The story behind NESTA’s New Logo

COVID offered NESTA’s Board of Directors time to improve the structure of the organization. To mark this 21st Century restructuring, a logo was approved for a Spring 2022 unveiling. Designed by John-Henry Cottrell with input from the Board, it took several years and versions; the main difficulty expressing the representation of NESTA and the inclusion of all fields of study within the Earth Science Systems Community.

Here’s what each shape and color represent:

Wave (Teal) = Oceanography  
Cloud (Grey) = Meteorology  
Comet (Yellow) = Space Sciences  
Mountain (Green) = Environmental Sciences  
Mountain (Orange) = Geosciences  
Mountain (Light Blue) = Climatology & Hydrology

The Big Dipper = Just as the Big Dipper points towards Polaris, the North Star that guided mariners on their journeys across the vast oceans, so too teachers assist students to find their true path in life. Teachers are the Big Dippers guiding students towards their own personal North Star.

Two Hemispheres of the Earth (flanking logo) = Represents equity in Earth Science for all students

“One Earth. Our Future.” = 1968 on the Moon, William Anders of Apollo 8 took the famous Earthrise photograph, allowing us to realize that we have one Home, and that all of our actions impact each other. Educating all students in the Earth Sciences passes on the legacy of Earthrise. Advocating Earth Science for All has never been more important than it is right now. And like our choices, they impact each other, the tagline is placed in the Ocean, the great regulator of our climate, for what is put into it in one place affects the entire Globe. So does our Advocacy impact the knowledge to make intelligent choices regarding the health of the One Earth. Our Future.

John-Henry can be reached at jcottrell@hemetusd.org
25 Years Ago in TES

Twenty five years ago, in 1997, TES was in its fourteenth year of publication. The focus of this Spring issue was “Looking for Patterns”. The front cover is a photo of the Earth’s Chronosphere showing the day and night pattern of the Earth. The Spring issue led off with a comprehensive 15-page article about Glaciers and their associated growth and feature patterns. The next article acquainted readers with the Antarctic Website. The next article dealt with an activity to Dig into Geologic Time. This was followed by a short article about Looking for Patterns, everywhere in science. Then there was an article which informed the readers about a curriculum effort called WebQuests. There was a blurb telling teachers about a professional development opportunity called TEA (Teachers Experiencing Antarctica), in which teachers were selected to go to Antarctic for a field season to participate in ongoing research. The author noted that a similar program existed for teacher participation in the Arctic (polar bears included?).

By Tom Ervin
Teaching Topographic Maps and Topographic Profiles

Richard M. Jones, University of Hawai‘i – West O‘ahu

NGSS Alignment
These activities would be appropriate for addressing 4-ESS2-2: Analyze and interpret data from maps and describe patterns of Earth’s features; MS-ESS3-B: Mapping the history of natural hazards in a region; SEP-2: Developing and Using Models; CCC-4: Systems and System Models.

Abstract
This article describes two economical and tested activities that can be used to help students (Middle School through College) translate two dimensional topographic maps, flat representations of the Earth’s surface into three dimensional models that depict elevation differences and the shape of the Earth’s surface.

Introduction
Teaching topography, the shape of the land, can be challenging for many teachers and their students. While topographic maps are created to aid in the visualization of the shape of the land, students often find the transition from a 2D representation of the elevation lines, to an accurate 3D representation of the places, distances, and those elevations extremely challenging. In most Earth Science courses, students are often given a simple topographic map and asked to construct a topographic profile, a cross-section, a “side view” of some arbitrary line that bisects the map, Figure 1. This topographic profile is supposed to reflect in the third dimension what the flat, two dimensional, topographic map contour lines really do represent hills and valleys.
Teaching topography and topographic profiles allows the students to explore and make sense of the phenomenon “changes in landscape” and engage them in the NGSS Science and Engineering Practices of patterns and scale and proportion and quantity. As students study the landforms in an area, especially one they are familiar, they will begin to understand the Earth Processes that are at work today and what Earth Processes were at work in the past. The basic tool Earth Scientists use to understand these processes are topographic maps.

The following activities have been adapted from existing materials to help students explore, examine, and use topographic maps of well-known locations as well as their own “locals” to make teaching topography, topographic maps, and topographic profiles a concrete, engaging, hands-on learning experience. After completing these two activities students should be able to construct a 3D representation of a topographic map and construct a respectable topographic profile of the topographic map as well. While these activities have been designed for the students to do independently, safety is always paramount, and teachers and other responsible adults are encouraged to provide adequate supervision.

**Helpful Definitions**

**Topographic Map:** A representation of the earth, or part of it that uses the use of contour lines to show the shape of the earth’s surface as well other kinds of geographic features, including roads, railroads, rivers, streams, lakes, buildings, built-up areas, boundaries, place or feature names, mountains, elevations, survey control points, vegetation types, and much more.

**Contour Line:** A line that joins points of equal height. Contours make it possible to show the height and shape of mountains, depths of the ocean bottom, and steepness of slopes. Basically, contours are imaginary lines that join points of equal elevation on the surface of the land above or below a reference surface, usually Mean Sea Level (MSL).

