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INSIDE THIS ISSUE

West vent in Halemaʻumaʻu crater at the summit of Kīlauea. Ponded lava within the spatter cone supplies lava into the lava lake through the tubed-over spillway. As the lava slows and cools, a thin crust begins to form on the surface. This photo was taken in November 2021 in Hawaiʻi Volcanoes National Park.

Photo Credit: L. DeSmither, USGS.

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Letter from the President

By Rick Jones, NESTA President 2020-2022

Aloha and Hauʻoli Makahiki Hou,

Throughout the year ***TES*** brings you timely, relevant, and varied articles. Some issues are focused on a specific topic, while others are broader in scope and cover multiple topics being addressed in schools and communities all around the nation. In this issue you will find diverse topics including a 5E mini-unit on glacial evidence, one on the Rock Cycle, community engagement through the use of Environmental History Trail Signs, and efforts in Los Angeles to empower students of color to pursue careers in space science.

I am looking forward to reading all the articles, particularly the articles relating to climate change and empowering students of color to pursue careers in space. Climate change, specifically, because the last month of 2021 and the first month of 2022 have displayed dynamic variation from the “normal” climate: torrential rains and flooding in the Northwest, crazy warm weather in the Rockies, and 70 degree days to the Denver area in December with unseasonably warm, windy, and dry conditions causing unprecedented late season fires. The article on empowering students of color to pursue careers in space comes as we celebrate the successful launch of the James Webb Space Telescope that will generate decades of data, holding amazing discoveries that this next generation of diverse and empowered space scientists will uncover.

As a teacher and an Earth scientist, I strive to keep up with current research, best practices and projects focused on using relevant, rigorous, and real experiences for my students. This issue provides a very powerful tool and will be amazingly useful in helping me keep current and to continue to count on NESTA and TES to be ***One Earth, Our Future***.

Mahalo nui,
Rick Jones
NESTA President 2020-2022

NESTA'S MISSION
To facilitate and advance excellence in Earth and Space Science education.

Letter from the Guest Editor

The Importance of Earth Science Knowledge to Understand our Climate Challenge

By Guest Editor, Joe Monaco

This editorial is not a debate about whether or not the planet's climate is changing. It is, and always has. We may not be pleased with this fact but hiding our heads in the sand and pretending not to see something that we don't like will not help anyone, including ourselves. This essay is not about placing blame on "someone" for changing our normal or about predicting an apocalyptic doomsday. Nor is it a righteous effort to fortify our beliefs that if we follow certain steps, all will be right and we will save the world from catastrophe. This editorial is about the importance of all planet Earth citizens understanding Earth system science and how that knowledge will help us to realistic outcomes and outlooks for our future.

Earth has operated without human "help" for many years. The earth's surface has been changing since day one. Chemicals found naturally in the air, have mixed with water to form a variety of acids which in turn join with minerals in the rocks. The altered minerals dissolve and even expand or contract causing the original rock to disintegrate over time. During the process, gases, such as CO_2, are released into the atmosphere. This in turn leads to the air's composition being altered. The decaying of leaves, dead plants, etc. also creates organic acids and the decomposition process releases CO_2 and methane into the air. These released chemicals, in turn, interact with rocks and ocean water through geochemical cycles that have been active since the beginning of time. Climate change is a constant process, but humans have changed the pace of climate change. Our extraction and use of materials from the Earth has triggered a cascading series of impacts. We all must learn how the Earth system operates so that we can minimize our impacts or even eliminate them in some cases. It is much easier to do things correctly than to try and fix them later on.

Humans have occupied the planet for a relatively brief period of time and we have needs that must be met to survive. We have also developed a taste for additional creature comforts. We want to communicate by writing, social networking, getting from place to place faster, be entertained, enjoy a healthy life and collect stuff. We have grown so accustomed to this that these things are now considered "necessities." Physics tells us that all these things require an expenditure of energy and this energy has to come from somewhere. However, there are consequences to these "necessities" that must be dealt with. Even those who advocate for fighting climate change are not willing to give up things such as smartphones, vehicles, processed foods, modern clothing, and a host of other things. If we use any of the aforementioned things, we are contributing to climate change in some way.

So where does this leave us? Humans must figure out how to survive on this planet in a sustainable way. Where do we start? A solid understanding of how the Earth system works is the first step to solving the climate challenge. All humans need to have an understanding of Earth's processes and cycles with and without human intervention. The Earth sciences are often cast aside and snickered at because many people have been told that studying the natural world isn't exciting, it isn't glamorous, or it doesn't provide high salaries. All students need an understanding of the Earth sciences and an appreciation of the natural world.

Making the study of Earth science a priority in our schools is one way towards a solution. Even though the topic of Earth Science is included in the Next Generation Science Standards, you'd be pretty hard pressed to find a school system that actually encourages students to take any Earth science courses. At some point in a student's school career, each learns a little about volcanoes, earthquakes, and dinosaurs. As they reach high school age, many students, and many adults for that matter, take the attitude that, "I know what volcanoes do, I know about hurricanes, etc." so I don't need to learn more details than was learned in the elementary grades. Having coached some high school "Science Olympiad" teams which included students on the so called "fast track or college track," it was readily apparent that many of these educated students were in the dark as soon as an event tested them on any of the Earth sciences. These are the very people who will be making decisions in their home towns about zoning laws, city masterplans, and local environmental regulations. Some will even go on to state level and national level (Congress, departments, and boards). How will meaningful decisions, laws, and regulations be put forth if these decision-makers lack a better background in the Earth sciences?

Nature uses the laws of biology, chemistry, and physics to run the Earth systems. The Earth sciences are constantly in the news; floods, storms, climate, heat waves, etc. and yet our educational systems place a low priority on the average citizen really understanding Earth science. People would be better able to respond to natural hazards if they had a better understanding of Earth science.

Climate change is real and has been a part of Earth's geologic past. Since a human lifetime is so brief, we are only familiar with how things have always been in our lifetime or the recent past and we view nature as becoming "unhinged" when events don't match our conception. Can humans stop climate change or slow it down? The Earth has been gradually warming since the last ice age but humans have changed the rate of change and we ignore this at our peril. We will have to learn to live with change. International efforts to foster cooperation and create solutions have been occurring for decades. Some of our solutions do not take into account how the Earth system works and only address a small part of the problem. We need to encourage a knowledge of the Earth sciences and its systems so that we can develop realistic solutions that slow the pace of climate change and allow us the time to adapt to the changes that it will bring to human lives.

About the Author

Joe Monaco, BA in Earth Science and MS in Environmental Studies, is a retired teacher with 37 years experience teaching middle school and high school in both Massachusetts and California. He has been a member of NESTA since 1987 and has had a passion for the earth sciences since childhood. He has presented numerous workshops over the years at NSTA and CSTA (California Science Teachers Association) conferences and has served as a LIT mentor in the AMS DataStreme program. Currently, he is the Membership Coordinator for NESTA. Joe can be reached at monacoj@aol.com.

Peg Steffen***The Earth Scientist*** is the journal of the National Earth Science Teachers Association (NESTA). It is published quarterly (January, March, June, September) and distributed to NESTA members.

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Empowering students of color to pursue STEM careers during the pandemic

Emma Case and Dieuwertje "DJ" Kast, Ed.D.,
University of Southern California

Abstract

The University of Southern California (USC) Joint Educational Project's (JEP) Wonderkids Program seeks to empower students of color from South Central Los Angeles to reach for the stars and know that they belong in STEM fields. As a result of the coronavirus (COVID-19) pandemic, the program had to make many adjustments including moving to an online format and restructuring to accommodate student's needs and access. In April of 2021, the program chose space as a STEM field to investigate, and students learned about the things that exist beyond Earth's atmosphere. The Wonderkids were joined by space enthusiast and communicator, Janet Ivey, and astronaut, Dr. Sian Proctor, who shared their passions about space with the students in a hands-on and interactive way. The Wonderkids program and its staff have worked to make sure that the students remain engaged and interested in STEM topics despite the equity and access challenges that the online sphere presents. By showing students scientists who look like them, the Wonderkids program seeks to combat the inequalities that exist in STEM fields especially around race and gender.

