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From the President

We have your back!

Wow! Another school session has started and what a year we had in 2020-2021! For many of us, our teaching world was not what we are comfortable or familiar with and often felt like a “Journey into the Unknown”.

In all honesty, I sometimes I felt, perhaps like John Wesley Powell as he plunged down the Colorado River in 1869 to explore the Grand Canyon, excitement and abject fear of the unknown ahead. But then I remember that NESTA had my back through this journey. I was able to look to my colleagues and my Association to make the journey easier to endure, to calm the rough water, towering rapids, swirling whirlpools that seem to be around every bend as we moved forward, downstream as it were...through year of COVID-19 teaching.

Knowing that NESTA was there with meaningful online resources (https://serc.carleton.edu/nesta/resources/earth_science_online.html), publications, like The Earth Scientist and up-to-date resources and information via the Monthly E-News and even more frequent posts on Twitter, Facebook, Instagram, and LinkedIn, I was be able to make it through our COVID-19 year and come out less bruised and battered. In reality stronger and filled with new skills and experiences that I can translate into meaningful student engagement and the unknowns of teaching focused on content and pedagogy that matters.

Whatever the journey has in store for us, know that we are all in this together and that the NESTA and other Earth System Science organizations “have your back” and will do their best to help you and me navigate through future unknowns, our transitions back to “normal” teaching, and continue to help us toward Earth science teaching excellence by providing relevant, reliable, real and ready resources.

So, this summer, regardless of where your “classroom was” and what your “teaching looked like” we have make this journey together and are stronger. One Earth. Our Future.

Richard Jones, President 2020-2022
richard.jones@hawaii.edu
Letter from the Editor

Last year teachers were challenged to transition their K-12 classrooms to new in-person and online formats. The challenge will continue this fall with new Covid variants on the rise. Permit me to highlight several key resources from the NESTA community that can assist in bringing quality earth, environmental and space science ideas to students wherever they are learning.

The Earth/Space Science Resources Index (nestanet.org/teachingresources) provides vetted lessons, interactive simulations and data resources from trusted sources. The site has organized resources in topical collections that together tell a broader storyline. Be sure to mark this Index as a first stop when looking for specific materials.

NESTA archives past issues of The Earth Scientist online (nesta.wildapricot.org/page-18388). These feature peer-reviewed articles about earth science teaching and include many well-illustrated ideas to include in K-12 classroom curricula.

Earth Science Week’s Diversity, Equity and Inclusion Strategies page at earthsciweek.org/content/diversity-equity-and-inclusion-strategies features DEI educational strategies organized under headings given in Appendix D of the NGSS Science Standards. These activities are geared towards serving the needs of all learners, regardless of background or identity and allowing all learners to participate fully in the learning process. Each strategy is accompanied by an example of a related geoscience-focused learning experience.

Want to get your students involved in the collection of science data? CitizenScience.gov is an official government website designed to increase the use of crowdsourcing and citizen science in the U.S. Dig into the catalog of a huge array of projects that can use the help of citizens of many ages. I counted 25 projects just in astronomy and space science!

I want to recognize the efforts of Carla McAuliffe in helping to put this issue together. I have appreciated her expertise and efforts in the review process, editing, and selecting the components for this issue. She and Tom Ervin have provided excellent advice on the process of producing a quarterly journal and have made this editor job much easier. Thank you, both.
Howard Thomas Dimmick
NESTA Science Educator
1939-2021

Howard Dimmick passed away recently in hospice care and it is appropriate that we recognize his long science education career and service to the National Earth Science Teachers Association (NESTA).

His life-long support to Earth science education is shown through the list of offices held and recognitions received. Howard became a NESTA member in 1985 and was elected to serve as NESTA’s President in 1996-98. He served as NESTA’s Treasurer from 2010-2021, a role he held at his passing. In addition, Howard was NSTA Conference Facilities Coordinator from 2010 – 2016 and NESTA Merchandise Coordinator from 2010-2021.

Howard was a longtime resident of Massachusetts and dedicated time and energy to the Massachusetts Marine Educators Association (MME) for many years. He was actively involved in educational endeavors through retirement and until the very end. He served as the Editor of their journal Flotsam and Jetsam, and at his passing had just sent to the printers his final issue.

In 2015, in Chicago, Howard was presented with NESTA’s Jan Woerner and Harold B. Stonehouse Award for Lifetime Achievement.

Many NESTA members appreciated Howard’s kind and thoughtful leadership. Upon learning of Howard’s passing, David Thesenga, a member of the NESTA leadership cadre, beautifully wrote,

“As the day wanes, it is with great sadness that I read [of Howard’s passing]. Howard was an amazing advocate, someone who would always enthusiastically help and provide ideas/opinions, and a treasure trove of information. His loss will be felt by me, as I often looked to him for conversation and a mentoring ear.”

Howard, NESTA thanks you.

A Tribute Video prepared for Howard Dimmick, by the Rest Haven Funeral Home in Ft. Collins, Colorado dignitymemorial.com/obituaries/ft-collins-co/howard-dimmick-10285516
25 Years Ago in TES

Twenty Five years ago, in 1996, TES was in its thirteenth year of publication. The focus of this Summer issue was the Ocean. The front cover is a photo of the interface between the atmosphere, hydrosphere and lithosphere as molten lava flows into the Pacific forming steam in Hawaii. The Summer issue led off with a seven-page article about Project JASON and the student explorations which could be done in conjunction with the Project. The next article dealt with Water Movement and Land Formation. The next article shared information regarding Perspectives on an Ocean Planet and was a summary of the TOPEX/Poseidon Project. This was followed by an article dealing with El Nino. And finally, there was a discussion of Virtual Reality as an emerging technology for Earth Science teaching and learning. Remember now, this was in 1996, 25 years ago.

By Tom Ervin
The Rock Cycle describes the processes by which the three primary classifications of rock (sedimentary, igneous and metamorphic) are naturally formed over long periods of time (typically over the course of decades or even centuries). For various reasons, this cycle presents a unique teaching challenge in the context of elementary school education, and in Kindergarten through twelfth grade education more broadly. Some of the reasons for this challenge include (but are not limited to) the prolonged temporal period over which the cycle takes place, as well as the hazards associated with these geological formations. For example, igneous rocks are formed through the cooling of magma after a volcanic eruption, something that is understandably difficult to demonstrate in a controlled, classroom setting.

Therefore, by allowing students to create models of these three types of rocks using a kid-friendly material such as Starburst candies, as well as simulate the process by which each of these rocks are formed, students can gain a better understanding of the Rock Cycle by engaging their senses and having autonomy in the learning process. In addition, providing students with tangible references to real-life examples of each of the rock classifications (through FOSS kits and magnifying hand lenses to observe each sample up close) encourages students to make connections between the simulated process (their Starburst rock models) and the actual end products of this complex geological cycle. This lesson, Starburst Rock Cycle, was adapted from Edible Rock Cycle for Kids (Abraham, 2020).

Simulating Rock Formation

Sedimentary Rocks

Sedimentary rocks are formed as a result of immense pressure being applied to compacted dirt and other inorganic matter from the Earth’s crust. These rocks are often the result of long periods of water or wind erosion and have distinct visual patterns and textures that allude to this erosion. To simulate this process, students begin by re-wrapping a Starburst candy (or multiple candies, to represent the different kinds of inorganic matter that may be combined to form a typical sedimentary rock). They use non-stick materials: first wax paper, then aluminum foil. They then apply pressure to the wrapped candy/candies using their own body strength (such as the heel of their
palm) for several minutes, before finally unwrapping the Starburst(s) to examine them. Students are encouraged to make comparative observations between the initial Starburst candy appearance and the appearance (shape, quality of touch, etc.) after applying pressure. Students are also tasked with comparing their model sedimentary rock to an actual sedimentary rock sample and to record their qualitative and quantitative observations in their science journals.

**Metamorphic Rocks**

Metamorphic rocks are formed as a result of combining heat with immense pressure applied to compacted dirt and other inorganic matter from the Earth’s crust. These rocks are often found in locations where natural heat (such as geysers or volcanoes) is produced and can be difficult to discern from sedimentary and igneous rocks. To simulate the process of forming metamorphic rocks, students follow the same re-wrapping procedure as with sedimentary rocks and apply pressure to their Starburst(s) in the same method as used to create their model sedimentary rocks. The key difference between the sedimentary and metamorphic rock simulations occurs after students apply pressure to their Starbursts. They then generate a moderate amount of body heat by rubbing their palms together and apply this heat directly to their model rocks for two to three minutes before unwrapping their Starbursts to examine the finished product. As with the sedimentary rock models, students are encouraged to make qualitative and quantitative observations of their models, as well as compare their metamorphic rock models to their sedimentary rock models and the real-life examples from the FOSS kit.

**Igneous Rocks**

Igneous rocks are formed when magma cools after a volcanic eruption. For this reason, igneous rocks often have a distinct and sometimes glossy appearance and are typically found in close proximity to volcanoes. Some igneous rocks have a crater-like, ashy appearance and texture to them, reflecting the ash that is produced after a volcanic eruption. To simulate the process of forming igneous rocks, students follow the same re-wrapping procedure with their Starburst candies as they followed to create their sedimentary and metamorphic rock models. However, because igneous rocks are formed as a result of immense heat, students use activated hand warmers (such as the Hot Hands products found in grocery stores/pharmacies for topical pain relief) to recreate this heat and distinguish the magnitude of heat from simply rubbing their palms together, as they did to create their metamorphic rock models. The simulation is most effective if students tightly wrap the activated hand warmers around their wrapped Starburst candies and secure them with a rubber band or other object, allowing the Starburst to slowly heat up and melt over the course of twenty to thirty minutes. After enough time has passed, students will unwrap their Starbursts and examine their final product, making qualitative and quantitative observations about its appearance, as well as comparing it to the appearance of the other model rocks and actual geological samples from the FOSS kit.

*Starburst Rock Cycle* supports NGSS Fourth Grade ESS1-1 (See Table 1).

During the lesson, elementary students record observations in their journals. Samples of student work are in the images below.

Links to the full lesson plans in English and Spanish are in the sidebar.

Figure 1. Weemes Elementary students make Starburst Rocks.
Photo Credit: USC Joint Educational Project.

Figure 2. Model of a sedimentary rock made from Starburst candies.
Photo Credit: USC Joint Educational Project.

Lesson Plan: [https://drive.google.com/file/d/1Os0y57SiZ0y3-75m4vzNe9hDn54JiYr/view?usp=sharing](https://drive.google.com/file/d/1Os0y57SiZ0y3-75m4vzNe9hDn54JiYr/view?usp=sharing)

Spanish version of the lesson plan: [https://drive.google.com/file/d/1ImUwVhlANPs6KX6DKLFr1J0qYbNn64x9/view?usp=sharing](https://drive.google.com/file/d/1ImUwVhlANPs6KX6DKLFr1J0qYbNn64x9/view?usp=sharing)
What do teachers think?