**Contour Interval:** The vertical distance between the elevations represented by adjacent contour lines on a map. The contour interval you select may be a multiple of the contour interval given on the topographic map.

**Topographic Profile:** A cross-sectional view along a line drawn through a portion of a topographic map. Simply a line which shows the “ups and downs” of a section across a topographic map. This is analogous to slicing a loaf of bread in half and viewing it from the side.

**Activity 1: Plastic Clamshell Topographic Maps**

For each 3D interpretation of your topographic map, you will need several clean and clear plastic clamshell containers cut in two along the hinge. These containers are typically used for cookies or salad at the supermarket. Square clamshells work best. Caution: cut edges of plastic clamshell containers can be sharp.

**Materials**

- Pick one of the simplified topographic maps provided via the author’s public shared file: [http://tiny.cc/TopoMaps](http://tiny.cc/TopoMaps) or visit the USGS Topographic Map Portal: [https://ngmdb.usgs.gov/topoview/](https://ngmdb.usgs.gov/topoview/) or Topozone: [https://www.topozone.com/](https://www.topozone.com/). Both are reliable sources.

  - If you select your own topographic map, you will need to print the map so that you have a 6 in. x 6 in. (15.2 cm x 15.2 cm) section that will provide enough topography (vertical variation) to be interesting.
  - When selecting your own topographic map, be sure to look for at least seven well defined contour lines.

- Plastic Clamshell Container Halves. These should be from the same side of the container so that they will “nest” correctly. The number of container halves needed will depend on the contour interval and the number of contours you choose to trace.
Procedure

- Select one of the topographic maps provided for the activity.
- Make sure that all your box halves are from the same side of the box so that they easily ‘nest’ within each other.
- Decide on your contour interval. You will need one clamshell half for the 0 elevation.
- Place the half clamshell, flat side down onto the contour map.
- Using a wet erase pen (Vis-à-Vis work best) trace the “0” contour, make sure that you label the contour interval on your clamshell half. This is your lowest contour.
- Now trace the next highest contour level, stack this clamshell half on top of the “lower” clamshell half.
- Repeat this step for each contour line, stacking the clamshell halves as you move to higher and higher contour lines. The natural spacing between each clamshell, roughly 5 mm, provides a representative 3D increase in elevation.

Once you complete your stack of clamshell halves, look down on the stack from above. You should see the 3D topography pop up as the topographic lines stack.
Activity 2: Creating Topographic Profiles

Topographic profiles, or cross sectional views of landforms, give a more natural view of an area. These “views” show the topography present, the hills and valleys from the side. For each topographic profile you will need two, three-inch square Post-It Notes©. Pale colors tend to work best.

Materials
- Two 3in x 3in (7.6cm x 7.6cm) Post-It Notes© (or similar self-adhesive stacking note paper source).
- Pencil or pen
- Ruler or straight edge
- Scissors
- Student Worksheet Example
  - Profile Grid Box (See Insert)

Procedure
- Place the top of your Post-It Notes© (non-sticky edge) along the first profile line, A – A’ on the topographic map you selected.
  - If you downloaded your own topographic map you will want to draw a profile line across some interesting portion of your map.
- Mark the Post-It Notes© with a tick mark and the elevation of the contour that crosses the profile line where the top of your Post-It is located.
- Once you have marked your contours on both post it notes, lift them from the topographic map and transfer them to the profile grid box that correspond with the appropriate profile line.
- Make sure that the bottom of your Post-It Notes© (the sticky side) is affixed to the bottom of the profile box. Please note that the bottom of the Post-It Notes© will be located below the “0” contour interval.
- Use a ruler to carefully plot a point for each of the contour line tick marks you made along the top of your Post-It Notes©.
- Using a pencil, smoothly connect the plot points you have on your Post-It Notes©.
- Carefully remove the post it notes from the profile grid box and cut along the line you drew connecting the contour tick marks.
- Return the lower portion (with the sticky side) of the Post-It Notes© to the profile box.
- Now carefully fold the upper portion of the sticky notes upward along the “0” elevation line, making them perpendicular with the profile box.
- Lift up your paper so that you can look directly at the vertical profile that you created.

Image 4: Constructing the Post-It Notes© Topographic Profile  Photo credit: R. Jones
Once you complete your topographic profile, pick up your topographic grid box worksheet and look across
the profile horizontally. You should see the vertical profile of the topography pop up.

![Image 5: Finishing the Post-It Notes® topographic profile](Photo credit: R. Jones)

**Image 5:** Finishing the Post-It Notes® topographic profile  

![Image 6: The Completed Post-It Notes® Profile placed on the A – A' Transect Line on the Simplified Topographic Map](Photo credit: R. Jones)

**Image 6:** The Completed Post-It Notes® Profile placed on the A – A' Transect Line on the Simplified Topographic Map

**Going Further**

Now that you have created your profiles, what can you determine about the steepness of the slope from the space between successive topographic contour lines?