Introduction

In the fall of 2021, Dr. Sian Proctor went to space on SpaceX's Inspiration4 crew, fulfilling her lifelong dream of becoming an astronaut. Dr. Proctor was the first Black female pilot in space, and she shared with the predominantly Black and Latinx Wonderkids students how her love and passion for both space and art got her a spot on the Inspiration4 crew. In April 2021, before she flew on Inspiration4, she joined the University of Southern California's (USC) Joint Educational Project's Wonderkids program to share her life story with elementary students from South Central Los Angeles.

Figure 1. Promotional image for Dr. Sian Proctor's Space Speaking Engagement from Wonderkids' Space Week.

Credit: USC Wonderkids Program.

Wonderkids is an after-school program that teaches kindergarteners through fifth graders about Science, Technology, Engineering and Mathematics (STEM) careers. The program seeks to empower the young people of South Los Angeles to believe in themselves and their ability to pursue any career they want. Since the students of the Wonderkids program are exclusively students of color (100% identify as BIPOC, (Black, Indigenous and people of color)), the program has made it a priority to bring in speakers in STEM fields who look like themselves (Kast, 2021). In the spring 2021 semester, our speakers were 100% female with 83% self-identifying as BIPOC (Kast, 2021). By making this a priority, the program hopes to provide the representation that is too often lacking in STEM and inspiring students to persist in STEM fields throughout their K-12 experiences and beyond.

During the Spring 2021 semester, the six-week program offered two, hour-long lessons per topic weekly, divided by grade level on Wednesdays and Fridays. The first hour of programming was aimed at Kindergarteners through second graders and the second hour was aimed at third through fifth graders. The first lesson introduced some main ideas from STEM fields with a fun experiment to keep students engaged and interested. During the second lesson, the program brought in a scientist, generally a woman of color, from the field to talk about their own experiences in that field and to share their love for science. The (STEM) fields chosen for Spring 2021 were animal science, polar science, dermatology, anatomy, stem cells and space. Dr. Proctor's presentation took place during the space-themed week.

Pre-COVID, the Wonderkids program would operate on-site in several Title 1 or low-income elementary schools in the Los Angeles area. However, the pandemic shifted the entire program online using Zoom as an operational platform. The Wonderkids team had to be creative about designing science activities that required materials available at home to keep everything accessible for the students. The team also employed breakout rooms to give the students small group attention.

Students completed a pre and post-test for each STEM field by drawing or writing a response to the question "What is [insert STEM field here]?" at the beginning and end of each week to check for prior knowledge and to assess what they learned throughout the week. All sessions were recorded through Zoom, and instructors created videos after each week to recap the activities, the guest speaker, and the demonstrated learning from students for the families that could not attend that session as well as to document what the program was doing for funder and archival purposes.

Space as a STEM field

Wonderkids staff chose to cover the topic of space because of accessibility and equity issues. Currently only 16% of the STEM workforce is Black or Hispanic (Funk & Parker, 2018), so the Wonderkids Program seeks to improve representation by showing students scientists who look like them. The program also chose to cover space because of a deep and passionate interest from the students from the previous semester. Helen, a fifth grade student, made a solar system model to demonstrate the science she was most interested in learning about during the fall semester. Helen returned in the spring semester and was able to learn from Dr. Proctor. During space week, Helen said "I am so so happy. Thank you."

Wonderkids Space Week's Content

For space week, the students learned where space technically starts, what it's like in space, what things we have on Earth that are not in space. They completed part of the *ISS-above Curriculum* (ISS, n.d.) "setting your plate in space." where students investigated how difficult it would be to do normal, easy, everyday things (like eating) in space. The students used paper plates, utensils, tape, bagged food, and cardboard to create a place setting that could stand the test of gravity (i.e., being flipped upside down).

Figure 2. Student showing off the effectiveness of his place setting in zero gravity.
Photo credit: USC Wonderkids Program.

Luca, a kindergarten student, employed tape to secure his food before discussing the problems that astronauts might experience in space.

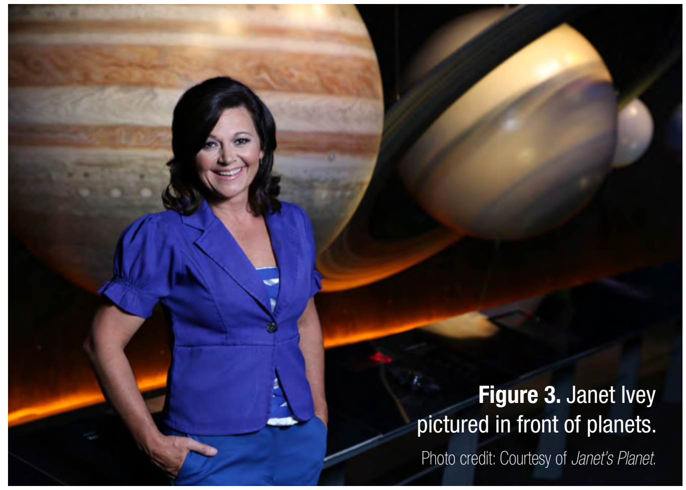

Figure 3. Janet Ivey pictured in front of planets. Photo credit: Courtesy of *Janet's Planet.*

Wonderkids Guest Speakers for Space Week

After our experiment on Wednesday, Wonderkids had two speakers join them that Friday for the Space unit. They had Janet Ivey, who served as our guest speaker for our kindergarteners, first graders, and second graders, and Dr. Sian Proctor, who spoke to the third through fifth grade group. Janet Ivey, is the creator and CEO of the award-winning children's series, *Janet's Planet*. Ms. Ivey has over 29 years of experience working in children's education and entertainment.

Ms. Ivey engaged the students with a scavenger hunt through the solar system, telling the students about each planet before asking them to find something that reminds them of that planet. Students found bowls, playdough, shirts, globes, and other items that reminded them of the planets and celestial bodies.

Figure 4. Students show off items that remind them of the sun. Photo credit: USC Wonderkids Program.

The K-2 students left Ms. Ivey's talk with an invigorated interest in the solar system and the knowledge that they can achieve their dreams, wherever those may take them. Sophia, a first grade student, drew a picture of the solar system saying she drew "all the planets, like Earth, moon, Venus, Mercury, Mars, Saturn, and Uranus."

Figure 5. Sophia shows Ms. Ivey her solar system. Photo credit: USC Wonderkids Program.

Dr. Sian Proctor worked with the third through fifth grade class. She is a geoscientist, explorer, space artist and science communication specialist with a passion for space exploration. Her motto is "Space2Inspire," which she used to encourage people to "use their unique, one-of-a-kind strengths and passions."

Dr. Proctor spoke to the third through fifth graders about her journey through academia and space programs, including when she was almost chosen as an astronaut for a NASA team. She never gave up on this dream, and by combining her passion for art and space, she was finally able to achieve her dream of getting the opportunity to go to space. As a final activity, she and the students designed their own "mission patches," showcasing the people and things that are important to them. She had this to say of the USC Wonderkids Program: "It's always great helping kids think about their unique strengths and passions so that they can inspire themselves and those around them." The students were indeed inspired, excitedly asking Dr. Proctor

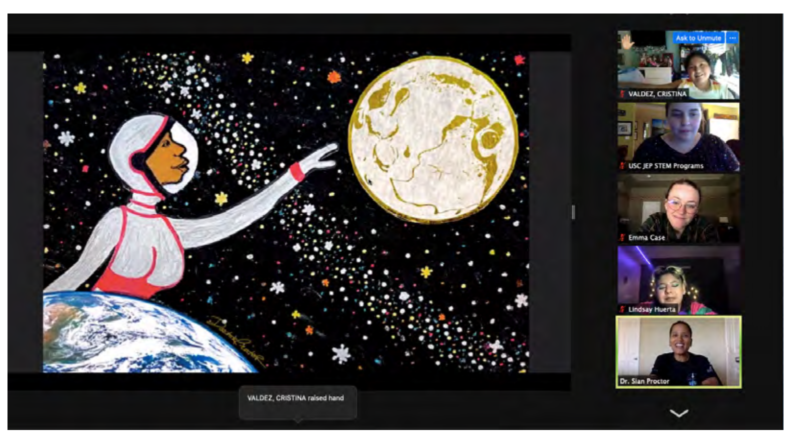

Figure 6. Dr. Proctor shows students some of her artwork. Photo credit: USC Wonderkids Program.