The Starburst Rock Cycle was the first official lesson the students entered in their science journals. Although tempted by the candy itself, they used the Starburst candies as tools to make models of different rocks. Many were enamored by the bright colors and mixes they produced. Some students even thought to use heavy books and supplies to simulate added pressure when making sedimentary and metamorphic rocks. Despite the very structured nature of this lesson, students are encouraged to think outside the box and create their rocks in unique ways.

When asked to record their findings, students reported both qualitative and quantitative observations, mentioning the colors, number of distinct layers, and shapes of the rocks. This lesson immensely appealed to the students and even their teachers.

Table 1. Grade 4 performance expectation, science and engineering practice, disciplinary core idea, and crosscutting concepts congruent with Starburst Rock Cycle

<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Cross-Cutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-ESS1-1 Identify evidence from patterns in rock formations and fossils in rock formations and fossils in rock layers for changes in a landscape over time to support an explanation for changes in a landscape over time.</td>
<td>Constructing Explanations and Designing Solutions</td>
<td>The History of Planet Earth.</td>
<td>Patterns can be used as evidence to support an explanation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Local, regional, and global patterns of rock formations reveal changes over time due to earth forces, such as earthquakes.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>The presence and location of certain fossil types indicate the order in which rock layers were formed.</td>
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</table>
“What an innovative way to teach about rocks. It illustrates the rock cycle concepts beautifully and who doesn’t love candy? The students love it because the concepts are solidified. It’s an effective use of tools in the classroom and demonstrates those ideas in a hands-on way, which is the best for developing concepts in science,” writes Vanessa Brown, 4th grade instructor at Foshay Learning Center.

Nicole Butler of Weemes learned something herself from this lesson. “My students get so excited about science that they can hardly contain themselves. This lesson is a great way for them to visualize change in an experimental manner while still having fun. Working with their hands allows them to be creative and reinforces the idea that they are scientists.”

**Conclusion**

Students and teachers alike can engage in and have fun with lessons like the Starburst Rock Cycle. The structure of the lesson reinforces concepts and vocabulary while allowing students to experiment and learn on their own terms. Delta Education provides a content reader that can be used to accompany the lesson (Druger, S. D., Gasper, E., Knowles, M., Pratt, S. E., & Underwood, D., 2010).

**References**


**About the Authors**

**Rita Barakat** is a Neuroscience Ph.D. Candidate and former National Science Foundation (NSF) Graduate Research Fellow at the University of Southern California. She obtained her Bachelor's Degree in Molecular Neurobiology at the University of California Berkeley in 2015. Rita has previously served as the Assistant Program Director for the Young Scientists Program (YSP), part of the Joint Educational Project, and is currently a science curriculum writer and instructor for the Neighborhood Academic Initiative (NAI) Program. Her disciplinary research focuses on the structural and functional neuroanatomy of reading, specifically in the context of developmental dyslexia. She is also interested in the linguistic and affective aspects of STEM education, and plans to pursue further research in this area as it pertains to higher education. She can be reached at rbarakat@usc.edu.

**Angelina Crittenden** is a fourth-year Human Biology undergraduate student, minoring in Forensics and Criminality and Health Care Studies, following the pre-medical track. She is also a program assistant for the Young Scientists Program (YSP) and Medical STEM Program (MSP) for the Joint Educational Project at the University of Southern California, teaching underrepresented minority students in 2nd and 4th grade. She is also a member of the Cancer Survivorship Advisory Council at USC Norris Comprehensive Cancer Center, helping to build a website to bring resources to cancer patients and their caregivers. She can be reached at acritten@usc.edu.

**Dieuwertje “DJ” Kast, Ed.D.**, is the Director of STEM (Science, Technology, Engineering, and Math) Education Programs for the University of Southern California’s (USC) Joint Educational Project, which includes managing the Young Scientists Program. She has provided STEM instruction to over 29,000 underserved students, 600 educators, 20 school principals, and countless community members. She holds a doctorate in education, focusing on Teacher Education in Multicultural Societies in STEM at USC. She received her master’s degree in education and biology teaching credential from the USC Rossier School of Education and she received her bachelor’s degree in Biology and a Master of Science in Marine Environmental Biology in 2011 from USC. Her mission is to level the playing field for underserved students in STEM. Her education philosophy is focused on hands-on, inquiry-based and authentic STEM learning experiences. She can be reached at dkast@usc.edu.
Abstract

One of the largest active magma bodies within Earth's continental crust lies ~19 km beneath the Socorro, New Mexico region of the Rio Grande Rift. Since the mid-1960s, scientists have utilized various methods to discover and characterize the magma body, its history, and its impact on the surrounding environs. This article presents an introductory and related hands-on activity designed to complement a recent National Science Foundation-funded study of the Socorro magma body by then-PhD student Brad Sion under the direction of Drs. Gary Axen, Fred Phillips, Bruce Harrison, and Jolante van Wijk of the Earth and Environmental Science Department at NMT and compatible with MS-ESS2-2 of the Next Generation Science Standards. Through these place-based educational learning experiences, students acquire the evidence required to satisfy this expectation in an engaging manner that reflects the work done by scientists within the geoscience fields.

Introduction

The second-largest active magma body within Earth's continental crust lies ~19 km beneath the Socorro, New Mexico region of the Rio Grande Rift. Discovered by Allan Sanford, a professor of seismology at New Mexico Tech (NMT), in the 1960s, the Socorro magma body (SMB) covers an area ≥3,400 km² (Balch et al., 1997) and causes both seismicity and uplift in the overlying crust. Given a desire to resolve the nature, impact, and history of the intrusion, as well as the likelihood of future volcanic and seismic activity, the study of the SMB is ongoing.

The introductory and multi-disciplinary hands-on activities presented here complement a recently completed National Science Foundation-funded study led by New Mexico Tech Professors Axen, Phillips, van Wijk, and Harrison. Research into the history of surface uplift above the SMB undertaken by Dr. Sion for his Ph.D. dissertation provided a unique opportunity to develop and assess place-based educational (PBE) learning experiences specific to the New Mexico region. “PBE is distinguished from other situated, context-rich teaching and learning modalities (for example, project-based learning) by its unequivocal relationship to place” (Semken et al., 2017, p. 543).

In emphasizing this regional phenomenon, students acquire the evidence needed to meet the Next Generation Science Standards (NGSS), Middle School Earth and Space Sciences performance
expectation MS-ESS2-2 in an engaging manner that reflects the work done by scientists within the field. While this performance expectation is founded on the elements listed in Table 1, the activities herein engage students in nearly the full gamut of science and engineering practices and address a variety of crosscutting concepts. Moreover, though intended for a middle school audience, the activities could readily be adapted for implementation at the high school level and beyond.

**Discovery of the Socorro Magma Body**

A series of strip-chart seismograms from Sanford and Long’s 1965 study of microearthquake crustal reflections near Socorro, NM, along the Rio Grande Rift, introduce students to the magma body. Microearthquakes, defined here as those with a local (body-wave) magnitude ≤ 2.0, are common in New Mexico due to rift-related extension of the continental plate in a westerly direction but are anomalously common in the Socorro area (Stankova et al., 2008). The introductory activity requires students to recognize and question the S xP and S xS reflections that follow the direct S-phase by roughly 2.5 and 5.0 seconds in Sanford and Long’s (1965) charts. Those familiar with seismograms and the properties of P- and S-waves are likely to do so with little prompting. However, standard earthquake seismograms, of like magnitudes, may be provided for comparison or a mini-lesson on the properties of seismic waves conducted to support student discussion.

Affirmation of student observations and questions follows; this may be accomplished by sharing the information gained via similar seismographic analysis, mainly “the existence of a rather extensive layer (~ 1200 km²) of magma in the crust along the axial region of the rift” (Sanford et al., 1977, p. 385). Such reflections occur when a seismic wave encounters a subhorizontal interface with a distinctly different seismic velocity, such as a magma body, and all or some of the energy bounces back. The use of travel-time curves, readily found online, to approximate the depth of the intrusion closes out this introduction.

**Documentation of Uplift**

A multi-day investigation during which lab groups simulate magma body inflation using a modified tabletop sandbox and document surface uplift follows the introductory activity. For this task, students use water to inflate a balloon embedded in sand and a caliper to take depth measurements to the surface of the sand. The latter occurs before inflation, and at mid- and maximum-inflation at regularly placed points along a string or dowel.

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**Table 1. Target NGSS performance expectation for Socorro Magma body inspired activities and its underlying SEP, DCI, and CCC (National Research Council, 2013)**

<table>
<thead>
<tr>
<th>Performance Expectation</th>
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<tbody>
<tr>
<td>MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth’s surface at varying time and spatial scales.</td>
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<table>
<thead>
<tr>
<th>Science and Engineering Practice</th>
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<tr>
<td>• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students’ experiments) and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future.</td>
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</table>

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<thead>
<tr>
<th>Disciplinary Core Idea</th>
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<tr>
<td>• The planet’s systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth’s history and will determine its future.</td>
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<table>
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<tr>
<th>Cross-Cutting Concept</th>
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<tbody>
<tr>
<td>• Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.</td>
</tr>
</tbody>
</table>

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*Figure 1. Students simulating uplift in the sandbox. Photo Credit: Eddie Moore.*

*Figure 2. Students taking depth to surface measurements. Photo Credit: Eddie Moore.*
that stretches the length of the box (See Figures 1 & 2).

After data collection, each student enters their group’s measurements into a spreadsheet and plots a graph, creating a series of elevation profiles. These two-dimensional cross-sections visualize the changes in the sand’s surface throughout the “magma body” or balloon’s inflation. Students then utilize the spreadsheet’s functions to calculate relative uplift at the individual measurement points and plot a second graph, creating an elevation-change profile (See Figure 3). From this profile, they infer the approximate location of the “magma body” along the points plotted and derive an average rate of uplift for those points above it. If computer access is limited, students may also process and plot the data manually.

In completing these tasks, students document surface uplift in a manner reminiscent of:

- Reilinger and Oliver (1976), Reilinger et al. (1980), and Larson et al.’s (1986) analysis of leveling data along the length of the Rio Grande Rift to clarify the rate and extent of the doming above the Socorro magma body;
- Fialko and Simons (2001) and Finnegan and Pritchard’s (2009) examination of interferometric synthetic aperture radar (InSAR) data to refine the rate of uplift;
- and Sion et al.’s (2018) recent use of longitudinal elevation profiles of abandoned Rio Salado terraces to constrain the duration and timing of said uplift.

Group and whole-class discussion support the completion of a three-part conclusion—summary, analysis, and reflection—at the close of this activity. The former, group discussion, involves the creation of new groupings comprised of representatives from each lab group. This reconfiguration allows students to compare their elevation and elevation-change profiles, as well as their average rate of uplift in anticipation of their summary and analysis. Whole-class discussion not only extends this conversation but facilitates the introduction of profiles and interferograms from the studies above. The intended applications for these artifacts are two-fold: (1) to provide fodder for the students’ reflections on the accuracy of the simulation and (2) to later serve as evidence from which to construct an explanation of how geologic processes alter the landscape at varying temporal and spatial scales.

This activity lends itself to extension should time allow. In past iterations of the lesson, students proposed increasing the amount of inflation, experimenting with the shape of the balloon or its depth in the box, and introducing objects, such as rocks, into the sandbox.