The vertical exaggeration means that your vertical scale is larger than your horizontal scale. For example, you could use one inch is equal to 5000 ft. for your vertical scale, while keeping the horizontal scale the same as is given on your map. Vertical exaggeration is often used if you want to discern subtle topographic features or if the profile covers a large horizontal distance (miles/kilometers) relative to the relief (feet/meters). To determine the amount of vertical exaggeration used to construct a profile, simply divide the real-world units on the horizontal axis by the real-world units on the vertical axis. In this case we need to think in common units...we have kilometers in the horizontal and meters in the vertical...remember that one kilometer is 1000 meters.

For example the vertical scale for the topographic profile grid given in Figure 1 is 1 cm = 20 m

The horizontal scale on this activity is 1 cm = 1 km or 1 cm = 1,000 m

The vertical exaggeration for this profile is 1000/20 or 50 times the horizontal.

For sample questions that can be associated with any topographic map students select, please visit: tiny.cc/TopoMaps

**Resources/References**


Topo Map Mania! Retrieved from: teachengineering.org/lessons/view/cub_navigation_lesson05
Visualizing Topography: Retrieved from: serc.carleton.edu/NAGTWorkshops/visualization/examples/vistop.html

About the Author
Richard Jones, Ed. D., is the Director of the V.E.T.S. (Veterans Empowered Through STEM) Program and Professor of Science Education and Natural Sciences at the University of Hawai‘i – West O‘ahu. Rick was a Middle School and High School Earth Science teacher for 20 years in Hawaii, Montana, and Wyoming. He is Past President of NESTA and a Past President of the Montana Science Teachers Association and the Hawaii Science Teachers Association. His mission is to make science a verb for his students, every day. He can be reached at rmjones7@hawaii.edu

NGSS-ESS Working Group
The NGSS-ESS Working Group is a collaboration between the National Association of Geoscience Teachers, the National Earth Science Teachers Association, and the American Geosciences Institute supporting implementation of the Earth and space science Next Generation Science Standards.

To learn more about our programming and to receive notifications of upcoming webinars: https://bit.ly/joinNGSS_ESS
To view past webinars visit AGI’s YouTube channel: https://bit.ly/webinarsNGSS
Sample presentation slides from NGSS-ESS Working Group webinars. Top slide courtesy of Twin Cities PBS, https://www.tpt.org; Bottom: Drone photo by Steve Brimm Photography
Abstract

Computation is quickly becoming an essential part of science investigations. Especially in the geosciences, where enormous datasets are collected throughout the investigation of Earth-scale processes, scientists turn to computation to help them filter, analyze, and visualize the data. This fact is reflected in the Next Generation Science Standards, which include “using computational thinking” as a key science practice. The GeoCode project’s curriculum module “Assessing Seismic Hazards and Risk with Code” integrates science practices with computational thinking. In this module, students produce data visualizations of GPS movement in California, create code to investigate how land movement causes earthquakes, and synthesize different datasets to assess how deformation build-up poses risks to people and their communities. Through interactions with the GeoCoder model, students build block codes to investigate GPS velocities, the earthquake cycle, and how the rate of land deformation correlates to seismic hazard and risk. Results from classroom implementations indicate students made significant learning gains and recognized the value of coding in helping them understand the complex earthquake cycle system. In addition, teachers reported high student engagement and interaction with the materials.

Introduction

For many middle and high school science teachers, the idea of computer coding in an Earth science class might sound far-fetched. These two disciplines are traditionally separated into not only discrete classes, but also completely different departments. However, today’s Earth scientists and geoscientists routinely use computational models in their work. It’s time to introduce coding as a necessary and accessible practice for Earth science students, too.

The three-dimensional learning model espoused by the Next Generation Science Standards is a vision for teaching science not just as a body of knowledge, but also as a process for acquiring and refining knowledge (NGSS Lead States, 2013). Students in K-12 science classrooms are expected to learn the practices of real scientists but doing so in Earth and space sciences can be challenging. The processes and structures involved in the study of the Earth are too large, both physically and temporally, to fit into a classroom (Pallant et al., 2020).
For example, consider the study of latent heat in the Earth’s energy budget or its impact on weather and climate patterns. Chemistry students can set up an experiment with ice, a hot plate, a thermometer, and a calorimeter to investigate phase change and the latent heat of water, and by the end of a single lab period, they will have all the data they need to draw a graph and construct explanations about the phenomenon. In an Earth science classroom, on the other hand, students would want to explore the far-reaching and interconnected effects that latent heat absorption and release have on the atmosphere and oceans. A real-world investigation into this would require enormous datasets, collected over many years, across hundreds or even thousands of miles, and are best analyzed via computer. Fortunately, abundant computer-based simulations and models, virtual labs, and online access to real-world datasets are now available to middle and high school teachers and students.

The goal of the National Science Foundation-funded Visualizing Geohazards and Risk with Code (GeoCode) project is to integrate scientific and computational practices in the study of volcanic eruptions and earthquakes, using large, real-world datasets. The project developed a weeklong module for middle and high school students that integrates Earth science content with computational thinking practices while engaging students in an authentic geoscience problem. More information about the GeoCode project can be found at learn.concord.org/geocode-seismic.