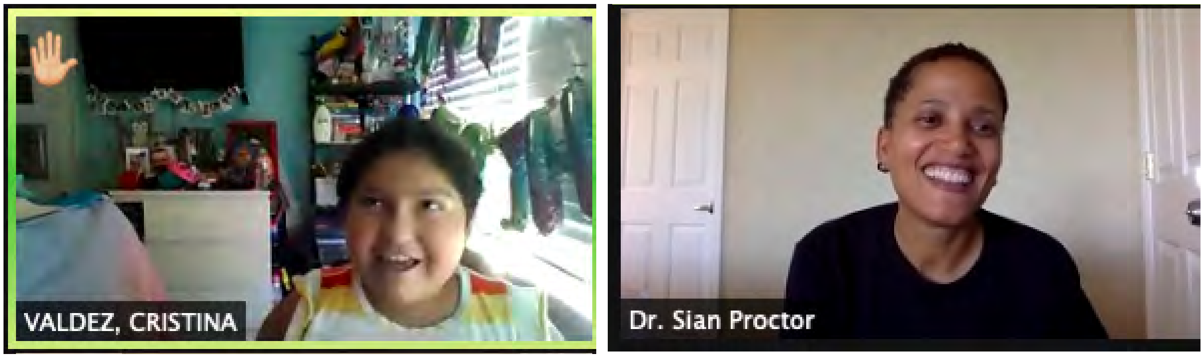

Figure 7. A Wonderkids Student, Cristina, asks Dr. Proctor a question. Photo credit: USC Wonderkids Program.

questions about her experience on analog missions and her upcoming trip to space.

Cristina, a fifth grade student, was inspired to design a patch during Dr. Proctor's speaking session that said "Making History." She described the patch saying, "It's me or any woman, it doesn't really matter, going to the moon for the first time." Cristina also demonstrated her love for space during the parent showcase at the end of the semester. She created a "little space book about what I learned in space." She included the Mars simulation Dr. Proctor worked on, the solar system, facts about each planet, and Dr. Proctor's story.

Figure 8. Cristina shows off her space book. Photo credit: USC Wonderkids Program.

Wonderkids Impact on students

Although most students understood a little about space prior to the Wonderkids "Space Week," they demonstrated growth from their pre-tests to post-tests. Their writings and comments reflected greater understanding of the details about space science and they related their drawings to topics covered during both the Wednesday and Friday sessions. Their drawings included diagrams of the solar system, different planets they "visited" during the scavenger hunt, rockets, and astronauts.

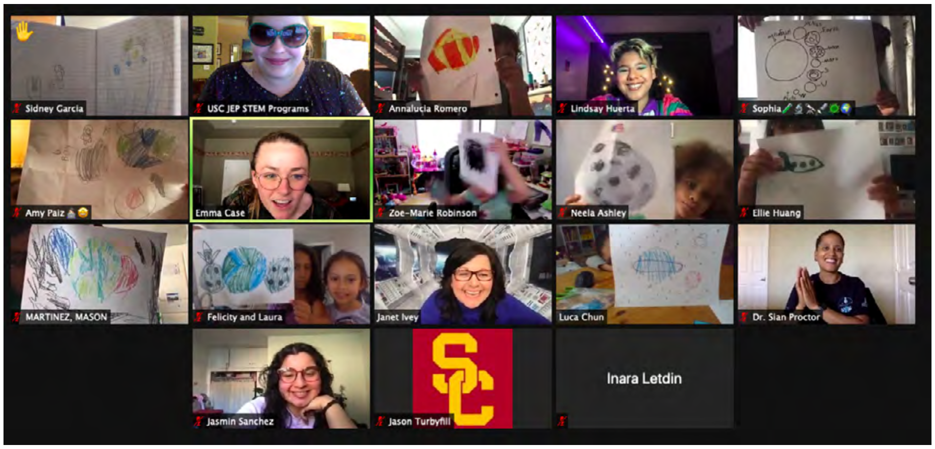

Figure 9. Students show off their post-test drawings for space week. Photo credit: USC Wonderkids Program.

Parents and guardians of students also noticed a difference in their children's interest and understanding of STEM fields and their belief to be a part of those fields. An end-of-semester evaluation of the program collected both quantitative and qualitative feedback from parents and guardians. The survey found that 80% of parents "strongly agreed" or "agreed" that their student had talked about or practiced something they learned from Wonderkids.

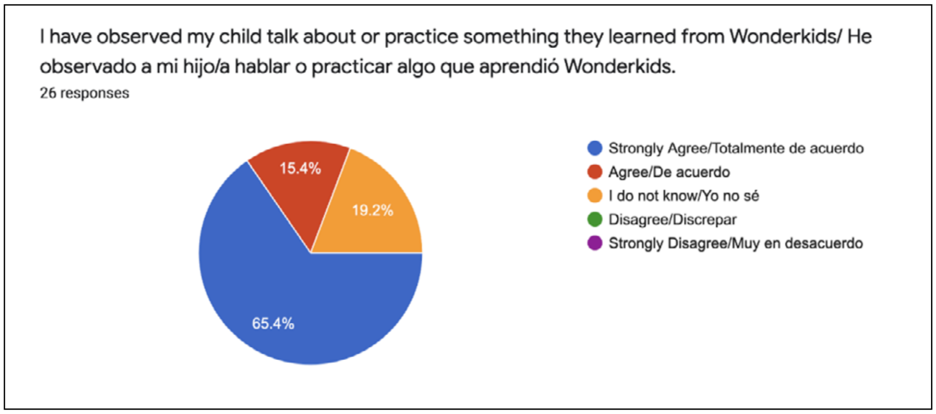

Figure 10. Parent/guardian responses to the post evaluation statement "I have observed my child talk about or practice something they learned from Wonderkids."

Parents and guardians had an opportunity to share quotes from or about their students. One female student was heard saying, "There are many women who are scientists." A parent shared that her daughter "loves to talk about the solar system and space. She asks about the planets and shares facts she learned." Another parent shared that her daughters are "thinking like scientists now. They are so curious about everything that surrounds them."

One Wonderkids student was particularly inspired by Dr. Proctor. Nicole, a fourth grader, has been our resident artist in the Wonderkids Program for the past two semesters. She loves being creative and making beautiful drawings for all our pre and post-tests. Because of her love for art, she was particularly inspired by Dr. Proctor's ability to combine her passions for science and art, saying, "Dr. Proctor is not only a scientist but she is an artist who is going to outer space."

Limitations

The Wonderkids Program had to restructure every aspect of its programming because of the pandemic. Teaching online has its perks and its limitations. Many limitations have to do with the digital divide, where some students struggle to find a good internet connection, have microphone issues (exacerbated by literacy issues that can limit using the chat), or problems streaming video. Another issue specific to a hands-on STEM program was access to materials. Though the program made it a priority to choose experiments that used common household items, there were students who still did not have access to materials, making it difficult or impossible for them to perform the experiment at home. To mitigate this, the program made sure to clearly demonstrate every experiment so that the students who did not have access to materials could still follow along and learn. The program also had three teachers, so when performing experiments, breakout rooms were employed to divide the students into small groups. This allowed for more individualized instruction, which was especially helpful since students and teachers could not be together for hands-on help.

Conclusion

By inviting scientists into the homes and lives of students they represent, the Wonderkid students are able to see the wide range of possibilities for them in their future in the STEM fields. Though representation in STEM is still severely lacking, the Wonderkids Program hopes that by bringing these scientists to students who might otherwise never meet them, that the students can be inspired to pursue their dreams, whatever those might be, and truly reach for the stars to realize their potential.