### Construction of the Sandbox

Affordability and accessibility of materials guided the design of the sandboxes for the simulated magma body inflation. Assembly of the sandbox pictured (See Figure 4) requires a 16 qt plastic storage container with lid, a 150 ml plastic syringe with tubing, a 10” latex balloon, and duct tape. Sand, as well as a lighter, a potholder, and a nail of approximately the same diameter as the tubing are also needed.

![Figure 4. Construction of the Sandbox, showing a 16 qt plastic storage container with lid, a 150 ml plastic syringe with tubing, a 10" latex balloon, and duct tape. Sand, as well as a lighter, a potholder, and a nail of approximately the same diameter as the tubing are also needed. Photo Credit: Eddie Moore](image)
container with lid, a 150 ml plastic syringe with tubing, a 10” latex balloon, duct tape, and sand, as well as a lighter, a potholder, and a nail of approximately the same diameter as the tubing.

To begin, heat the nail with the lighter and create a hole for the tubing in the side of the container towards the base, using the potholder to prevent burns. (A drill and appropriately sized bit may also be used.) Then insert the tubing and duct-tape the balloon to the end within the box. (While there are likely other ways to affix the balloon to the tubing, this method has proven effective over multiple uses.) Once attached, tape the tubing to the base of the container to prevent the balloon from surfacing. A generous layer of sand completes the assembly. Attachment of the syringe occurs only during simulation of magma body inflation.

I recommend keeping the inner workings of the sandbox from the students until the end of the activity. Their initial reaction upon seeing the surface lift is typically one of wonder and curiosity.

**Conclusion**

The Socorro magma body is an unusual crustal feature associated with the Rio Grande Rift in the region of Socorro, New Mexico. Since the mid-1960s, scientists painted a portrait of the SMB and the geomorphic changes it causes with increasingly specific brush strokes via the collection, analysis, and interpretation of geological and geophysical evidence. Their methods and the conclusions drawn inspired the design of an introductory and hands-on activity, including simulated magma body inflation using a budget-friendly modified tabletop sandbox and documentation of surface uplift, to support completion of the NGSS MS-ESS2-2 performance expectation. In undertaking these activities, students are better able to articulate how the geologic processes associated with the Rio Grande Rift altered New Mexico’s landscape at varying temporal and spatial scales and employ a battery of science and engineering practices that will serve their future scientific endeavors.

**Acknowledgment**

The design and implementation of these activities address the broader impact component of a recently concluded study of the Socorro magma body supported by the National Science Foundation under NSF EAR-1348076.

**References**


**About the Author**

**Hope Cahill** works at El Dorado Community School, a K-8 public school in New Mexico. A recent graduate of the New Mexico Institute of Mining and Technology’s Master of Science for Teachers program, she currently teaches sixth and seventh-grade Integrated Science and previously taught Earth and Life Science. Hope also works with several community organizations and programs, including STEM Santa Fe, the Santa Fe Alliance for Science, and the Supercomputing Challenge. She believes strongly in inquiry and place-based education and endeavors to provide students a new lens to interpret and understand the world around them. She is one of two state science finalists for the prestigious 2020 Presidential Award for Excellence in Mathematics and Science Teaching and is anxiously awaiting the national results. She can be reached at hcahill@sfps.k12.nm.us.
Real-Time Investigations Using Student Devices

Dr. Donna Governor, University of North Georgia

Abstract

Smartphones are now everywhere, and while most students have one, it seems that they are used for nearly everything except making phone calls! Students are constantly plugged into their devices for music, games, text and photo journaling. They use their phones to take pictures of homework assignments, search for information to help with current projects and shop for books. But seldom do students realize the potential of their devices to engage in scientific research by accessing real-time data. This article provides places you can find real-time data, offers guidance for use in the classroom and provides a sample activity for using real-time data.

Introduction

Real-time data are posted by scientific agencies and organizations that monitor and report on Earth and Environmental conditions in actual time. Multiple government-run agencies are responsible for collecting and reporting this data including NOAA, USGS, NASA and others (see Table 1). Available data includes weather conditions, earthquakes, streamflow, waves, populations, wildfires, Moon phases, land use, tides and more. All these data are available to the public via websites, and more often than not, can be imported into an app for easy access on student devices. Showing students that their devices can be used for much more than social interactions provides them with the tools to become critical thinkers and the enthusiasm for learning more about the world they live in.

How to Find Data

Most data to facilitate exploration of the natural world is provided by U.S. Government agencies such as NASA. Other agencies and organizations provide data as well (See Figure 1, Figure 2).

Figure 1: (below left) NOAA’s National Data Buoy Center (ndbc.noaa.gov) provides real-time data for ocean conditions at various buoy locations. Notice that the data for this buoy includes location (lat/long), air temperature, current winds, water depth and more.

Figure 2: (below right) The US Department of Agriculture provides data for multiple years on crops (nassgeodata.gmu.edu/CropScape). Students can compare how land use has changed over time. The data shown here are for Okaloosa County, Florida in 2019.
Table 1: Websites for Real-Time Data

<table>
<thead>
<tr>
<th>Domain</th>
<th>Type of Data</th>
<th>Website</th>
<th>URL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Astronomy</strong></td>
<td>Variable Stars</td>
<td>Association for Variable Stars</td>
<td><a href="https://www.aavso.org/">https://www.aavso.org/</a></td>
</tr>
<tr>
<td></td>
<td>Space Science Mission Data</td>
<td>NASA Space Data Archive</td>
<td><a href="http://nssdc.gsfc.nasa.gov/">http://nssdc.gsfc.nasa.gov/</a></td>
</tr>
<tr>
<td></td>
<td>Satellite Tracking</td>
<td>NASA Spaceflight</td>
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Nearly all the real-time data you could use is available on a website, but much of that data has been imported into an app for personal devices. There are benefits to using websites rather than apps, but I've found that apps also have their advantages. Websites are more stable and most government URLs (Universal Resource Locator) have been stable for more than two decades now (See Figure 3).

However, when websites are accessed through personal devices, there are some disadvantages. Not all browsers are small-screen friendly. For example, websites that are built with responsive design will “snap” to fit the screen of each device. For others, only a small section of the page may appear, making it difficult to work with. Websites often can be overwhelming for students, providing more data than needed for a single investigation.

Finding data using apps can be preferable in that they are designed for small devices, and generally with one specific purpose, in mind (See Figure 4). That can help by keeping students’ attention focused on the desired data. While some of these apps have a cost, I’ve found that I can get data rich apps for free if I’m willing to take the time to look at the options. Students find apps novel and engaging, and seldom have I had students who wandered off to another app when using their devices for authentic investigations. When selecting apps to access real-time data, you will need to look for apps that are cross platform, working on both iOS and Android devices, or find parallel apps that you can use for each system. It is often easier to search from the App store for an app that can be used to access the desired data and is free. Then, see if it is available on both platforms, and if not, look for a similar app for the alternate system.

**Using Devices in the Classroom**

Students are more authentically engaged when they get to use their personal devices for real-time investigations. Initially expect some resistance as students are not used to using their smartphones as an investigative tool! Sometimes students will say that their data plan is limited so they can’t download a new app, so give them a couple days warning before using an app for a lesson to download at home. They can then obtain the app using wifi at home, or school, depending on your school’s policy for allowing app downloads. If they are unable to download or do not have the app on their device for any reason, it should not be an excuse to give up on the activity. For most investigations every student doesn’t need their own device and when necessary, students can share. For successful investigations you need at least a 1:4 student to device ratio for activities. Of course, many schools now have tablets available which can be pre-loaded with specific apps and used for this type of investigations which is a great back up plan. But if given a choice, have students use their own devices to make learning more meaningful.

If you plan to use websites to collect data using a website rather than a native app (a specific program designed to run on a small screen), practice with a phone, rather than a computer. You’ll want to know how a website functions on a personal device, and exactly how to navigate if it is a responsive design website, as it looks different from what you see on a computer monitor.

Figure 3: The US Environmental Protection Agency’s website data services include air quality data (epa.gov/outdoor-air-quality-data).

Figure 4: NASA’s Visualization Explorer App provides a narrative and visual approach to exploring Earth’s systems and other worlds (svs.gsfc.nasa.gov/nasaviz/index.html).
Not only will you need to be able to show students how to find the data that you want them access, but you will also need to be able to tell them if there are settings that might need to be updated. For example, have students who are investigating earthquakes set the parameters to only show events over a magnitude of three (3). Otherwise, there will be so many data that it will be difficult to see the patterns you want them to explore. Also, when working with barometric pressure ask students to change the settings to show “millibars” rather than “inches,” which is the appropriate metric measurement for scientific investigations.

When you introduce the investigation, it is a good idea to have made some screenshots of the main screen of the website or app ahead of time. This can help students see how to navigate to find the information you want them to obtain. In the Engage section of the Teaching Module included (Figure 5), you can see how adding a screenshot can help make it easier for students to find the data they will access. Often students can help each other and those that are most techno-savvy often easily pick up on settings and functions of apps and find new features that you probably weren’t aware of.

Of course, you will want some sort of management system for your students to make sure they stay on task. The natural consequence for inappropriate use of a personal device would be to lose access. Students who abuse the privilege might need to have to assist their peers as notetakers, rather than collecting data. In truth, the author has never had to take away a personal device as students are legitimately engaged when using their devices for exploring real-time data.

**Teaching Module: Exploring Extrasolar Planets and the Stars they Orbit**

One of the most exciting advances of the 21st century involves the discovery of a multitude of extrasolar planets. In 1992 the first few planets around other stars were discovered using radial-velocity method. This technique resulted in the discovery of a few dozen planets by observing the “wobble” of stars as they were being orbited by massive planets. Since the launch in 2009 of the Kepler Space telescope, thousands of additional exoplanets have been discovered using the transit method. In this technique the light output of stars is measured and observed for variations that indicate the passage of a planet in front of its host star. The discovery of these extrasolar planets is exciting when considering if the potential for life outside our Solar System is possible. In order to better understand our own Solar System, students can explore these extrasolar planets and the stars they orbit.

**Engage**

To engage and get your students’ interest, start with a news article about a recent exoplanet discovery. The 2016 discovery of Proxima B is a great way to engage students as it is our closest planetary neighbor outside our Solar System. Numerous articles are available to read, but you might want to start with an online video from Space.com: [space.com/33834-discovery-of-planet-proxima-b.html](http://space.com/33834-discovery-of-planet-proxima-b.html). Guiding questions for this activity include:

- What do we know about this planet?
- What do we know about its host star?
- Why is there so much excitement about this discovery?
- Is it possible there is life on Proxima B? Why or why not?
- How does it compare to Earth?
Explore

There have been thousands of extrasolar planets discovered to date. NASA keeps an ongoing record of confirmed planets, their characteristics and information about their host stars. Allow students to explore this information to try to identify planets that might be Earth-like and if their stars might be able to support life. This data is available on the NASA Extrasolar Planets website (exoplanetarchive.ipac.caltech.edu/) or through several different apps. For iOS users, the corresponding app is “Exoplanet” (exoplanetapp.com/) and for Android users, the app “Exoplanets” is appropriate (play.google.com/store/apps/details?id=com.do_apps.catalog_655&hl=en_GB). Both are free apps.