In “Assessing Seismic Hazards and Risk with Code” students use GPS position data from across California as evidence of crustal deformation along the San Andreas Fault Zone to answer the driving question: Who in California is at risk from an earthquake? Although raw GPS data is difficult to interpret, by transforming it into visualizations, students can see the emergence of patterns in the speed of the land’s movement and its direction. By modifying the inputs into a model, students learn about the factors that are important to explore. Further, coding the visualizations themselves allows students to see the importance of computation for authentic investigations.

Because California is one of the most active seismic areas in the United States, the region’s seismicity is monitored by many organizations. Project partners at UNAVCO manage the data from the GPS stations. We worked closely with UNAVCO scientists and with seismologists at the University of South Florida to design the curriculum and model the ways they conduct research and computational modeling.

**The GeoCoder**

The module incorporates a block-based programming tool called GeoCoder, consisting of a programming workspace and a map visualization (Figure 1). The GeoCoder is designed so that every block in the program workspace on the left produces a visual output on the right. The outputs include easy-to-interpret data visualizations and land deformation models, similar to representations used by scientists. The module scaffolds students as they learn to program simulations, create and interpret data visualizations, and consider the likelihood of hazards. With this design, students have the ability to:

- Run simulations easily with multiple inputs
- Create code to control output visualizations
- Create scientific visualizations of large datasets
- Analyze data and models in order to develop scientific explanations
- Design experiments to answer scientific questions

Students learn how scientists collect data using GPS technology, use the data to explore and model plate motion, create hazard maps, and make forecasts about future hazards. They also
learn how coding enables them to make sense of otherwise inaccessible content in the same way scientists do.

**Data Visualization with Code**

Students begin their investigation of seismic hazards and risk by exploring the network of GPS stations in California and the data provided by the network. Using a set of several hundred active GPS stations, students are prompted to find patterns in the speed and direction of the land in California. Which direction is the land moving? How fast is it moving? Are all places moving at the same speed?

Each GPS station has a record of its own attributes, such as its current latitude and longitude, speed (in millimeters per year), direction of movement, and date it was added to the network. Several stations in the GeoCoder also have a record of their daily position data starting from the day they were installed to the day they were downloaded to the GeoCoder software. By using code blocks to define a specific station and the time range of data they want to see, students can visualize the daily position of that station over time and, therefore, the movement of the land it is bolted to (Figure 2). The ability to quickly and efficiently manipulate this large dataset allows students to become scientists themselves, comparing multiple plots of thousands of real data points in order to identify trends and draw conclusions about the velocity of GPS stations in California.

**Coding Deformation Models**

After investigating real-world GPS movement, students explore how different rates of land motion are related to the occurrence and frequency of earthquakes. Students use the Deformation Simulation in the GeoCoder to simulate the movement of two tectonic plates and the deformation of the land on those plates (Figure 3). Using block code, students can set the speed of the two plates, the friction level between the plates, and the amount of time, in simulated years, to run the simulation. To try out the GeoCoder yourself and build your own code, visit [https://geocode-app.concord.org/branch/master/index.html?unit=Seismic](https://geocode-app.concord.org/branch/master/index.html?unit=Seismic).

The wording of the code blocks, or syntax, helps students bridge the gap between the science concept they are investigating and the computational processes they need to carry out in order to use the visualization to ultimately answer the driving question. For example, the conditional statement at the bottom of the code in Figure 3 uses scientific terms to describe what is going to happen in the visualization when students run the code. In regular language, the code says, "If the amount
of deformation in the model is greater than the maximum amount of deformation the plates can undergo, as determined by the friction level [set by students], then an earthquake will occur in the Deformation Simulation. If not, loop back to the beginning and run through another year of simulated plate movement.”

A key concept in computational thinking is being able to translate a scientific investigation into code, and the descriptive code blocks lower that barrier. The GeoCoder design is intended to help students gain a deeper understanding of the earthquake cycle and why earthquakes occur while they also learn about common coding features such as loops and conditional statements.

In addition, the Deformation Simulation helps students build a mental model of how the surface of the Earth reacts to the plate movement they set in the code. As the simulation runs, the grid lines on the two plates bend and squish according to real mathematical models of deformation around a transform fault. When an earthquake occurs, once-connected grid lines snap apart and back to straight, representing the elastic deformation of a brittle surface land. Immediately after an earthquake, land deformation begins to build up again, and the earthquake cycle continues. Students use the simulation to help explain why many places in California experience earthquakes every few years—and why scientists know “The Big One” is coming.

**Student Experience**

The “Assessing Seismic Hazards and Risks with Code” module was piloted at a mountain community Colorado high school first in April 2020, again in December 2020, and most recently with 87 ninth grade students in three Honors Earth science classes in December 2021. While all students began with similar prior content knowledge of plate tectonics, they had varying amounts of coding experience. Some students carefully followed the tutorials to write their first lines of code, while others were able to jump ahead to use functions before they were introduced.

In focus group interviews after completing the module, students generally agreed that the block coding became easier as they stepped through the activities and gained coding practice. One student remarked that using the code blocks to change the parameters of the model allowed her to understand the resulting changes in the visualization more easily. In particular, adjusting the inputs to the Deformation Simulation helped her to comprehend the relationships between friction, deformation build-up, and earthquake frequency in a way that had eluded her during a previous lab using physical models.