Acknowledgements

USC Wonderkids Program would like to thank our funders, the USC Good Neighbors Campaign, Dr. Sian Proctor, Ms. Janey Ivey, and our other two teaching staff, Jasmin Sanchez and Spencer Huerta, for their contributions to the program.

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About the Authors

Emma Case is a senior studying Environmental Studies at the University of Southern California. Through the Joint Educational Project, she works for both the Young Scientists Program and the Wonderkids Program. She is passionate about science, the outdoors, and increasing inclusivity in education and the outdoors. She serves as President of SC Outfitters, an outdoors organization whose mission is to decrease the barriers to the outdoors and help the students of USC get outside. She can be reached at ecase@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 dkast@usc.edu.

Energy Transfer

This new column, submitted by NESTA members from their years of teaching, are intended as short class activities that can be woven into your lesson sequences or units.

This one would be appropriate for introductory work for PS3.A: Definitions of Energy or PS3.B: Conservation of Energy and Energy Transfer.

This classroom idea was used to help students visualize the concept of energy transfer using small containers. You can use plastic or paper cups or any small container that can serve as a "unit" for heat energy. The students represent the molecules to be heated.

Conduction is the energy transfer process whereby the molecules pass along heat energy from one molecule to the next as in a fireman's brigade. The molecules themselves do not actually move, but instead they pass along units of heat energy. To demonstrate this:

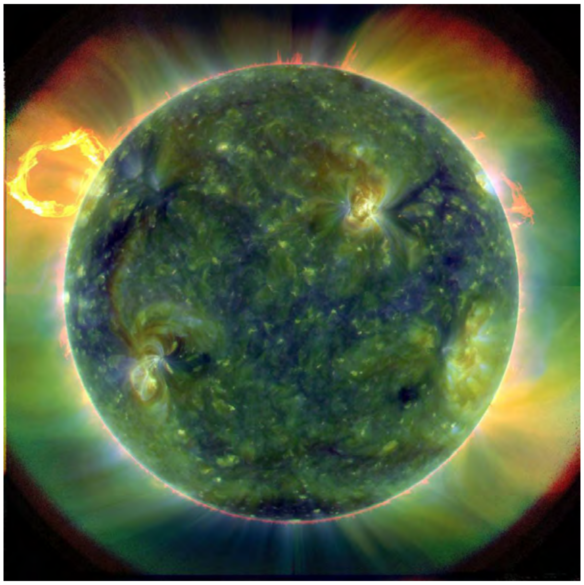
- Set up a table full of the empty containers. Tell the students that the table represents a cup of hot tea, made hot because of all the heat energy there, i.e., lots of containers.
- Have the students line up, shoulder to shoulder, in a single row of molecules. They now represent the molecules in a metal teaspoon. We "dipped" one end of the spoon into the hot tea, and the student at the table end of the "spoon", picked up a container of heat energy and passed it to the student on their right, who in turn passed the same container to the person on their right. Continue this process of picking up energy packets and passing them to the right, moving the heat energy so eventually the student at the farthest end of the spoon had containers of heat energy. The heat in the tea cup had been conducted up the length of the spoon's handle and now the far end of the spoon contained heat energy that had originally been in the teacup at the back of the room.
- Stress that the students (molecules) **did not** move in this process, just the heat energy.

Convection is the energy transfer process whereby the molecules actually move from one location to another, carrying with them the heat energy. To demonstrate this:

- Gather the containers at one table at the rear of the room.
- Have the students form a circle from the energy table with the buckets to an empty table at the front of the room and complete the circle to the back of the room again. Tell students that the front table represents a bedroom in a home, and the back table is the furnace in the basement.
- When the bedroom gets cold enough, the wall thermostat senses the temperature change, and tells the furnace to light its flame. The flame heats up the molecules of air (students) and those students in the furnace pick up a container of heat energy and begin to move up the heat pipe (a pathway cleared between desks) leading to the bedroom, "carrying" with them their packet of energy. [To avoid confusion, I had their merry-go-round go clockwise.] Once the furnace pipes got the heated molecules to the bedroom, the students deposited onto the front table their container of energy and now less warm, they continued in the circle back to the furnace to get more energy. This merry-go-round motion continued until the bedroom's thermostat sensed that the bedroom was warm enough, and told the furnace to shut off its flame. Each student molecule of air had moved and carried a unit of heat energy from the heat source, via the system of furnace pipes, up to the now warmer bedroom.
- Stress that the students (molecules) **did** move to transfer the heat energy.

To begin their thinking about **radiation**:

- Draw a quick sketch of the "Earth" on the whiteboard at the front of the room.
- Then ask, "How do we [pointing at the sketch of the Earth] get heat energy from the sun [pointing at the tableful of containers at the rear of the room]?" Have students brainstorm their ideas and discuss whether conduction or convection would be able to move heat from the sun. Discuss whether the heat could be transferred by a fire-man's brigade (conduction) or through heat pipes (convection). Ask them to think about what would be needed for conduction or convection of the sun's heat energy.
- Challenge the students "Since the sun's heat energy gets to earth, and there is no giant spoon to conduct the heat energy, and there is no system of pipes for molecules to convect the heat energy, how do you think we can get these containers of solar heat energy from the sun to the Earth?" Finally, someone may suggest, "We could throw it!"
- When radiation moves through space, it is as a packet of energy that "radiates" out from the sun. It might not be wise to have students throwing containers at the Earth, but perhaps they can visualize the result.

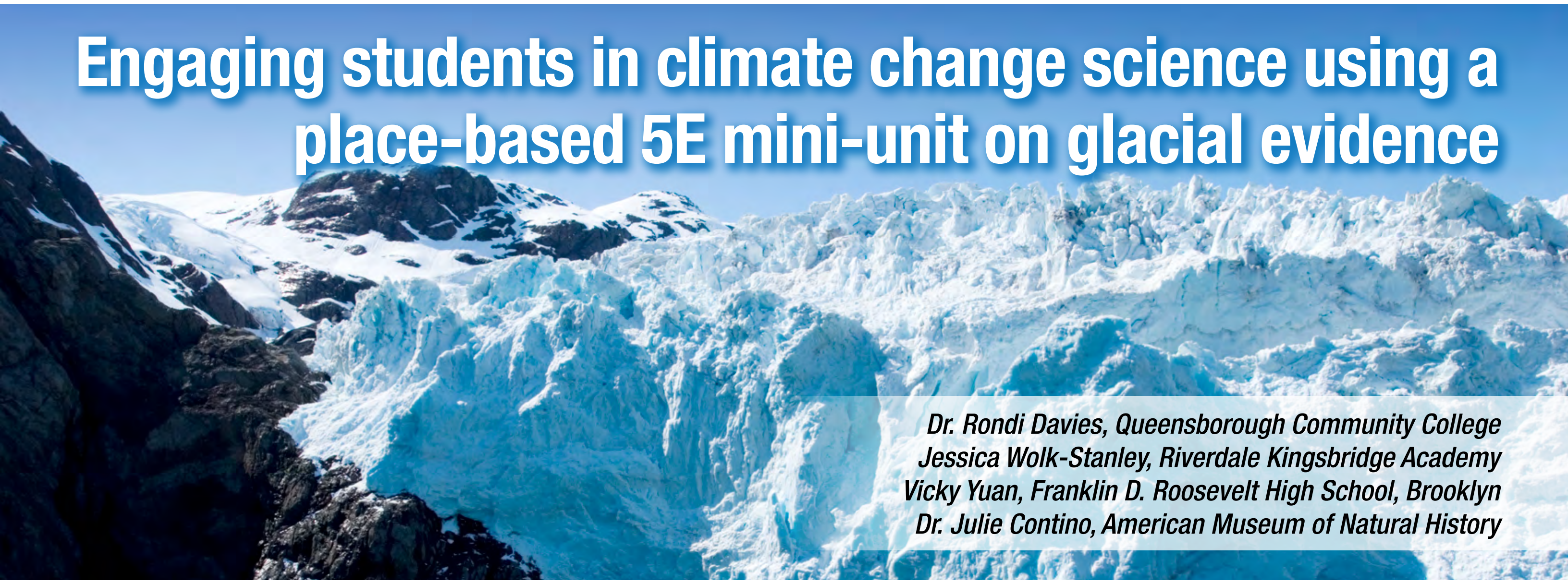


A full-disk multiwavelength extreme ultraviolet image of the sun taken by SDO on March 30, 2010. False colors trace different gas temperatures. Reds are relatively cool (about 60,000 Kelvin, or 107,540 F); blues and greens are hotter (greater than 1 million Kelvin, or 1,799,540 F).