You may have to introduce some basic information and terms about how the data are displayed to enable students to understand how to interpret the data. For example, the orbital period is how long (in days) it takes a planet to orbit its star. The size is usually reported by comparing it to Earth (i.e., 1.35 Earth radius) or Jupiter (4.66 Jupiter’s Mass). Students should also attend to how far the planet is from its host star, reported in AUs (Earth-Sun distance). Important information to focus on for the host star is the spectral class or temperature, magnitude and stellar mass (usually compared to our Sun). Regardless of whether you are using the NASA website or an app, there is a wealth of additional information provided for each exoplanet.

Give students time to explore the catalog of discovered extra solar planets with the following questions in mind:

- What exoplanet did you find most interesting? Why?
- What is the latest planet discovered?
- What information is included about each planet and it’s host star?
- How do most extra solar planets compare with Earth?
- How do most stars where extra solar planets are found compare with our own star, Sol?
- Why is it important to look at the information for the host star when trying to decide if an extra solar planet might be habitable?

Explain

Once students have time to explore, encourage them to share their findings. Start a discussion and give them opportunities to ask their own questions. This is the appropriate time to provide a lecture, read expository text, or watch a video about stars and exoplanets. Emphasize how special Earth is, as it is just the right distance from just the right size star. To set students up for the following activity, focus on characteristics of stars and introduce students to the Hertzsprung-Russell (HR) Diagram. This is an important tool for understanding the nature of stars by plotting temperature, which corresponds to the class and color of the star, against the brightness (absolute magnitude) of each star. The resultant diagram shows a mass luminosity relationship for stars on the “main sequence,” which defines the characteristics of stars during most of their life. In general, more massive stars blue are brighter, hotter and put out more energy than cooler, red stars. Our Sun is quite average, having a mass, temperature and brightness that is in the middle of the main sequence.

Elaborate

To build an understanding of our own star, Sol, this stage involves students investigating other stars and creating their own HR Diagram. Since it is important to understand life on Earth is only possible because we have the right kind of star (and are at the right distance and size), students need to extend their learning by discovering more about characteristics of stars. For example, our star is a G2 class...
A star with a surface temperature of just over 5,000K. Proxima Centauri is a much cooler M class star, just over 3,000K. Life could only be possible for a planet orbiting Proxima Centauri if it is much closer to the host star. By having students explore characteristics of stars, they gain a better understanding of our own star and how it supports life on Earth. The full lesson can be found at bit.ly/lifeline_stars.

In this activity, students use an app (Star Chart, available on both iOS apps.apple.com/us/app/star-chart/id345542655 and Android play.google.com/store/apps/details?id=com.escapistgames.starchart&hl=en_US) or a website, Heavens Above (heavens-above.com/skychart2.aspx) to find information about stars. The advantage of using the app in this case is that it shows the current location of stars in the sky and can be used to identify constellations passing overhead in real-time. Students should each locate ten (10), in addition to the two given (Sol and Proxima Centauri) and use the data to create an HR diagram. You may wish to have students work in teams to collect and chart more data. The more data graphed, the easier it will be to see the main sequence and our Sun’s position in relation to other stars. Figure 5 provides instructions for completing this activity.

**Evaluate**

To evaluate this activity, bring your students back to the Engagement activity. Is it possible for life to exist on Proxima B? Why or why not? Journal prompts are a great way for students to explain what they learned. For this evaluation ask your students to respond to the following question:

*Proxima Centauri is a low mass red star. How does this compare to our own star? How can a planet that is as close as the newly discovered one is to its star be possibly Earth like? Why wouldn’t it burn up? Construct an argument that explains if this newly discovered planet is capable of supporting life. Be sure to cite information about the planet (available in the app or website) AND its host star.*

**Conclusion**

Student devices are great learning tools for multiple investigations in the Earth and Environmental science classroom. Whether you use them to track Earthquake data, explore water quality, investigate the relationship between wind and waves, predict tides or something else. Personal devices are often thought of as the scourge of the classroom as students sometimes don’t know when to put them down. But by turning them into devices for exploring real-time data, students begin to appreciate the power of their smartphones and investigations can become meaningful interactions with our planet and beyond in real-time.
Abstract

Augmented Reality (AR) is an emerging technology that has been suggested to have enormous potential as an educational tool. Augmented Reality Sandboxes, created from a fusion of a table-top sandbox, a Microsoft Kinect and a projector with simulation and visualization software are uniquely suited to bring large-scale geologic and environmental topics into classrooms in a tangible way. The Young Scientists Program at the University of Southern California, with funding from the American Geophysical Union’s Celebrate 100 Grant, installed AR Sandboxes in seven Title 1 schools in Los Angeles, as part of a wider mission to increase the presence of emerging technologies in low-income schools.

Introduction

The Young Scientists Program (YSP), a Science, Technology, Engineering and Math (STEM) Education program within the University of Southern California’s Joint Educational Project (JEP), used funding from the American Geophysical Union (AGU) Celebrate 100 Grant to expand its Augmented Reality (AR) Sandbox program. YSP had only one full AR Sandbox setup that has been used in Emerging Technology workshops for 4th and 5th grade students, teacher professional development sessions and parent workshops on technology integration in low-income schools and in beta testing for use in weathering and erosion curriculum in one YSP school in 4th grade classrooms. The grant allowed us to scale up the program to install one sandbox into each of the seven Title 1 schools we partner with.

Why Use Augmented Reality Sandboxes with Elementary Students

AR Sandboxes, whilst popular in undergraduate classrooms for geoscience majors and some geology-based high school classrooms, are rarely used at the elementary level. This is unfortunate, since many of the Next Generation Science Standards (NGSS) incorporate concepts that are directly relatable to the sandbox including weathering, deposition and erosion. Augmented Reality systems are those in which real and virtual environments and objects can coexist and be acted upon in real time (Azuma, 1997). This combination of virtual and real allows users to access contextually relevant multimedia content in a way that allows for an immediate integration of new information into action by further engaging with the AR system. This has led several researchers to note AR’s great potential to enhance educational experiences (Bower et al., 2014). Research suggests that the use of AR in the classroom can boost student motivation and retention of information,
particularly for students not well served by traditional text-based education practices (Billinghurst & Duenser, 2012) as well as improve student’s attitude towards learning and their perception of the subject matter’s relevance to their own lives (Jerry & Aaron 2010). Vitally for science education, the use of AR may reinforce and promote student’s understanding of the nature of scientific inquiry in addition to learning the subject matter (Heath, 2017). Augmented Reality as technology accessible outside of highly specialized fields (e.g. medicine) is a recent phenomenon. As an emerging technology, it is less likely to be available to low-income schools and their students, something we are aiming to change. By bringing in our AR sandbox setups through the Young Scientists Program students will have access to the benefits above and critically, their teachers will also be able to experience and learn about the technology so that as increasing access becomes possible, they will have the confidence and familiarity to use AR effectively in their classrooms.

Through the Young Scientists Program the AR Sandboxes were installed in seven Title 1 schools within the Los Angeles Unified School District. These schools serve thousands of students who come from socioeconomic backgrounds which are underserved and underrepresented within the Earth & Space Sciences (Latinx, African American, low-income, etc.). A detailed breakdown of the demographics of the students in six of the schools served by YSP is shown in Table 1. In addition to directly serving the students, these sandboxes can be used to facilitate teacher professional development sessions in order to empower educators to more confidently lead Earth Science instruction. The AR Sandbox technology is open source but still inaccessible in terms of resources (financial, budget for physical materials, etc) for many low-income schools. The AR sandboxes that have been installed in the low-income schools aim to level the playing field for the students in geoscience.

### In the Classroom

The large scales at work in many geological and hydrological processes are a particularly good fit for AR as the real portion of the experience can be classroom table scale, while the virtual overlay can represent much larger scales such as that of an entire watershed. The AR Sandbox setups used by YSP were developed by Deezmaker’s Diego Porqueras (2017) and combine a real sandbox with virtual topographic maps and water generated by a closed loop of a Microsoft Kinect 3D camera.

### Table 1. *Demographics of six of the Title 1 schools in Los Angeles in which Augmented Reality Sandboxes were installed.*

*Sourced from the California Department of Education*

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**Total or Average in %**

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simulation and visualization software and a projector. Users can create topographic models in real time by moving the sand into different landforms which are then augmented by the projected elevation contour map. This tool can be used to demonstrate patterns in bathymetry/topography, how water moves through watersheds, how watersheds may be altered and how weathering and erosion shape a landscape. Because of the versatility of the Sandbox itself, real landscapes and watersheds may be recreated, allowing students to understand these concepts for environments relevant to their lives. For example, our classrooms recreated the Los Angeles Basin and allowed the students to explore and understand how water moves through their local area. Instructions and diagrams for initial system setup were generated and available for dissemination along with diagrams outlining how to set up the sandbox to mimic real watersheds. The complete lesson plan is shown on pages 24–26.

Mr. Craig Hinkel, a 5th grade teacher with the AR Sandbox installed in his classroom said, “the augmented reality sandbox takes STEM to the next level. It gives kids a chance to physically engage in science. It’s like a 3D etch-a-sketch for geology”. He plans to use it for some of the geoscience themed standards in fifth grade and present it at their Weemes Science Night so that community members including family and guardians of his students can participate in this hands-on exploration of geoscience.

References
Augmented Reality (AR) Sandbox Lesson Plan

Subject/ Grade Level: Earth Science/ Fourth and Fifth Grades

Materials:
- Moveable cart or permanent tabletop surface
- Projector
- XBox 360 Kinect with power adaptor
- Linux computer with specific graphic cards for water simulations
- Sand containment area
- “Play” sand with three-dimensional objects
- Square tubing/ other structure for mounting the projector and XBox 360 Kinect above the sandbox
- Computer program to run on Linux OS: SARndbox (AR Sandbox), XBox SDK drivers

NGSS Essential Standards and Clarifying Objectives:
4-ESS1-1. Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time. [Clarification Statement: Examples of evidence from patterns could include rock layers with marine shell fossils above rock layers with plant fossils and no shells, indicating a change from land to water over time; and a canyon with different rock layers in the walls and a river in the bottom, indicating that over time a river cut through the rock.] [Assessment Boundary: Assessment does not include specific knowledge of the mechanism of rock formation or memorization of specific rock formations and layers. Assessment is limited to relative time.]

4-ESS2-1. Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation. [Clarification Statement: Examples of variables to test could include angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow.] [Assessment Boundary: Assessment is limited to a single form of weathering or erosion.]

4-ESS2-2. Analyze and interpret data from maps to describe patterns of Earth’s features. [Clarification Statement: Maps can include topographic maps of Earth’s land and ocean floor, as well as maps of the locations of mountains, continental boundaries, volcanoes, and earthquakes.]

4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans. [Clarification Statement: Examples of solutions could include designing an earthquake resistant building and improving monitoring of volcanic activity.] [Assessment Boundary: Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.]