Pre- and post-test performance showed that students made significant gains in their understanding of plate motion, deformation, and seismic risk. On a teacher-created pre-test, the mean score for all 87 students was 21%. The post-test mean score was 76%. The largest gains were in students’ ability to represent graphically the cycle of deformation and release along a fault. Significant gains were also made in students’ abilities to discuss factors that affect seismic risk for a location. [The GeoCode: Seismic project’s official pre- and post-tests can be found at learn.concord.org/geocode-seismic. You must have a teacher account (it is free) and be logged-in to view and assign these activities.]
Teacher Feedback

The four Earth science teachers at the pilot school have found GeoCode to be a valuable way to involve students in real-world investigations of hazards and risk. They have made it a permanent part of the ninth-grade science curriculum and plan to use two GeoCode modules with students every year. (In addition to “Assessing Seismic Hazards and Risks with Code,” GeoCode developed another module called “Assessing Volcanic Hazards and Risks with Code.”)

The first year of the GeoCode implementation was at the beginning of the pandemic, and instruction was completely asynchronous online. Even without any face-to-face contact, students were able to complete the activities with a sufficient level of understanding. The 2020-2021 school year brought a hybrid in-person/online setting, and the pilot teachers reported that their students fared better with that increased access to teacher help. Finally, the December 2021 implementation was in a regular classroom setting, and students thrived through the ability to work with their classmates and have teacher guidance daily. While the module is robust enough to be used by students independently, the pilot teachers agree that it is most effective when used with a teacher to facilitate the lessons.

According to the teachers who implemented the pilot, the greatest advantage of the GeoCode module was the use of large, real-world datasets. Giving students the opportunity to analyze and visualize these datasets allows them to participate in authentic geoscience practices in the classroom. Coding helps students change different variables in the visualization of the data deliberately and systematically and see the changes in the outcomes immediately, thus helping them to better understand cause and effect relationships in a complex system. By integrating computer coding into Earth science content, the GeoCode module offers problem-solving opportunities to students not only in science, but with writing code as well. Students can engage in three-dimensional learning in the Earth science classroom.

The GeoCode: Seismic curriculum and assessments can be accessed for free at learn.concord.org/geocode-seismic.

References


About the Authors

Christopher Lore began working at The Concord Consortium three years ago after receiving a B.S. and M.S. in geology from Rensselaer Polytechnic Institute. At The Concord Consortium, Christopher has worked to build earth systems models that allow students to explore complex, interacting systems that are too big to see in a lab. Christopher can be reached at clore@concord.org

After earning a degree in geology at UC Santa Barbara, Stephanie Seever worked in petroleum and environmental consulting before beginning to teach high school science in 1998. This year, she is teaching part time while also working with The Concord Consortium as a teacher consultant on several projects aimed at bringing real-world data and better models into Earth science classrooms. Stephanie can be reached at sseevers@jeffcoschools.us
Abstract

This activity is an engaging way to introduce students to tsunami science and safety. By reading and analyzing indigenous stories, students learn how indigenous citizen scientists observed, studied, and communicated their tsunami safety information to their communities through oral histories and traditions. This activity leads into further instruction about tsunami science and safety. Links to the activity’s readings and worksheet are provided at the end of this article.

Introduction and targeted audience

This activity can be used for introductory geology, hazards, oceanography, or Earth Science courses. In the college setting, the courses can be for majors or non-majors. The activity can be adapted for middle school or high school students. This activity has been taught in small (24 maximum) introductory geology and geological hazards classes, both in person and synchronous online through Zoom. No prior tsunami knowledge is assumed.

Activity Part 1: Each group analyzes one indigenous story

In this jigsaw activity, students are placed in groups. Each group reads a different written record of an indigenous oral history about tsunamis: Native Hawaiian, Maori, and Native American oral traditions. To guide their interpretations, students answer activity questions. They analyze how the tsunami is described (tsunami characteristics) and any safety information.

Activity Part 2: Comparison of stories between groups

After students study their assigned story, the groups are mixed. Each new group has at least one representative from each of the original groups. In other words, collectively at least one student in the new groups has read each story. Students summarize their assigned story for the other members of the new group. Members within the groups then compare stories. They discuss the descriptions of tsunami characteristics (one wave vs. multiple waves, etc.) and what safety information is conveyed (for example warning signs of a tsunami, such as an earthquake).
Activity Part 3: Class discussion

Finally, the instructor leads a class discussion. Representative(s) from each group share their observations. Their observations can be recorded on the board, on paper, or on a shared electronic document, with categories such as what happened before the tsunami, tsunami warning signs, tsunami characteristics, (number of waves, was the first wave the biggest, etc.) and advice. The instructor could then ask the students to circle the similarities and to star the differences between the stories.

Using information from the discussions and the comparative table, students reflect: Do all tsunamis have the same characteristics? Do all tsunamis cause the same amount of damage? What should people do to protect themselves from tsunamis? What safety information can you glean from these stories?

Teaching Tips

By asking questions, instructors can facilitate small group and student discussions.