Credits: NASA/Goddard/SDO AIA Team

ANECDOTE: This activity always worked well, but one day as the class was furiously "radiating" their energy cups toward the Earth, my building's associate principal strolled by my open classroom door, got my attention and indicated that I join him in the hallway. Once in the hall, he moved in close and with intensity yet at extremely low volume he professionally inquired, "What the (fill in your own words here) are you doing?" I had a good answer, all in the name of science.

Tom Ervin was a high school Earth science teacher for 37 years in Iowa. He is past president of NESTA and of the Iowa Academy of Science and served as the TES editor for 7 years. He is presently on NESTA's Executive Committee. Tom can be reached at tombervin@gmail.com.



Engaging students in climate change science using a place-based 5E mini-unit on glacial evidence

Dr. Rondi Davies, Queensborough Community College
Jessica Wolk-Stanley, Riverdale Kingsbridge Academy
Vicky Yuan, Franklin D. Roosevelt High School, Brooklyn
Dr. Julie Contino, American Museum of Natural History

Abstract

Science educators, including in-service science teachers, science professors, and science teacher educators, collaborated to develop a 5E mini-unit on New York's glacial history for a diverse population of urban undergraduate and high school students who face challenges such as learning remotely during COVID-19, limited science literacy, and/or acquiring English language skills. The goals of the curricular materials were to use place-based learning to increase students' science knowledge of landforms that shape their local urban environment and changes that have occurred and will occur due to climate change, while stimulating students' interest in science and further developing their science identities. We aimed to make the content relevant and accessible to students from a variety of cultural and educational backgrounds by providing students with equitable ways of learning and demonstrating knowledge in order to validate their identities and experiences and communicate an asset-based view of the value of their input in the learning environment.

Introduction

When remote learning was mandated for New York City public education institutions due to the COVID-19 pandemic, Earth science educators with specialties in geology and pedagogy met regularly over two months to develop a mini-unit on glaciation that applies best pedagogical practices to meet the needs of diverse urban undergraduate and high school students. These students are ethnically and racially diverse, include a high proportion of English language learners, tend to have limited science literacy, are from groups underrepresented in STEM fields, and were shown to be more disadvantaged during remote learning (Barber et al., 2021).

Our goal was to develop curricular materials that would engage and motivate students by using a familiar local geologic context in order to inspire a connection with their environment. We aimed to: increase scientific skills such as measuring, observing, modeling, interpreting data, and reading maps; increase content knowledge of glacial processes that shape the local environment and changes that have occurred in the past and will occur in the future due to climate change; and use pedagogical strategies to develop science interest and science identities. The lessons were developed for synchronous remote learning and can be adapted for in-person learning with slight modifications.

Methods

The methods we focused on during curriculum design included:

1. **Place-based learning:** focusing on local and regional environments has been shown to boost engagement, make content more relevant for students, and attract underrepresented groups into science (Semken et al., 2017).
2. **5E instructional model:** using a framework based in educational theory on how students learn facilitates the process of conceptual change (Bybee et al., 2006).
3. **Science skills:** focusing on practices such as observing, measuring, interpreting data, modeling, sketching, reasoning by analogy, working in groups, engaging in virtual field trips, and storytelling that validate and reflect the diversity, identities, and experiences of all students and communicate that that they are valued and their varied experiences are an asset in learning (Gay, 2002).

The Next Generation Science Standards (NGSS, 2013) are a three-dimensional approach (Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts) to K-12 science education that focus on developing student skills alongside content knowledge, in other words to "learn science by doing science". (Understanding the standards, n.d.) This 5E mini-unit allowed students to work toward developing models to illustrate how surface processes operate at various scales to form continental features. Students were provided opportunities to examine the relationships in Earth's systems that form glacial evidence along with analyzing and interpreting empirical evidence in order to make claims about and explain glacial phenomena over time.

According to Bybee et al. (2006), in the Engage phase, the teacher assesses learners' prior knowledge and engages them in new content by using short activities that promote curiosity. In the Explore phase, students participate in a common activity that entwines concepts, processes, and skills, and can surface misconceptions. The Explain phase ties the experiences from the prior phases to science concepts and the learners can explain their understanding. During the Elaborate phase, teachers challenge students to extend their understanding and apply it to new situations. Lastly, the Evaluate phase involves assessing students' understanding and evaluating their progress.

Table 1. High school NGSS performance expectation, science and engineering practices, disciplinary core ideas, and crosscutting concepts connected to the 5E mini-unit (NGSS, 2013)

Performance Expectation HS-ESS2-1. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.
Science and Engineering Practice
Developing and Using Models Modeling • Develop and use a model based on evidence to illustrate the relationships between components of a system. **Analyzing and Interpreting Data** • Analyze data using tools, technologies, and models (e.g., computational, mathematical) in order to make valid and reliable scientific claims.
Disciplinary Core Idea
ESS2.A: Earth Materials and Systems • Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
Crosscutting Concept
Stability and Change • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. **Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. • Empirical evidence is needed to identify patterns.

We started with the phenomenon of changes in the Alaskan landscape over 100 years and our overarching question was: How do glaciers change the landscape? Each part of the 5E model (Table 2) was a lesson that took approximately 45-90 min (in a high school setting, approximately 1-2 class periods).

Table 2. A summary of the 5E phase, purpose, and associated activity for the mini-unit

5E Phase	Purpose	Activity
Engage	Surface prior knowledge about glaciers.	Compare images of glaciers from the past 100 years and observe and sketch a glacial landscape.
Explore 1	Observe that glaciers move.	Measure and graph the rates of Alaskan glacier advance and retreat.
Explore 2	Observe that glaciers shape the landscape.	Use physical models to explain how glacial landforms are created.
Explain	Describe how glaciers create erosional and depositional landforms.	Sketch, reason by analogy, and work in groups to explain how glacial erosional and depositional features are formed.
Elaborate	Apply knowledge to identify glacial features in New York State and connect to past climate.	Take a virtual field trip with Google Earth or Google Maps to identify and interpret glacial landforms across New York State and connect to New York's past climate history.
Evaluate	Apply knowledge to identify other glacial features in the Glacier National Park, the Andes Mountains, or Mars.	Role play as a scientist and write a report that interprets the features on a currently glaciated landscape.

The 5E Teaching Module

Engage

Students viewed sliders on a website (https://contrib.pbslearningmedia.org/WGBH/ipy07/ipy07-int-glacierphoto/index.html) showing images of Alaskan glaciers in the present and past (Figure 1a). They were asked to notice changes and patterns and to speculate on why this may have occurred. We also asked students to sketch their observations (Figure 1b).

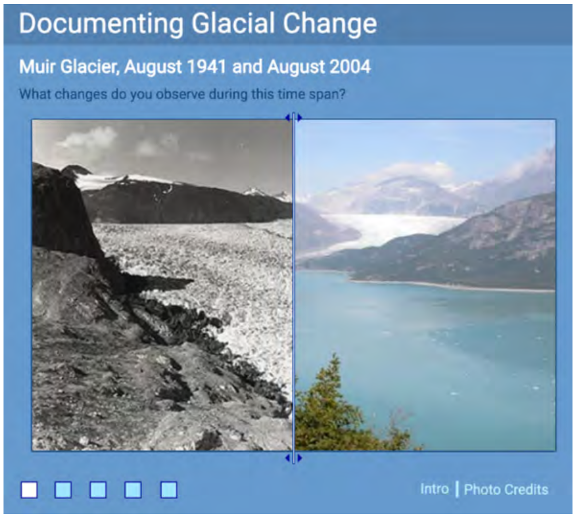


Figure 1a. Interactive slider/curtains showing changes to glaciers over 100 years. < screenshot from: https://contrib.pbslearningmedia.org/WGBH/ipy07/ipy07-int-glacierphoto/index.html>

Figure 1b. Example of a student sketch of a glacier from the PBS Learning website. Some students used digital tools to create their sketches.