Lesson Objective(s): Students use an Augmented Reality sandbox to understand several Earth science processes.

Differentiation Strategies to meet Diverse Learner needs:
- Think-pair-share, for students that learn best when engaging with classmates.
- Multisensory learning, to accommodate students that are auditory learners and visual learners, as well as encourage students to engage their senses in the learning process.
- Awareness of social and cultural backgrounds of students, in order to reinforce the real-life application of what they are learning.

ENGAGEMENT

Background Information for Educators

“Augmented reality (AR) is a live direct or indirect view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPS data. With the help of advanced AR technology (e.g. adding computer vision and object recognition) the information about the surrounding real world of the user becomes interactive and digitally manipulable.” (Graham 2012).

“Deezmaker built a hands-on activity combining a real sandbox, and virtual topography and water created using a closed loop of a Microsoft Kinect 3D camera, powerful simulation and visualization software, and a data projector. The augmented reality (AR) sandbox allows users to create topography models by shaping real sand, which is then augmented in real time by an elevation color map, and topographic contour lines. The AR Sandbox can be used to demonstrate bathymetry and other watershed capabilities. It allows students to model different land structures and demonstrate how events like erosion and weathering change a landscape.” (Deezmaker 2017).
**Bathymetry:** Generating a heat map of elevation.

The order of elevation on a surface is defined by color:

- **Blue** (corresponds to the lowest elevation, such as deep-sea oceans in the AR Sandbox)
- Green
- Yellow
- Orange
- Red
- **White** (corresponds to the highest elevation, such as snow-capped mountains in the AR Sandbox)

Begin the lesson by introducing the vocabulary terms related to earth science that students will be observing using the AR Sandbox:

- **Erosion** refers to the removal of surface material from Earth’s crust, primarily soil and rock debris, and the transportation of the eroded materials by natural agencies from the point of removal. (Illustration below is modeled with AR Sandbox)

- **Deposition** is the geological process in which sediments, soil and rocks are added to a landform or land mass. Wind, ice, and water, as well as sediment flowing via gravity, transport previously eroded sediment, which, at the loss of enough kinetic energy in the fluid, is deposited, building up layers of sediment.

- **Weathering** is the disintegration or alteration of rock in its natural or original position at or near the Earth’s surface through physical, chemical, and biological processes induced or modified by wind, water, and climate. This process is illustrated in the AR Sandbox with straws and water flow program modeling.

- **Watersheds** are the land and water areas, which contribute to runoff to a common point. A watershed is an area of land and water bounded by a drainage divide within which the surface runoff collects and flows out of the watershed through a single outlet into a larger river or lake.

**EXPLORATION**

Prior to beginning the AR Sandbox demonstration, make sure that all the necessary equipment is calibrated appropriately:

**Calibration Procedure:** Create a target that lines up on the sand and targets the Sandbox program that’s running. Match up the crosshairs on the target 12 times across the whole sandbox.
Once the AR Sandbox is calibrated and ready-to-go, begin simulating different landforms at various elevations and ask students to identify these two properties:

1. What type of landform are the students viewing/interacting with in the AR Sandbox?
2. At what elevation is this landform (based on the heat map generated by the AR Sandbox software)?

**EXPLANATION**

Ask students these “Follow-up Questions” to gauge what they learned about various earth science processes, as well as the merits of using AR technology to simulate these processes:

- How were you able to tell if a landform or watershed was high or low in elevation in the sandbox?
- What types of erosion processes did you observe in the sandbox?
- What happened to the landmass or watershed after erosion occurred?
- How do you think the real-life processes compare to the simulations you observed in the sandbox?

Record the responses generated from the class, and have students record their own observations in science journals, if these are a part of the classroom.

**ELABORATION**

To expand upon this activity, students can consider other ways that augmented reality technology can be used to help us understand our environment, or other scientific processes:

- What other simulations would you like to see using augmented reality? How do you think this simulation would work?
- Why do you believe that it is helpful to use augmented reality to understand complicated and large-scale processes such as weathering and erosion?

**EVALUATION**

Students may be evaluated based on the extent of their participation in the AR demonstration, as well as the quality and quantity of observations and notes taken in their science journals and/or their responses to the activity questions.

**REFERENCES**


Abstract

Bring innovation to your Earth science teaching by accessing the Earthlearningidea (ELI) website (earthlearningidea.com). The website is full of imaginative teaching approaches such as the ‘All Powerful’ strategy for approaching fieldwork in a new way, the ‘What was it like to be there?’ way of getting a feel for how rocks form, physical modeling activities that enable visualization of long-term geological processes, gaming activities that are large-scale simulations and others.

These are just a few of the innovative approaches available through the website; there are many more. Earthlearningidea activities are free to download as pdf documents, each one fully describing the activity and how it can be used in teaching. There are more than 300 activities currently available in English, with a new one being added every two weeks. The latest figures show that Earthlearningidea pdfs have been downloaded more than 5 million times at a current rate of more than 45,000 per month, the ELI blog has been accessed from more than 200 countries and there are over 1000 translations in eleven languages on the website. Do join us by accessing and using Earthlearningideas and telling your friends and colleagues about the Earth science education innovations available at the click of a computer button.

Innovative approaches to teaching Earth science using Earthlearningidea

All Powerful Strategy

We have used the ‘All Powerful’ strategy (See Figure 1) to debate the geological history of an area in the field or in the virtual field. To use this approach, have your students examine a rock exposure. Then ask them “If I were ‘All Powerful’ what would I have to do to re-create the view you see before you?” For example, when viewing the Deccan Traps in India, you might begin by stating, “If I were ‘All Powerful’ and wanted to re-create the view you see before you, I would move the land we’re standing on today over a ‘hot spot’ producing lots of fast-flowing lava that, when it cooled, recorded the latitude at which it formed (30°S) – what should I do next?”

Their responses might include:

- Ensure that the lava keeps flowing, to build up one of the thickest and widest sequences of lava flows on Earth
Move the area thousands of kilometres north to its current position (18°N)

Push the land up so that rivers start cutting down into the lavas

Keep pushing the land up and create rainstorms so rivers cut down, making valleys

Ensure the land reaches its current height (around 1000m or 1 km)

Encourage humans to build a dam to make a reservoir, to build settlements and to farm the land

Encourage the Indian government to build a sight-seeing area on the edge of the road

This activity asks what series of events would be necessary for the view before the students to be recreated. The activity can be used at a range of scales from a small quarry to a landscape-wide interpretation.

The underlying principles of the activity are that:

- All rock sequences and their characteristics can be explained as a series of discrete events.
- Many geological events happen on a landscape-sized scale, that are often most easy to visualize in the field.

We have tested this approach with teachers in a number of different field localities, with positive feedback including that it puts the geological history into a ‘fun’ context and it has encouraged participants to think of aspects of geological histories that they had never considered before. The full lesson can be accessed here (earthlearningidea.com/PDF/203_All_powerful.pdf).

What Was it Like to be There? Approach

Try the ‘What was it like to be there?’ approach (See Figure 2) which asks students to imagine what it was like to be there when a rock formed, using trigger questions like:

- Could you stand up?
- What would you need to survive?
- What might you see?
- What might you hear?
- What might you taste, smell?
- What might you sense?

The underlying principle of the activity applies the Principle of Uniformitarianism, that the ‘present is the key to the past’. We use our experiences of the world today and apply them to the past, using evidence preserved in the rocks.

This approach can work very well to help students ‘visualize’ what it was like to be there in an ancient sedimentary environment, such as a fossil coral reef or even a granite intrusion. The full lesson can be accessed here (earthlearningidea.com/PDF/What_was_it_like_to_be_there_-_rock.pdf).
Other Approaches


Many of the innovative ideas published as EarthLearningIdeas are listed in Table 1 and have not, to our knowledge, been previously published elsewhere (apart from those EarthLearningIdeas, published as Earth Science Education Unit (ESEU) activities, or as activities demonstrated at 'Bring and share' sessions at the United Kingdom’s Earth Science Teachers’ Association (ESTA) conferences, and subsequently published in ESTA’s magazine, Teaching Earth Sciences).

The evolution of EarthLearningidea

When a bid for funding to the International Year of Planet Earth (IYPE) for funding to run Earth Science Education Unit (ESEU) workshops (see, King & Thomas, 2102) for details of the ESEU initiative) in four

Table 1. EarthLearningIdeas Samples

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<thead>
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<th>Topic</th>
<th>Title</th>
<th>URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geological time</td>
<td>How many for a million?</td>
<td>earthlearningidea.com/PDF/149_Million.pdf</td>
</tr>
<tr>
<td>Geological time</td>
<td>How long does it take?</td>
<td>earthlearningidea.com/PDF/150_Quick_slow.pdf</td>
</tr>
<tr>
<td>Earth materials</td>
<td>Rocks from the big screen</td>
<td>earthlearningidea.com/PDF/163_Rocks_from_big_screen.pdf</td>
</tr>
<tr>
<td>Earth materials</td>
<td>Human magnets!</td>
<td>earthlearningidea.com/PDF/209_Human_magnets.pdf</td>
</tr>
<tr>
<td>Earth materials</td>
<td>‘Rockery’ rock cycle game</td>
<td>earthlearningidea.com/PDF/182_Rock_cycle_game.pdf</td>
</tr>
<tr>
<td>Earth as a system</td>
<td>Mini-world water cycle</td>
<td>earthlearningidea.com/PDF/168_Water_2.pdf</td>
</tr>
<tr>
<td>Earth as a system</td>
<td>‘Tagging’ water molecules</td>
<td>earthlearningidea.com/PDF/173_Tagging.pdf</td>
</tr>
<tr>
<td>Investigating the Earth</td>
<td>Journey to the centre of the Earth – on a toilet roll</td>
<td>earthlearningidea.com/PDF/196_Journey_centre_E.pdf</td>
</tr>
<tr>
<td>Investigating the Earth</td>
<td>Why won’t my compass work on the other side of the Equator?</td>
<td>earthlearningidea.com/PDF/197_Compass.pdf</td>
</tr>
<tr>
<td>Evolution of life</td>
<td>How many Great, Great, Great, Great, Grandparents?</td>
<td>earthlearningidea.com/PDF/200_Inheritance.pdf</td>
</tr>
<tr>
<td>Evolution of life</td>
<td>Fossils! a game showing how fossils form and survive</td>
<td>earthlearningidea.com/PDF/202_Fossil_game.pdf</td>
</tr>
<tr>
<td>Evolution of life</td>
<td>Bringing a fossil ‘back to life’</td>
<td>earthlearningidea.com/PDF/37_What_like_be_there_fossil.pdf</td>
</tr>
<tr>
<td>Evolution of life</td>
<td>Sea shell survival</td>
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<td>Earth in space</td>
<td>A screaming roller coaster</td>
<td>earthlearningidea.com/PDF/169_Roller_coaster.pdf</td>
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<td>Earth energy</td>
<td>Weathering limestone – with my own breath!</td>
<td>earthlearningidea.com/PDF/214_Weathering_limestone.pdf</td>
</tr>
</tbody>
</table>
About the Authors

Professor Chris King is Emeritus Professor of Earth Science Education at Keele University. He is Chair of the International Union of Geological Sciences Commission on Geoscience Education (IUGS-COGE) and of the European Geosciences Union Committee on Education (EGU-CoE). He is secondary coordinator for the Earth Science Teachers’ Association (ESTA) in the UK. He trains geology teachers in initial teacher education and leads the group of facilitators which has so far provided teaching workshops to nearly 40,000 science and geography teachers across the UK. He co-runs the Earthlearningidea website with Peter Kennett and Elizabeth Devon, publishing teaching ideas regularly, with more than 45,000 global downloads per month. He is responsible for writing the IGEO textbook available at: http://www.igeosced.org/teaching-resources/geoscience-text-books/. Chris can be reached at chris@earthlearningidea.com.