Students may need help differentiating between what happened before the tsunami (potential warning signs) and what happened during the tsunami (characteristics of the tsunami) in the stories.

It is also important to highlight key safety information preserved in the stories (for example, the sea receding before the tsunami began to inundate land). For reference, some key links to information about modern-day tsunami safety are: The USGS Tsunami and Tsunami Hazard website and the Ready.gov link on tsunamis.

When students notice that the stories do not describe a tsunami in the same way, take this opportunity to introduce students to the idea that each tsunami can be different and that warning signs may or may not be present. Or help students develop hypotheses about tsunami warning signs, tsunami characteristics, and if all tsunamis share the same characteristics.

Extensions

After completing the activity, students study current scientific tsunami knowledge, for example why an earthquake can cause a tsunami. Here is a link to an OER (Open Educational Resource) tsunami reading that can be used to extend the activity. The reading is free and can be modified for different classrooms. Students can then compare information from their indigenous tsunami stories to our current understanding of tsunamis.

This lesson can also be extended by discussing how the preservation of oral traditions saved lives during the 2004 Indian Ocean Tsunami. In Simeulue Island, oral traditions informed generations that feeling an earthquake and observing receding water were signs that a tsunami would soon arrive and to immediately move to higher ground. Although close to the epicenter of the 2004 Indian Ocean Tsunami, only seven of approximately 75,000 people on the island died. Similarly, oral histories saved many Moken people in the 2004 tsunami by warning them to move to higher ground when seeing signs of a possible tsunami.

Instructors can tie this lesson into hazard management and public safety. Because of the success at Simeulue Island and other locations, disaster management personnel are now recognizing the importance of indigenous knowledge and are using traditional knowledge to improve local hazard preparations. Legends, stories, poems, and songs educate future generations of the warning signs of tsunamis and what actions to take.
NGSS Alignment

The activity and extensions align with the following:

- ESS2.B Plate Tectonics and Large-scale System Interactions
- ESS3.b Natural Hazards
- SEP.8. Obtaining, Evaluating and Communicating Information
- CCC.1. Patterns
- The Nature of Science in The NGSS

Conclusion

Students have responded positively to this activity. While we haven’t had the opportunity to collect data, the students do seem more interested in learning about tsunamis and more confident with their knowledge of the material at the end of the tsunami unit or lessons. Students were amazed to learn that oral traditions have saved lives in modern times by providing safety information about tsunamis.

Link to the Activity, References, and Resources

For student handouts (activity worksheets), use the following link: Student handout and links for the tsunami activity (Microsoft Word 2007 (.docx) 19kB July 6, 2021). Links to indigenous tsunami stories are included within the activity forms found online at the links provided above. Links are also provided to articles about Simelue Island, its oral traditions, and the 2004 tsunami.

An OER Tsunami reading (Tsunami: Science and Safety) can be found at the following link: OER tsunami reading. (PDF (.pdf ) 1,952kB June 10, 2021). A Microsoft Word version can be provided by request. Contact the author at sglancy@hawaii.edu

In addition to the links provided above, additional links to information on tsunami safety and indigenous tsunami stories are provided here.

About the Author

Sarah Glancy is a lecturer at the University of Hawai’i – West O‘ahu, a diverse, indigenous-serving institution. She teaches Earth Science classes and labs, primarily Introductory Geology and Geological Hazards. She can be reached at sglancy@hawaii.edu
Abstract

Innovative Earth science educators are often looking for new ways to use technology to both teach modern Earth science and to use emerging technology to capture students' interests. In recent years, off-the-shelf drone aviation technology has simultaneously become amazingly user-friendly and inexpensive enough to be within reach of many classroom Earth science teachers. One only has to unveil a drone to students to hear their gasps of wonder and excitement. In response, teachers are finding ways to use the natural excitement surrounding drones to actively engage students in perfecting their developing precision flight skills to uniquely capture scientific images and data, efficient computer coding techniques for autonomous mapping flights, knowledge and understanding of FAA requirements for safe and legal drone piloting, understanding of transient weather conditions, and abilities in cinematic video editing to communicate scientific evidence and conclusions. To encourage student learning in these domains, we are initiating drone competitions across the state to help students highlight and celebrate their achievements.

Introduction

As human beings, many seem to be fascinated with escaping Earth’s surface and taking to the skies. Aviation visionaries have long wondered how humans can soar by flying aircraft. In today’s world, aircraft can effectively meet their goals without necessarily needing to carry human operators aloft. Unmanned, robotic aircraft have been around in one form or another for nearly 100 years, primarily as an emerging technology-based reconnaissance asset of military endeavors (Buckley, 1998). But in more recent years, increased attention to the technology of unmanned aerial vehicles (UAVs)—more commonly referred to as drones—is rapidly gaining attention across many constituents. Much of this recent growth in the public’s drone awareness is due in large part to modern drones’ capabilities to readily capture images, video, and scientific data in unique ways. Moreover, drone technology is becoming far less expensive to purchase and far easier to remotely program and pilot than drones were just a few years ago.