Explore 1

Each student collected and tabulated data on glacier movement from three Alaskan glaciers and made a graph of one of the locations. They noticed where glaciers advance or retreat and calculated rates of movement. We then discussed potential causes for these movements including glacial melt

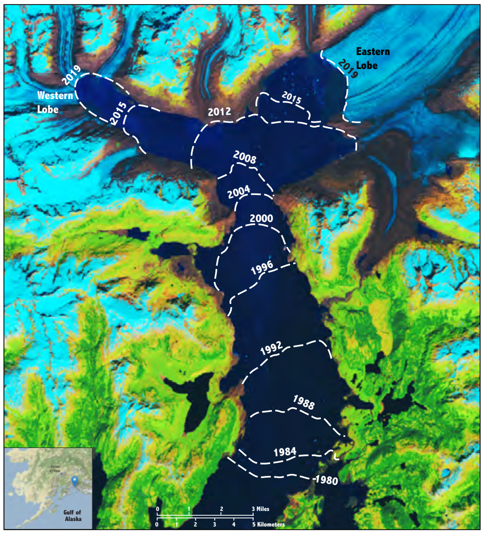


Figure 2a. Students measure the distance of glacial retreat using a ruler and scale bar. They then calculate the rate of movement. Here is an example from the Columbia glacier.
NASA.gov https://landsat.visibleearth.nasa.gov/view.php?id=145525

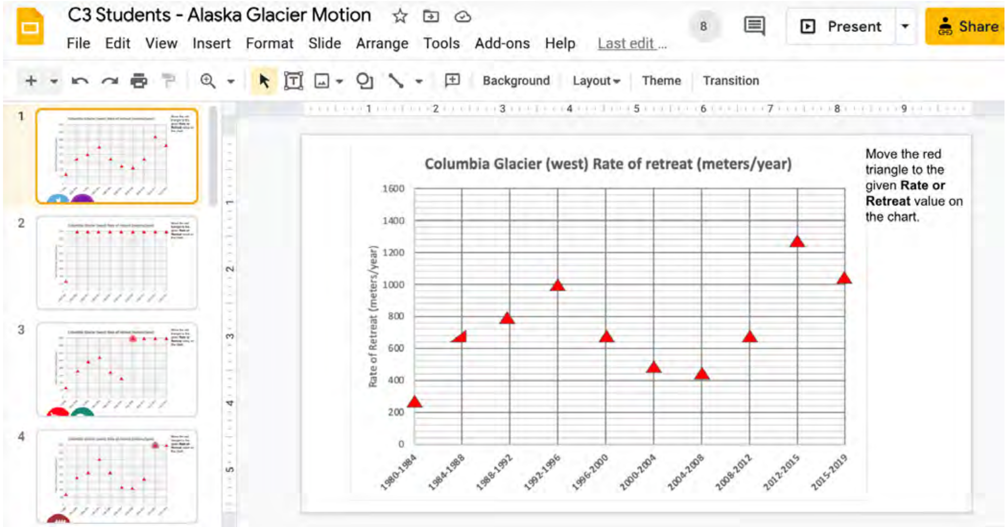


Figure 2b. Google slides were used to graph the rate of glacial retreat for the Columbia glacier.
< screenshot from: https://docs.google.com/presentation/d/1ElslDuFLnCvRJz6hiKN5tJ3K7n093fBpZ8mlPM9FqLg/edit?usp=sharing>

due to temperature increases and climate change. In order to make graphs in a remote learning situation, we had students manipulate points on a graph using Google slides (Figure 2a & 2b) which strengthened their technology skills. In the classroom, students could graph using paper or an Excel spreadsheet.

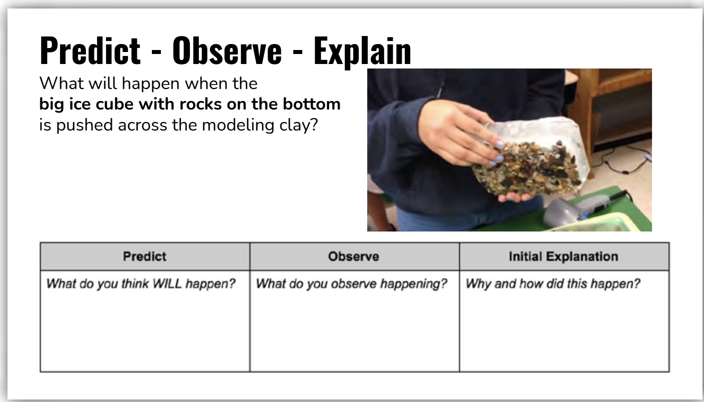


Figure 3. Video demonstration and POE chart on the formation of glacial striations and erratics. < screenshot from: https://www.youtube.com/watch?v=hkFUolG06Nc>

Explore 2

Students observed how glaciers change the landscape when they watched a demonstration by the teacher in real time as well as a video of an investigation. (In the classroom, students could partake in the demonstrations.) Students then completed a Predict-Observe-Explain (POE) chart for each investigation as seen in Table 3. The POE is an instructional strategy that involves sharing a phenomenon with students and having them make predictions. Students then record observations, and lastly, develop initial explanations for their observations.

Later, students completed the "Analogy of a model tool" which asked them to identify parts of the model and compare each to the real world.

Table 3. Student samples from the POE for the model for the formation of glacial striations and erratics.

Predict	Observe	Explain
• The green clay will have traces of pebbles and the clay will turn hard. • The ice can't move due to the rough face of the block and the sticky face of the clay. • I think that the clay will have some pebbles stuck to it after it was pushed along the clay.	Rocks are being left behind and the ice melted over the clay. The ice caused fractures in the clay.	The movement of the ice with rocks over the putty caused the rocks to carve the putty and drop rocks.

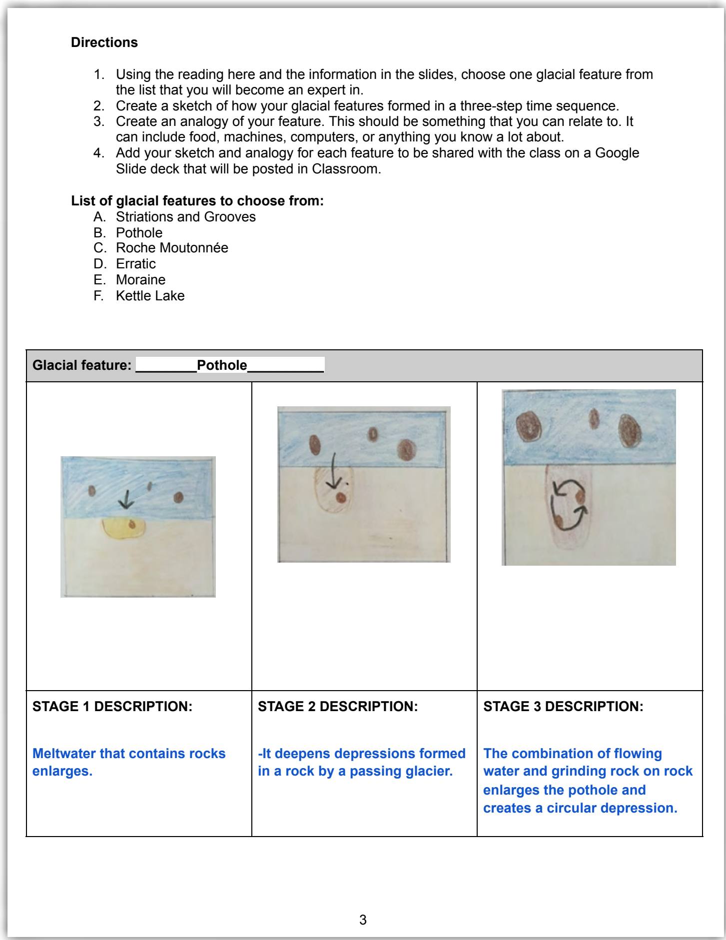
Table 3. Compiled student work of Rondi Davies, Jessica Wolk-Stanley, and Vicky Yuan.