Peter Kennett is a retired teacher of geology in secondary schools in England, mostly Sheffield. He previously worked as a geophysicist with the British Antarctic Survey. He is a past Chairman of the Earth Science Teachers’ Association, and since retirement has worked ad hoc for the Earth Science Education Unit, as well as working closely in a voluntary capacity with Chris King and Elizabeth Devon to devise and edit activities for https://www.earthlearningidea.com. Peter can be reached at peter@earthlearningidea.com.

Elizabeth Devon is a retired teacher of geology in secondary schools and at the University of Bath. For many years, she gave secondary and primary Earth science workshops for the Earth Science Education Unit. She has been chair-person of various geological societies and manages and writes various geological websites and blogs, including Earthlearningidea. Currently, she works in a voluntary capacity with Chris King and Peter Kennett to devise and edit activities for https://www.earthlearningidea.com. Elizabeth can be reached at elizabeth@earthlearningidea.com.

developing countries across the world failed, we put our brains to bear on how else we could contribute to the IYPE in 2008, and Earthlearningidea was born.

The initial plan was to publish Earth science activities at weekly intervals during 2008, aimed particularly at classrooms and teachers in the developing world with few resources. The three of us, with no funds available, planned to do this on a voluntary basis. The 52 activities published during the IYPE were so well received that we decided to continue. During the first year, a colleague in Argentina offered to translate some of the activities into Spanish on a voluntary basis too. Since then Earthlearningidea has evolved to a publication in English every two weeks, the inclusion of ELI+ activities (needing slightly more sophisticated equipment, as available in a normal school science lab, or more abstract ideas than other Earthlearningideas) and ELI Early Years activities for young pupils. The ideas have also been translated into 12 other languages by volunteers in various countries. See Table 1 for a list of some recently published activities.

The data for March 2021 show the following:

- 5,235,457 pdf, video and powerpoint downloads of Earthlearningideas so far (not including the separate websites set up to disseminate Earthlearningideas in different languages, such as Portuguese, German and Polish)
- 50,863 mean number of pdf downloads per month in 2020
- 361 Earthlearningidea activities published in English
- 1,215 translations from English by December 2020, into twelve other languages, Spanish, Catalan, Portuguese, Norwegian, Italian, German, Polish, South Korean, Slovak, Japanese and one in Tamil
- 209 countries and 12,092 towns and cities in which the Earthlearningidea blog has been accessed
- 10 top countries:
  - United States
  - United Kingdom
  - India
  - Canada
  - Australia
  - Spain
  - Philippines
  - Italy
  - Germany
  - New Zealand

We remain amazed, but thrilled by this success, and welcome you to join us (we can pay you exactly the same as we get paid ourselves, i.e. nothing at all!).

Conclusion

If you would like to be involved, then please:

- Try some of the Earthlearningideas yourself, either in the classroom or on family open days
- Tell all your friends and colleagues about Earthlearningidea
- If you have an activity suitable to be written up into an ELI format, then please send the idea to us (although we can’t promise to include all the ideas we receive)
- Revisit the ELI website on a regular basis, to access more innovative ideas to use in your teaching.

Reference

Abstract

Classroom teachers must plan for the use of modeling by students. Getting an initial sense of students’ ideas can lead to the discovery of misconceptions and ways that you can scaffold learning for students. Allowing students to revise their models is equally important as their understanding increases. Peer and teacher feedback builds students’ confidence and lets students see modeling as a tool toward understanding key earth science concepts. This article contains some teaching strategies to help you use modeling in your teaching.

Introduction

As a high school student, I had great difficulties with spatial reasoning or explaining scientific processes. Modeling earth science processes would have helped me to form explanations in order to visualize the seen and unseen parts and understand better how they worked together. One key earth science concept is plate tectonics, where plates meet to cause mountain building, volcanic eruptions, and earthquakes. Modeling the plate interactions would have helped me to better understand the resulting geologic impacts.

Teachers can help students use models explain all a variety of scientific phenomena. “Our students use modeling to test ideas, hypothesize about relationships, and revise their thinking as they learn more. The models make reasoning more public to peers and the teacher, which in turn opens up possibilities for continual refinement” (Windschitl, 2018).

A scientific model is a representation of a system or a phenomenon in the natural world that can be shared with others and revised over time in response to new evidence and understandings. These representations can take the form of drawings, diagrams, or even flow charts. Models help predict and show relationships among variables between systems and their components in the natural and designed world(s). Scientists use models to make unobservable events and processes visible so members of their community can pose new questions for investigation that may result in changes to the model, and then to construct better ideas for how the natural world operates.

Models are central to disciplinary work. One can find drawings and revisions of drawings everywhere; on whiteboards in laboratories, recorded in the pages of scientists’ notebooks, and displayed at scientific conferences. Students are more than capable of
Suggestions for Teaching Modeling

- Start with modeling. Give students an open-ended question that embeds the concept of focus and let them draw a model to grapple with it.
- Have students draw models before they write an explanation. They can think as they draw and then write a strong explanation.
- Give each student an individual whiteboard to draw their models on. This makes it easy to revise their model as they hear compelling arguments for changing it.
- Have students to draw models at multiple steps in exploring a concept, for instance, before, during and after a demonstration.
- Ask students to find ways to show the causal patterns or interactions in their diagrams. Help them develop a class vocabulary for illustrating and discussing the causal patterns.
- As often as possible, have all students share their models with the class. It removes the social burden of deciding to share. Arrange the desks in a circle and go around sharing, discussing, and critiquing.
- Critique models as a regular part of class discussions. Some models have more explanatory power than others, but no model explains everything about a particular phenomenon. Each model fits in some ways and not in others.
- Don’t hold back on the “scientifically accepted” model, but don’t present it as “the right answer” either. It is best when a student presents some version or part of it and you can work towards it together as a class. Critique it as you would any other model.

Add: We think (evidence from a lab, activity or reading) supports part of our model, but we want to add __________ to make it clearer and more accurate.

Revise: We think that (evidence from a lab, activity or reading) supports part of our model but we want to change __________ to make it more accurate.

Remove: We think (evidence from a lab, activity or reading) contradicts __________ in our model, and we want to remove it or find out more about it.

Question: We still have questions about ____________.

Figure 2. Harvard Graduate School. Tips for Teaching Modeling in Science.

Figure 3. Scaffold of Revising Initial Models, (Windschitl, 2018).

Illustrating their thinking about complex phenomena through drawing and writing. Their models can also be used to generate questions, think about what information they still need and revise explanations.

Modeling should not be a one-time event in the classroom. It is a dynamic process that unfolds over time as students gradually change their understandings of an event or process being studied (Windschitl, 2018). As they learn more, students may add cause and effect relationships, discard some parts of a model, or modify labels to reflect different or new scientific language.

Models usually contain only features that are important for understanding the system or phenomenon they represent and leave extra information out. For example, student might make a model of pulleys and weights or draw the pulleys, strings or ropes and weight. They might include what was exerting a lifting force, and any opposing forces. What might be left out are features of the object being lifted and the details of the person or thing doing the lifting.

Revising Models Based on New Evidence and Ideas

Models are meant to be changed. After a few lessons, students will want to revise some of their original ideas and add new ones. They might want to change cause-and-effect relationships, or question hypotheses that they put into their initial models. Students are “often reluctant to reconstruct models that they have invested time and energy in” (Windschitl, 2018). Students’ hesitancy can reflect the thinking from years of schooling, that any product for a class is final, and that if you change your thinking, it means that your initial ideas were wrong. Students do not like writing on top of their original models; or even worse, starting all over again on a blank piece of paper. The teacher can help make the revision process interesting and engaging for students rather than frustrating, and assist them to see the value of rethinking their initial models.

One way to overcome this hesitancy is to have students use colored sticky notes directly placed on the first model as a helpful way for them to indicate how ideas can change with new information or evidence. Each color represents a specific kind of comment. The four scaffold questions for revision found in Figure 3 reflect the ways that scientists change models: adding an idea, revising an idea, removing an idea, and posing a new question. The students decide what kind of changes they want to suggest, select the appropriate colored note, compose the comment and then apply it to the model. Notice that there are no categories for commenting on how artistic the drawing and how neat the handwriting is. Keep the comments relevant to the thinking and concept.
With a little practice, students become better at offering productive forms of feedback to peers. Early in the school year, have the students practice placing notes on their own models after a few lessons and provide comments about the reasons for requesting changes. A full sentence requirement on this will help students begin to shape parts of a final written explanation that will eventually accompany their drawn models.

These notes also serve to make students’ thinking visible to others. As you walk around the room, you ask some questions to check their thinking and get them to explain more while they are working on their ideas. Students may then unpack more of their reasoning and conclude that some of their ideas are not a good thing to add to the model.

**Modeling of Global Climate Change**

Global climate change is one of the big ideas of science that is better understood through the development of models. Teaching tips and resources are provided below for incorporating modeling in your classroom. These include the climate system, greenhouse effect, deforestation, the carbon cycle and rising sea levels.

**The Climate System and Greenhouse Effect**

Most people think about the climate of a familiar region. They can visualize how rainy their region is during summers and know what type of weather to expect in the winters. Understanding the climate of a single place—likely the place where they live—is the first step in comprehending the enormity of what is meant by global climate. Climate is studied and measured at a very large scale, ultimately encompassing the entire Earth system, and over long periods of time, from decades to centuries. The primary source of energy on Earth is the sun which emits energy into space in the form of electromagnetic radiation. When this energy reaches Earth’s atmosphere and surface, it interacts with matter in the air, ocean, land, and life. Solar radiation from the sun can be converted into other forms of energy such as heat and chemical energy and powers the global climate system.

- **Teaching Tip:** One way to help students understand the energy system is to encourage them to create an energy story line. Ask them to trace how energy changes form as it interacts with matter on or near Earth’s surface and to illustrate the various parts of Earth’s global energy balance and how the sun’s energy changes forms when it interacts with air and land surfaces.

- **Teaching Resource:** An interactive model from the Concord Consortium ([authoring.concord.org/activities/280/pages/1745/ac42feef-2d06-4eab-9b31-b3c2d9144f62](authoring.concord.org/activities/280/pages/1745/ac42feef-2d06-4eab-9b31-b3c2d9144f62)) allows the student to see the relationships between temperature, carbon dioxide, and water vapor. Just as in real life, the only factor you can control is the amount of CO₂ emissions. Experiment with the Human Emissions slider to observe what happens to temperature and water vapor when carbon dioxide levels change.