For innovative Earth science teachers, any low-cost, high-impact, data gathering technology that is easy to acquire and use is often of great interest. Modern drones fit this criterion and, as a result, are quickly finding their way into STEM classrooms and STEAM curricula across the world (viz.,
Slater, Biggs & Sanchez, 2022; Bolick, Mikhailova & Post, 2022. Earth science education seems to be particularly well poised to take advantage of what learning opportunities drones can offer (Finch, 2022). For one, in much the same way as the widespread availability of Google Earth brings tremendous opportunities for teaching Earth science (Blank, Almquist, Estrada & Crews, 2016), the photographic, remote sensing, and mapping capabilities of drones brings students even closer to data that can be leveraged for teaching the enterprise and practices of science. For another, drone technology and its accompanying data-acquisition underlie many contemporary STEM and Earth science careers including, among many: erosional and environmental monitoring, mine mapping, natural disaster assessment, weather and climate studies, scientific documentary film making, and ground cover and agriculture studies. Moreover, many drone-based career opportunities stretch into fields beyond STEM including journalism, tourism support, real estate advertisement, transportation studies and inspections, and emergency services support. Such technology-based career pathways are often immediately obvious and innately attractive to students, and as a result can serve as fertile ground for developing naturally captivating and deeply engaging learning opportunities mitigated by clever Earth science teachers.

Drone Image Analysis

How much of that area in Figure 1 is planted in sweet potatoes if the house is 12-m long? Taking what Google Earth can offer to a whole new level of sophistication (viz., Selkin, 2006), the careful analysis of drone imagery is an important mapping skill to be taught to Earth science students. If students themselves take an overhead digital photograph of an area with a feature of known actual size, they can be taught to readily determine the scale of the image. In the case of Figure 1, where students know that the house is 12-m long, the actual length of any object or area in that image is determined by this formula: $L_{\text{actual}} \times 12\text{-m}_{\text{actual}} \div L_{\text{house}}$.

Developing and practicing such a skill allows students to determine the area covered by surface water or the size of an outcrop or even the volume of bulk material stockpiles, such as gravel, using drone photos that they themselves have captured. Using images taken by students themselves creates significantly more investment and ownership in solving a challenging problem than using an image acquired by someone or something else (Slater, 2018).

Teaching Precision Flight

One reason that drones are rapidly becoming more popular is that many contemporary computer-control flight systems are incredibly powerful. Most new drones are very easy for novices to fly. Many new drones have computerized altitude controls built in—in other words, in many cases, when a pilot releases the controls for a drone in flight, the drone automatically hovers in place instead of catastrophically crashing into the ground. These computer controls are often sophisticated enough to automatically adjust propeller speeds and attitude to stably maintain a drone’s position aloft, even in gusty winds.

Imagine students being able to quickly and safely acquire high resolution photographs of a rock outcrop normally too dangerous to personally climb. A piloted drone that can readily take off, maintain position so a pilot can take pictures, and safely land holds tremendous promise for students to collect difficult to obtain scientific data and images. Yet, such automated drones represent both a wonderful advantage and an expensive curse. On one hand, computer-mitigated drones are easy to fly, and invite even the most apprehensive student pilot to “give it a try.” On the other
hand, automated controls and preprogrammed flight routines can unexpectedly go awry, and an attentive pilot sometimes needs to intervene to avert a collision or complete loss of the drone.

As a result, our teaching experiences with drones lead us to believe it is important for STEM teachers to teach students how to actually fly drones safely, and not rely entirely on preprogrammed flight routines. Many teachers find that an after-school program a couple of days each week yields significant improvement in just a few weeks. To accomplish our goal of having students be accomplished and skillful pilots, we have built timed, obstacle course drone racing into our teaching sequence (Slater & Sanchez, 2022). We regularly set up obstacle courses for our students to navigate in order to develop their precision flight skills. Several of our favorite course designs are illustrated in Figure 2. These courses feature gates constructed from ½” PVC tubing, like those shown in Figure 3. To encourage students to improve their precision flight skills, we have leveraged students’ natural inclination for competition and arranged a series of weekend drone racing events for student pilots around the state where schools can compete with one another.

**Teaching Computer Coding**

One of the most important features of technology is its unique ability to consistently and accurately complete repetitive tasks. Imagine the need to regularly monitor tree growth near powerlines or unmitigated erosion around power poles. Drones are particularly well suited to travel to the same location and consistently collect data time and time again so as to acquire data to conduct a time series study. In much the same way, if a drone needs to go back and forth over a field in order to map it, a computer coded autonomous flying drone is a valuable tool to have in one’s arsenal of data collection techniques.