Explain

In this phase, students were asked to visualize and explain glacial processes by creating a sequence of annotated sketches to show how various glacial landforms develop (Figure 4).

They then developed analogies for this process from their own lives to enhance meaning-making and student connection to scientific content and processes. Examples of this include food, such

Figure 4. Example of an annotated student sketch showing the formation of a glacial pothole.


Directions

1. Using the reading here and the information in the slides, choose one glacial feature from the list that you will become an expert in.
2. Create a sketch of how your glacial features formed in a three-step time sequence.
3. Create an analogy of your feature. This should be something that you can relate to. It can include food, machines, computers, or anything you know a lot about.
4. Add your sketch and analogy for each feature to be shared with the class on a Google Slide deck that will be posted in Classroom.

List of glacial features to choose from:

A. Striations and Grooves
B. Pothole
C. Roche Moutonnée
D. Erratic
E. Moraine
F. Kettle Lake

Glacial feature: ________Pothole__________		
STAGE 1 DESCRIPTION: Meltwater that contains rocks enlarges.	STAGE 2 DESCRIPTION: -It deepens depressions formed in a rock by a passing glacier.	STAGE 3 DESCRIPTION: The combination of flowing water and grinding rock on rock enlarges the pothole and creates a circular depression.

3

Table 4. Samples of students' analogies for selected glacial processes

Glacial Feature	Student Analogies
Erratic	Finding random pieces of trash on the ground.
Pothole	Potholes are holes in the road that are caused by the pavement cracking.
Kettle Lake	Ice cream and cake: the ice cream is placed on top of a cake; it softens the cake and begins to soak into it; the ice cream melts on top of the cake creating an ice cream lake.
Striations	Scratching an eraser with the end of a paperclip.
Moraine	Sweeping: all the dust (broken bedrock) is swept (glacier movement) into a heap (moraine mountain).

Credit: Jessica Wolk-Stanley, Annabelle Jimenez

as ice cream melting on warm pudding as an analogy for a kettle lake, or urban phenomena such as a pothole on a road being an analogy for a glacial pothole (Table 4). This activity was designed to connect science content with student experiences and provide an equitable way for English language learners (and other students challenged by academic language) to participate and demonstrate understanding.

Elaborate

For the Elaborate phase, we developed a virtual field trip in Google Maps and Google Earth that highlighted local and regional glacial evidence. Each location included photos of glacial features that students could click on to examine.

Students applied their knowledge of how glaciers change the landscape to examples throughout New York State, while making connections to past climate change. This connected students to their local/regional environment and developed their

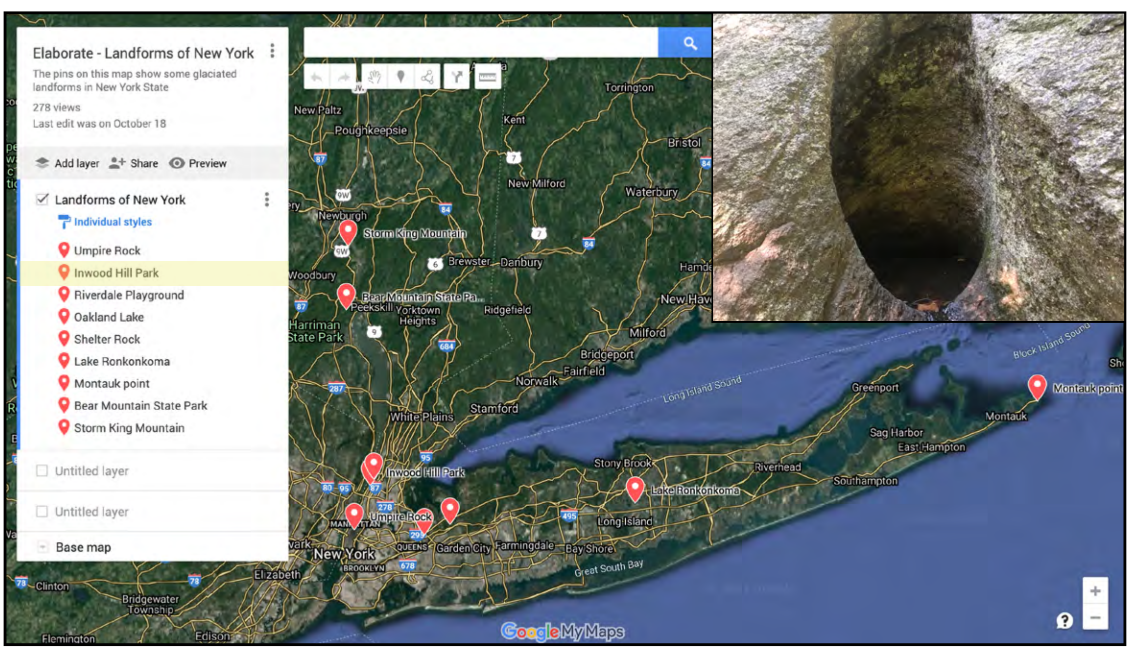


Figure 5. Google Maps view of nine virtual field trip sites in New York City and the surrounds that host glacial features. Inset shows glacial pothole at the Inwood Hill field site in northern Manhattan. https://www.google.com/maps/d/u/2/viewer?mid=18QK04DUYf6vRs3pP6Pdijm27SyadmMal&ll=41.09639048590813%2C-72.92907889999996&z=8 >

understanding of how past climate change shaped the landscape. This activity also supported map-reading skills and the use of technology and was a field experience accessible to all students.

Evaluate

In the final Evaluate phase, students were asked to take on the role of a lead scientist by applying their newly learned knowledge to new scenarios (Table 5). Set in the future, students selected from three options: lead geologist, primary investigator at NASA, or science professor, and wrote a proposal to examine new locations to look for glacial evidence.

Students were encouraged to include sketches of how potential glacial features may have formed. This allowed students to develop their science identity and allowed teachers to evaluate student learning.

Table 5. Sample student role-play scenario to document glacial features in new landscapes

Instructions: Choose an option below and write a detailed report as the lead scientist working on the project. Include scientific sketches of glacial landforms and processes you identify.

Scenario: You are the principal investigator at NASA for the next Mars mission. It is your job as the lead scientist to propose where to send the next rover. You are investigating whether ice was once present on Mars' surface and have to comb through preliminary data and existing images to help you narrow down where to send the rover. Write a proposal that indicates where the rover should land to look for glacial evidence and what led you to that decision. Include two or more landforms that indicate the possibility of glaciers and describe how they formed.

Student report: After careful evaluation of the data I've been sent, I have come to a conclusion as to where on Mars the rover should land. The images below were selected from the preliminary data I was given, and they both display places worth investigating. From the images themselves, I can infer that ice was once present on Mars' surface. In fact, not only was it just present, but it was in the form of a glacier.

The first image shows a surface on Mars that has very clear parallel lines etched into it. These lines can be compared to the striations we see on some rocks on Earth. Striations are formed when rocks and/or boulders get trapped underneath a glacier, and they scrape against the rock under them as the glacier moves. As they do this, the rocks leave parallel lines on the surface.

The second image displays an almost beach-like area on Mars. There is a small decline in the land, and at the bottom of it is an area filled with rocks and boulders varying in size. The best explanation for how all those rocks got deposited there is to say that it's a moraine. Moraines are formed when material like rocks and boulders fall off a glacier, or get in it's path. The glacier pushes this fallen material and deposits it elsewhere.