**Deforestation and the Carbon Cycle**

As the world seeks to slow the pace of climate change, preserve wildlife, and support billions of people, trees may hold a major part of the answer. Yet the mass destruction of trees—deforestation—continues, sacrificing the long-term benefits of standing trees for short-term gain. Forests still cover about 30 percent of the world’s land area, but they are disappearing at an alarming rate. Between 1990 and 2016, the world lost 502,000 square miles (1.3 million square kilometers) of forest, according to the World Bank (World Bank, 2016)—an area larger than South Africa. Since humans started cutting down forests, 46 percent of trees have been felled, according to a 2015 study in the journal Nature (Ehrenberg, 2015). About 17 percent of the Amazonian rainforest has
been destroyed over the past 50 years, and losses recently have been on the rise (nationalgeographic.com/environment/article/deforestation)

**Teaching Tip on Carbon Dioxide:** Carbon dioxide is the main greenhouse gas monitored by scientists and students tend to make carbon dioxide a villain just as they would the bad guy in a story. Yet, carbon dioxide is an important greenhouse gas that helps to keep our planet habitable. It is also the gas that plants need to live. Be attentive to how students talk about carbon dioxide because although it is one of the greenhouse gases causing climate change, it is also fundamental to life on Earth. Climate change is about having too much carbon dioxide.

**Teaching Tip on the Carbon Cycle:** Just as the water cycle includes places where water is found and processes that move it among those places, the carbon cycle includes reservoirs of carbon and the processes that move carbon among them. For example, as water moves from the ocean into the atmosphere through evaporation and back into the ocean through condensation, carbon can move from the atmosphere into plant sugars through photosynthesis and then back into the atmosphere through combustion (burning). This historical separation of carbon-cycle processes into different disciplines may prevent students from developing a coherent picture of the whole carbon cycle.

**Teaching resource:** A visual, interactive you can use to let students learn more about the carbon cycling in the Earth system can be found the Concord Consortium (authoring.concord.org/sequences/47/activities/280/pages/1741/d1ce6a5e-ea2e-4e2d-9475-4bc2a32e8bf6). Follow the arrows in the flowchart to see how carbon dioxide moves between different reservoirs.

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**Performance Expectation**

- Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth’s systems.

  nextgenscience.org/topic-arrangement/hsweather-and-climate

**Dimensions**

**Science and Engineering Practices**

**Developing and Using Models**

- Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). Use a model to provide mechanistic accounts of phenomena.

  Students need to make initial models to explain their understanding at the beginning of the unit in order for the teacher to determine the level of understanding for each student and to see if there are any misconceptions that need to be addressed. Also revising models allows students to update their thinking.

**Disciplinary Core Idea**

**ESS3.D: Global Climate Change**

- Through the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.

  Students can explore the scope of global climate change by looking at data to predict, model and determine the impacts of climate change and suggest some solutions. A natural connection to engineering could provide an engaging opportunity for students.

**Cross-Cutting Concepts**

**Cause and Effect**

- Empirical evidence is required to differentiate between cause and correlate and make claims about specific causes and effects.

  Using models can help students to see cause and effects visually. Having the opportunity to revise their models can give students the idea that science is updated, and it is something that scientists do. Also making explanations can help students to make their thinking public to peers so that it provides the basis for discussion.

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**Figure 4.** Developing and using models is widely used in the Next Generation Science Standards. NGSS Lead States (2013)
Melting Ice, Rising Sea Levels, and Climate Change

Warming oceans and air temperatures are causing ice on Earth to melt and impact is being felt at the Poles more than in any other location. When one looks at a globe, the Poles are easily distinguished by the white color that represents the ice and snow found in these locations. However, the average amount of ice and snow has been reduced over the past few decades. Most of the ice in the Arctic is present as sea ice and in the glaciers of Greenland’s ice sheet. The continent of Antarctica is covered by thick glaciers and has several large ice shelves.

Teaching Resource: Warming Seas and Melting Ice Sheets (nasa.gov/feature/goddard/warming-seas-and-melting-ice-sheets) describes how NASA has been monitoring the warming of the ocean and changes to the planet’s land masses, with a close eye on the ice sheets covering Greenland and Antarctica. It includes a video that describes the causes of sea level rise and how sea level has changed over the last two decades as observed by the Jason series of satellite missions. It also includes two animations. The first one shows the change in the Greenland Ice Sheet between January 2004 and June 2014, as measured by the GRACE satellites pair. The second animation shows the change in the mass of the Antarctic Ice Sheet between January 2004 and June 2014, as measured by the GRACE satellites pair.

Modeling is an important component of the Next Generation Science Standards. The NGSS Connection (Figure 4) shows an example of how modeling can be used in an earth science lesson or unit. Three-dimensional thinking is enhanced by the use of student modeling to depict or represent an earth science concept, particularly one that is complex.

References

About the Author
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Abstract

Air quality topics can be taught successfully in middle and high school science classes. When presented in an inquiry method, these topics align with the Next Generation Science Standards’ crosscutting concepts such as systems, modeling and stability and change. This article presents samples of low tech, low-cost activities for teachers to implement in their classes. These activities require minimal preparation and offer a variety of tasks and ways to demonstrate student learning. The activities were developed as part of an air monitoring project on high school campuses in the metropolitan Washington D.C. area called Our Air, Your Future: Creating Clean Air Advocates.

Introduction

Air quality is a less familiar topic to many teachers than water quality. Often lessons are unavailable or difficult to find online. As a result, teachers may shy away from delivering air quality activities. This is discouraging and unfortunate because clean air is a human right. On average, Americans breathe much cleaner air today than 50 years ago. The Clean Air Act of 1970 (EPA, 1970) has proven itself to be one of the most successful environmental laws in the United States. The Clean Air Act reduced criteria air pollutants (nitrogen oxides, ozone, sulfur dioxide, carbon monoxide, lead, and particulates) while the economy continued to grow, disproving the false dichotomy between a safe environment and a robust economy. National averages of the six criteria air pollutants plunged 77% while the US gross domestic product grew 285% between 1970 and 2019 (EPA, 2020).

However, pockets of people continue to breathe levels of air pollution higher than the allowable amounts set by the National Ambient Air Quality Standards (EPA, 2018). These populations have been targeted by decades of redlining and siting of highways and industry in their neighborhoods, and car-dependent modes of travel (Bullard, 2014). Marginalized populations are generally under-resourced, experience health disparities, and suffer health problems from their income and air quality disparities. These structural, inequitable systems have persisted over multiple generations. Thirty-six years of PM 2.5 concentrations from 1981 to 2016 were compared to geographic, economic, and demographic data from 65,000 U.S. census tracts to reveal the most polluted census tracts then remain the most polluted today--and the least polluted U.S. census tracts then remain the least polluted in 2016. (Powell, 2016) (Colmer et al., 2020) (Nardone et al., 2020). Additional
Intergenerational environmental struggles have also been compounded with disproportionately higher Covid-19 infections and mortality outcomes, demonstrating communities of color continue to be vulnerable in the United States (Liang et al., 2020). Teaching air quality with a focus on the student’s location and instilling an appreciation for the importance of geographical place and good current data, can build students’ interest these science lessons. Education can play a role to raise awareness about air quality and inspire students to seek clean air solutions that may benefit their friends, families, and communities. The first step is to teach the basics of air quality to middle and high school students.

A series of air quality lessons were developed to support an air monitoring project, called Our Air, Your Future: Creating Clean Air Advocates, in the metropolitan Washington, D.C. area (Virginia, District of Columbia, and Maryland public and charter schools). High school science classrooms received one Aeroqual S-500 sensor and one Purple Air sensor to collect and analyze campus ozone and fine particulate (PM 2.5) levels quarterly.

Aeroqual sensors were set up on campuses in locations with freely moving air sheltered from rain and snow but close to student foot traffic. Purple Air PM 2.5 sensors were set up at locations near the schools. They were installed using similar criteria of freely moving air. Purple Air sensors are outdoors weather resistant devices that collect data continuously and push it to the cloud. Data for any sensor on the map can be downloaded and analyzed in a spreadsheet. The Purple Air map is available to view online, purpleair.com/. Aeroqual sensors had to be set to collect ozone. They are hand held indoors sensors generally used by industry and research. The S-500 does not currently not have an online map community, and it does not push data to the cloud. Local data is collected by the device and transferred to a spreadsheet for analysis.

Local samples were collected quarterly and students practiced making and analyzing graphs, using Claim-Evidence-Reasoning (CER) methods to characterize their campus air quality by season. CER is an approach to make sense of data in general, and students learn to apply CER to analyze graphed ozone and PM 2.5. Claim-Evidence Reasoning has three parts. The claim is a true statement to answer a question the specific graph type can answer. Bar graphs ask, ‘Are the groups the same or different?’ Line graphs ask, ‘How does the data change over time?’ Scatter plots ask, ‘How do X and Y relate to each other?’ Evidence describes the ‘clues’ in the graph that substantiate the claim. Clues are numerical, e.g. bar height, increasing or decreasing data over time, or values for X and Y along a best fit line in a scatter plot. Finally, reasoning is the student’s proposed or probable science cause for the difference in bar height, change in data over time, or positive or negative correlation between X and Y variables.

To make sense of real-world data, 5E learning cycle activities were aligned with crosscutting concepts defined by the Next Generation Science Standards (NGSS, 2013). 5E was developed by Biological Science Curriculum Study to support constructivist learning. The five phases of a 5E lesson are Engage, Explore, Explain, Extend, and Evaluate. The phases allow the student to build knowledge from an event or phenomenon initially using the students’ own words then introduced to academic language and concepts. This is an active way of learning instead of passive lectures that transfer information from teacher to student. 5E places the student in the ‘driver’s seat’ and makes learning more familiar and accessible to the student who can observe, test, and analyze data. This transfer of information is more productive and feels like a more scientific way to learn science concepts than a lecture.
The activities were tested during the 2019-2020 school year before the pandemic shut down schools. The lessons were scaffolded and differentiated to ensure equitable access for English learners, special education students, and nontraditional students. Scaffolding divides a larger, complex topic into parts that are more easily processed by students while differentiated lessons offer images, diagrams, and appropriate word choices or language more accessible for English learners. Together, these strategies enhance the learning experience, making a difficult complex topic less impersonal and remote and more tangible and relevant.

The lessons were administered to middle and high school students in a nontraditional school program, learning environments designed to help students with various types of learning disadvantages (social or cognitive or both). Smaller classes, flexible scheduling, and attention to learning styles offer more opportunities to build trust and confidence. Student performance and feedback from the lessons were analyzed to improve and clarify tasks. Table 1 organizes the activities by Next Generation Science Standards and Our Air Your future: Creating Air Advocate lessons.

**Activity: Card Sorts**

Three different card sorts were used to compare and contrast two categories of air quality topics.