A growing number of drones are available that can be programmed to follow a specific sequence of commands with specific common coding block languages adopted by participating schools such as Python, Scratch, Blocky, Snap! or with languages specifically designed for use with drones, such as DroneBlocks. In this way, teaching STEM with drones can directly support larger school initiatives, such as the rapidly growing desire for schools to teach computer science and computational thinking (Bermudez, et al., 2019, Chung, et al., 2014).
Knowledge of Legal and Safety Issues

Although educators do not often need formal FAA Commercial Drone Flight certification—known colloquially as Part 107 FAA Licensure—in order to supervise student pilots who are learning how to fly, all pilots are required to be aware of and follow lawful drone flight practices. We accomplish this in part by challenging students to learn the rules of drone piloting and providing students with opportunities to take FAA Commercial Drone certification practice tests, readily found online at no cost. We have had great success with this both by using a “quiz bowl” competition and by having student teams compete to see who can answer the most questions taken from FAA sample tests correctly. Although competitive events are sometimes seen as being out of vogue in the Earth science classroom, there exists far more education research confirming the motivating benefits and increased achievement resulting from academic competitions than refutes the use of competitions as part of a larger portfolio of learning experiences (Abernathy & Vineyard, 2001).

Teaching about weather and atmospheric phenomena is a prominent aspect of many Earth science courses (Guffey, Slater & Slater, 2017). A significant attribute to being about to successfully pass a FAA Commercial Drone License test is an understanding of aviation weather. Expert drone pilots need to be able to identify weather patterns and atmospheric conditions by identifying and reading clouds.

Drone Videography

Since many schools target enrollment in Earth science courses toward a wide diversity of students—not just the college science pathway students—who have many interests. Serving a diverse population of students with varied interests and motivations is part of why many STEM educators are expanding their mission to a STEAM emphasis (Slater, Kilty & Burrows, 2022, p. 206). In response, we have found that we can expand the diversity of students who have an interest in drones by providing a pathway that emphasizes the “A” in STEAM—Arts. The pathway that is showing tremendous promise for us is in drone-based film making.

For the past few years, we have been hosting a student drone film festival. We challenge students to create 90-second, edited films that utilize video imagery, royalty-free music, and narration to embody a STEAM-related theme. These widely open to interpretation themes have included, “the breath of life,” “the magic of motion,” and “awakening from winter slumber.” Student drone films are scored from 1- to 3-points on an analytic rubric based on the extent to which they are: illustrative of precision flight, creative editing, appropriate adherence to a theme, inclusion of supporting music, and overall visual impact (Slater, 2020).

Conclusion

One might only think of students learning to fly drones as a technical career or an after school social club largely unrelated to teaching Earth science. Alternatively, when Earth science teachers begin to think about students learning to become expert drone pilots as part of a larger educational portfolio that includes learning and applying concepts surrounding remote sensing, aeronautics, weather, legal compliance, and a scientific communication through drone flight and film making, then purposefully including drones begins to make educational sense.

A year-long, full-fledged drone education program is probably overkill for doing a good job of teaching Earth science. Moreover, such an all-out approach can be quite expensive. Based on our
experience, we recommend that an Earth science teacher use two or three drones—not twenty—to support teaching Earth science in the domains described above. Furthermore, the use of competitions to encourage students to meaningfully engage with drones and STEAM seems like a more productive approach than making it a central, core part of an often already overcrowded curriculum. At the same time, a fully developed drone education program—perhaps in collaboration with an agricultural education program or journalism and tourism education program—could take full advantage of the many non-visible light cameras (e.g., IR, NVG, LIDAR) that can be readily attached to drones. In any event, using drones to collect data and communicate scientific ideas is well within reach of many Earth science teachers and capitalizing on students’ innate interest in drones seems well worth the effort to capture students’ attention.

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References

About the Authors
Dr. Tim Slater serves as the University of Wyoming Excellence in Higher Education Endowed Chair of Science Education where his is appointed as a Professor of Science Education and an Adjunct Professor of Physics. A Sequoyah Fellow of the American Indian Science & Engineering Society, Professor Slater earned his Ph.D. from the University of South Carolina, his M.S. from Clemson University, two Bachelor’s Degrees from Kansas State University, and has been a tenured professor at several U.S. universities. His primary area of scholarship is teaching and learning of STEM among future teachers and students who are seeking careers outside the STEM career pipeline. Tim can be reached at timslaterwy@gmail.com

Curtis Biggs is a Project Director for the University of Wyoming’s Office of Research & Economic Development where he works to transform the K-12 education system in Wyoming, produce the nation’s highest quality teachers, and set the bar for educator preparation nationwide. An expert in CTE Career & Technology Education, he earned degrees from the University of Nebraska-Lincoln and the University of Montana and is currently completing a Ph.D. in International Educational Leadership at the University of Montana. Curtis can be reached at cbiggs@uwyo.edu
The DataStreme Project includes online courses offered twice yearly by the American Meteorological Society. Choosing among three courses -- Atmosphere, Ocean, and Earth’s Climate System -- K-12 teachers interested in increasing their confidence and resources for Earth science teaching explore these themes during 13-week fall and spring semester courses in small mentor-lead cohorts. Participants earn graduate credits from California University of Pennsylvania and can qualify to become an Certified AMS Teacher.

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<th>Submission Deadline</th>
<th>Mailing Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring</td>
<td>January 15</td>
<td>March 1</td>
</tr>
<tr>
<td>Summer</td>
<td>April 15</td>
<td>June 1</td>
</tr>
<tr>
<td>Fall</td>
<td>July 15</td>
<td>September 1</td>
</tr>
<tr>
<td>Winter</td>
<td>October 31</td>
<td>January 1</td>
</tr>
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