- Human versus natural sources of air pollution
- Smog versus fog
- Nitrogen oxides versus volatile organic compounds

To prepare the activity, search for images to represent each category. Print and cut into cards. You can also go paper-free and make a Google Slide deck or Jamboard, and insert the images for students to sort. Card sorts are a fast way to acquire larger amounts of information. Students benefit from some ground rules, such as knowing some details to facilitate the sort into these categories. In this image, the student was prompted the category type is pollution source. To keep the sort simple and clear, natural sources generally occur independently of human activity. Some cards, like an image of a flame, do not fit neatly into one category; they may match either one, encouraging more sophisticated discussions.

These websites provide free photos:
- [pics4learning.com/](http://pics4learning.com/)
- [flickr.com/commons](http://flickr.com/commons)
- [pixabay.com/](http://pixabay.com/)
- [unsplash.com/](http://unsplash.com/)

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[nps.gov/subjects/air/sources.htm](http://nps.gov/subjects/air/sources.htm) provides examples for human and natural sources of air pollution.


**Activity: Modeling**

Modeling activities offer students an opportunity to make sense of real-world phenomena they cannot directly experience at the molecular level. Four modeling activities are described.
1. Marshmallow Treat Surface Area

Marshmallow treats are inexpensive in bulk. The treats are malleable and can even be easily pulled apart by hand if a plastic knife is not allowed in the classroom. Clay, soft granola bars, and cookies can all work instead of marshmallow treats.

Ask students to distinguish surface area and volume. Then, challenge students to increase the surface area of the marshmallow treat while keeping the volume the same. Surface area and volume can be confusing measurements to make for students. Teachers can clarify the difference between the number of surfaces exposed and the amount of space occupied with probing questions and every day events, such as the time it takes to boil potatoes whole versus cut up. The marshmallow treat is a proxy for human lungs to convey the concept of form and function. The key is to ensure students can transfer the analogy for surface area from marshmallow treat to lungs.

Prompt students to make labeled diagrams before and after altering the surface area of the marshmallow treat. Students should observe more surfaces exposed and can write a statement comparing the surface area before and after.

As an extension, ask students to consider the surface area of the lungs. Students can write a statement that applies their model to the lungs. Their statements should reflect the relationship between the structure of lungs and their function of gas exchange.

2. 1:10 Serial Dilutions to make a one part per million

Students may have a hard time visualizing parts-per-million. This activity provides them with an opportunity to create their own serial dilution using common blue food dye which contrasts well with water. Provide students with one drop of blue food dye in a well plate. A plastic egg carton or plastic wrap spread out on top of the lab sheet are alternatives to well plates. Use disposable pipettes and toothpicks to transfer and mix solutions.

In the first step, students dilute a drop of blue food dye with nine drops of water. They transfer one of the ten drops of the diluted solution to a new well and dilute again with nine drops of water. After each dilution, students identify the part per solution. They continue until they make one part per million. Ask them to keep track of the number of dilutions needed to get to one part-per-million. Have them compare the color of their various solutions. The coloring provides students with a visual to compare to the fractions. Most students cannot perceive any blue in their one part-per-million solution. Students use colored pencils or crayons to record their findings and predict what one part-per-billion could look like. Students should apply their knowledge of fractions to describe solutions with very small amounts of solute present. Very small numbers are confusing to students. Students struggle with this small scale, but the 1:10 generally convinces students the dye is present yet too difficult to see. They can express verbally the 1 ppm should be lighter than 10 ppm; however, modeling it with markers or colored pencils offers a qualitative way to demonstrate quantitative thinking.
3. Ozone reactions with clay

Students will need two colors of clay plus the clay container. Students also need color pencils, crayons or markers ideally the same color as their clay oxygen and nitrogen atoms.

They will need enough clay to make large marble-sized atoms, one nitrogen and for three oxygen of a different color. Do not make the spheres too large. The clay container needs to fit over the atoms during the smog formation reaction.

Use a piece of masking tape to label the container with 'VOCs' (volatile organic compounds).

Provide students with word equations to represent the formation of ozone from nitrogen dioxide and molecular oxygen.

**DAY**
- nitrogen dioxide reacts with molecular oxygen to produce
- nitrogen monoxide and ozone

**NIGHT**
- nitrogen monoxide reacts with ozone to produce
- nitrogen dioxide and molecular oxygen

Word equations inform which and how many atoms and molecules to make. Touching atoms represents molecules. Students model the formation and decomposition of ozone with clay at their desks, then they record their observations using simple color-coded geometric shapes (spheres) to represent the chemical reaction. This activity may necessitate more step-by-step coaching from the teacher. Students must translate the chemical change from word and chemical equations to three-dimensional models with clay and finally demonstrate their thinking with two-dimensional shapes on paper. Students practice chemical change in different ways, maximizing the chance of matching student learning styles. For example, kinesthetic learners may gravitate towards the clay modeling instead of the word or chemical models while visual learners may feel more comfortable and excel with the same word and chemical models.

Students make smog by repeating the formation of ozone. They invert the clay container labeled VOCs over the molecule of nitrogen monoxide to represent the chemical reaction between nitrogen monoxide and VOCs, producing smog. Smog is a mixture of compounds, and ozone is a significant component in the mixture.

nitrogen monoxide reacts with VOCs to produce smog (mostly ozone and NO + VOC’s)

4. Diurnal ozone graphing and CER analysis

Create a google slide with X and Y axes and bars that students can drag and drop into the graph in order to represent the diurnal pattern of ozone.

Draw X and Y axes on a blank slide. Label X with alternating Noon and Midnight over a three-day period. (four midnights and three noons). Label the Y axis Low and High (to represent relative amounts of ozone).

Create seven bars of the same color. Make three tall ones and four short ones. The X axis is labeled alternating Midnight and Noon for three days. The Y axis is labeled with qualitative concentrations, high and low. Students can drag and drop the bars to show peaks and valleys of ozone over

Figure 4. A student draws two-dimensional models based on three-dimensional clay modeling of an ozone reaction.

Photo credit: Elizabeth Spike
time. Students make the graph themselves which may activate learning a process that is not readily obvious to them in nature.

Students can drag/drop the bars according to the rules:

- Daytime favors the production of ozone which means a higher concentration of ozone is present during the day.
- Nighttime favors the breakdown of ozone which means a lower concentration of ozone is present at night.

Students observe higher amounts of ozone during the day and lower at night. Students can analyze the diurnal pattern with the Claim-Evidence-Reasoning method. This scaffolds the analytical thinking process into manageable parts for students to successfully explain graphed data.

Bar graphs compare groups of data. Ask students to decide if Noon and Midnight ozone concentrations are the same or different. Next, ask students for clues in the graph to support the claim of different bars. Finally, ask students to propose a possible cause to explain the difference in ozone concentrations.

Encourage students to incorporate the Sun’s role of activation energy. Remind students how they physically removed an oxygen atom from nitrogen dioxide in order to form ozone in the clay modeling activity. Removing an atom requires energy. Student hands supplied the energy to split the nitrogen dioxide molecule, but in the real world, the Sun delivers the energy to split the nitrogen dioxide molecule.

**Conclusion**

These activities are all easy to prepare, are low cost and low tech. Students will enjoy the opportunity to explore various air quality topics themselves, independently of the teacher. The activities are differentiated, scaffolded, and interdisciplinary. They incorporate different tasks and tools allowing students to show their learning in different ways.

Air quality lessons pique student curiosity of the natural and social systems within which they live. Teachers can place students on the path of awareness of the air they breathe; ideally the activities will inspire students to ask questions and pursue inquiries into clean air as a public health priority.
Table 1. The activities are correlated with NGSS crosscutting concepts. Each activity has a reference to the Our Air, Your Future: Creating Clean Air Advocates (OAYF) lesson and a driving question (DQ).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Can-do Statement(s)</th>
<th>NGSS Crosscutting Concept, the OAYF Lesson, and the Driving Question (DQ)</th>
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<tbody>
<tr>
<td><strong>CARD SORTS</strong></td>
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<tr>
<td>Human versus natural sources of air pollution</td>
<td>I can identify human versus natural sources of air pollution.</td>
<td>Systems and Systems Models</td>
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<tr>
<td>Smog versus fog</td>
<td>I can identify smog versus fog.</td>
<td>Lesson 1: Air Pollution Connects Atmosphere to Biosphere</td>
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<td>DQ: How do the atmosphere and biosphere interact?</td>
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<tr>
<td>Nitrogen oxides versus volatile organic</td>
<td>I can identify sources of nitrogen oxides versus volatile organic compounds.</td>
<td>Systems and Systems Models</td>
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<tr>
<td>compounds</td>
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<td>Lesson 7: How Humans Affect Ozone</td>
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<tr>
<td></td>
<td></td>
<td>DQ: How do humans affect ozone?</td>
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<td><strong>MODELING</strong></td>
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<td>Surface Area with marshmallow treats</td>
<td>I can describe surface area and explain how it affects gas exchange in the lungs.</td>
<td>Structure and Function</td>
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<td>Lesson 2 Health Consequences</td>
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<td>DQ: How do ozone and particulates affect your health?</td>
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<tr>
<td>1:10 Serial dilutions to make a one part per</td>
<td>I can describe a one part per million and extrapolate to one part per billion</td>
<td>Scale, Proportion, and Quantity</td>
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<td>million solution</td>
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<td>Lesson 4: Reporting Pollutant Measurements</td>
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<tr>
<td></td>
<td></td>
<td>DQ: How do we report pollution measurements?</td>
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<tr>
<td>Ozone reactions with clay</td>
<td>I can compare and contrast ozone reactions.</td>
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<td></td>
<td>I can describe how smog is made.</td>
<td>Lesson 5 How Nature breaks down Ozone</td>
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<td></td>
<td></td>
<td>DQ: How does nature make and break down ozone?</td>
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<tr>
<td>Diurnal ozone graphing and CER analysis</td>
<td>I can analyze ozone data to describe the diurnal pattern.</td>
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</table>

About the Author

Elizabeth Spike, MS in Secondary Science Curriculum, is an alternative school teacher of science for grades 7 to 12 in Fairfax County Public Schools in Northern Virginia. She is a former North American Association for Environmental Education’s ee360 Community Fellow where she developed Our Air, Your Future: Creating Clean Air Advocates. As part of her academic training to develop educational materials and resources to support participating teachers in her air monitoring project, she was selected and attended Project Atmosphere, the American Meteorological Society’s week-long professional development in Kansas City, Kansas in 2019. She can be reached at easpike@fcps.edu.

To learn more about Our Air, Your Future: Creating Clean Air Advocates please visit sites.google.com/view/ourairyourfuture/home and complete the feedback form forms.gle/f4yjdHmViUaQqhu38.

References


Nardone, A., Casey, J. A., Morello-Frosch, R., Mujahid, M., Balmes, J. R., & Thakur, N. (2020). Associations between historical residential redlining and current age-adjusted rates of emergency department visits due to asthma across eight cities in California: an ecological study. The Lancet Planetary Health, 4(1), e24-e31. doi.org/10.1016/s2542-5196(19)30241-4


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<td><strong>Windows to the Universe Educator Membership</strong></td>
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Colorado panorama by balloon. The yellow areas are aspen leaves changing color. Boulder, CO is visible on the right, and Colorado Springs is on the left.

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