In conclusion, there is too much evidence that glaciers once existed on Mars to ignore. The rover should be sent to these two locations to further investigate them, and to see if there's any other glacial evidence close to them.

Table 5. Student work of instructor Jessica Wolk-Stanley.

Conclusions

During a year of remote learning caused by the COVID-19 pandemic, this group of science educators came together to address some of the learning inequities that students face and to be intentional and inventive in teaching. The outcome was a place-based, 5E mini-unit about New York glacial landforms which adopted pedagogical practices to promote learning and stimulate science interest and identity for diverse learners underrepresented in STEM fields. In Spring 2021, each of the classroom educators taught the curriculum at the community college and high school levels. We found that regardless of their initial knowledge, all student groups increased their content knowledge of how glaciers carve the landscape by 41% (Davies et al., 2021). Equal learning gains for all groups (including ELLs) suggests our use of equitable pedagogical methods was successful. One challenge we faced when teaching the mini-unit in an online setting included motivating students to work in groups. Additionally, students needed further scaffolding for measuring the distance of glacial movement in the Explore 1 phase and developing analogies for glacial processes in the Explain phase.

The cross-disciplinary collaboration between scientific and education specialists was a mutually beneficial professional development experience in terms of mentorship and feedback. It allowed for rigor in working with scientific and pedagogical approaches, the sharing of technology strategies for active online learning, and also provided needed support during interrupted education.

For access to the mini-unit and teacher's guide visit: https://tinyurl.com/3c88v7mv

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The Rock Cycle Revisited

Dr. James Ebert, SUNY Oneonta

Abstract

All models are imperfect representations of their targets (Gilbert and Ireton 2003). As simplified representations, models emphasize certain aspects of the target and obscure or omit other aspects. It is important to discuss the limitations of each model with students, especially middle and high school students. The Starburst model of the rock cycle, published in the summer 2021 issue of *The Earth Scientist*, was intended for elementary students, but this model is limited in helping older students understand the processes of lithification, formation of foliation in metamorphic rocks and does not model formation of igneous rocks from a molten state. Lithification, formation of foliation, formation of solid materials from a melt, and the influence of rate of cooling on crystal size can be modeled in more realistic ways that avoid common misconceptions associated with the processes of the rock cycle, an important concept for Earth science literacy.

Introduction

Models are simplified representations that enable better understanding of target concepts (Ingham and Gilbert, 1991; Gilbert 1995; Gobert and Buckley 2000; Gilbert and Ireton 2003). Models are important components of the process of science as practiced by scientists (Manduca and Kastens 2012) and in teaching science by science educators (Kastens and Rivit 2008). Physical models are especially useful in facilitating students understanding (Dede et al. 1999; Bryce et al. 2016). Unfortunately, many commonly used models can create or reinforce misconceptions. The Starburst candy model (Barakat et al. 2021) is a simple model intended to introduce elementary students to the rock cycle but it contains inaccuracies and may promote common misconceptions related to processes that form rocks (Kusnick 2002; Kortz and Murray 2009). Problems with simple models are examined below, followed by descriptions of more accurate models of rock-forming processes for use with older students who can better understand complex processes.

Sedimentary Rocks

Some descriptions of how sedimentary rocks indicate that they are formed as a result of immense pressure being applied to sediments from overlying Earth materials. To illustrate this, some models use a stack of candy or clay compressed vertically. This model implies that the weight of overlying rocks compresses sediments to form sedimentary rock. Pressure is simply not a factor in the formation of sedimentary rocks. Further, changes in shape occur during deformation and metamorphism but **not** in the formation of sedimentary rocks.

Students sometimes conflate pressure with compaction. Compaction rearranges grains thereby reducing porosity but it does not result in lithification, the conversion of sediment to rock. Lithification involves locking sediment grains together by the addition of mineral cements precipitated from the groundwater that flows through the pore spaces in the sediments. Cement crystals (commonly calcite or quartz) precipitate on the surfaces of sediment grains (Figure 1). As these crystals grow, they eventually interlock "gluing" the grains together forming sedimentary rock. If compaction precedes cementation, the effect is that there is less porosity to fill with mineral cement.

Figure 1. Crystals of calcite cement in a lithified Pleistocene conglomerate. Photo Credit: James Ebert

Compaction is not necessary to form sedimentary rocks. In tropical settings where $CaCO_3$ sediments (commonly mollusk shells, corals, etc.) accumulate, seawater is supersaturated with $CaCO_3$ and cementation can occur on the sea floor with no overlying sediments to induce compaction (Figure 2). Some Pleistocene glacial sediments (e.g., outwash) have been lithified by cements precipitated from groundwater (Figure 1). These young conglomerates formed at Earth's surface and have never been buried, so compaction has not occurred.

Figure 2. Lithified beachrock in the Florida Keys. Photo Credit: James Ebert

Metamorphic Rocks

Barakat et al. (2021, p. 7) state that "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..." Metamorphic rocks form as a result of heat and pressure applied to pre-existing rock. However, in the geothermal settings described, heat is present, because such areas are associated with magma bodies and lack the pressure needed to form metamorphic rocks. Metamorphic rocks form most commonly in the roots of mountains (regional metamorphism) by the interaction of lithospheric plates. Here, heat to form metamorphic rocks results from higher temperatures deep in Earth's crust and the pressure is from collision of tectonic plates. Middle and high school students should be developing a more complex understanding about plate movement and interaction, along with the formation of metamorphic rocks.

To simulate formation of metamorphic rocks, simple models have students compress the candies and then expose the candies to heat generated by students rubbing their hands together before handling the candies. Pressure is directed vertically in the Starburst model, unlike the predominantly horizontal forces present in mountain systems and heat is applied as a separate process. In mountains, heat and pressure act concurrently to form metamorphic rocks.

Figure 3. Folded foliation in metamorphic rock (gneiss) illustrating the effects of horizontally directed forces. Photo Credit: James Ebert

Simple models may indicate that metamorphic rocks "can be difficult to discern from sedimentary and igneous rocks" (Barakat et al. 2021). The procedures for formation of sedimentary and metamorphic rocks in simple models are nearly identical and so are the results. In reality, metamorphic rocks are readily distinguished from sedimentary and igneous rocks because they display observable features including foliation (alignment of crystals), deformation (folding of foliation; Figure 3), recrystallization (enlargement of pre-existing crystals) and growth of new minerals (e.g., chlorite, muscovite, biotite, garnet, amphiboles, etc.).

Igneous Rocks

Igneous rocks form by the cooling and crystallization of melted rock (magma). This liquid phase enables the growth of mineral crystals as the magma cools. Although volcanoes are the most visible manifestations of igneous processes, many igneous rocks form when magma cools below Earth's surface. Simple models use heat from hand warmers to represent the heating process and candies may be softened but not melted into a liquid state. This would not show the difference between the modeled processes of metamorphism and formation of igneous rocks. Using a microwave oven to melt the candies is more useful but this process is not transparent to the students.

Realistic Models of Rock Formation for Middle and High School Students

Sedimentary Rocks

Lithification of sediments can be modeled effectively with aquarium gravel. Place a small pinch of sodium acetate trihydrate (Read the Materials Safety Data Sheet (MSDS) first.) into a small plastic cup. Measure 60-70 grams of aquarium gravel; wet it and place on a paper towel to absorb excess water. Add the gravel to the cup containing the sodium acetate powder (crude model for deposition). Then, add a supersaturated solution of sodium acetate trihydrate (instructions on making a supersaturated solution can be found online). Within minutes, crystals of sodium acetate will precipitate in the pores between the gravel particles (Figure 4). After 30-60 minutes cut the cup away to reveal the sedimentary "rock" with clearly visible cement crystals that have lithified the gravel. This model directly confronts the common misconceptions that sedimentary rocks are formed by pressure, compaction, drying or accretion ("growing pebbles" of Kusnick 2002) as these processes are absent in the formation of the synthetic rock (Rappa et al. 2011). Details of this model may be obtained from this author.

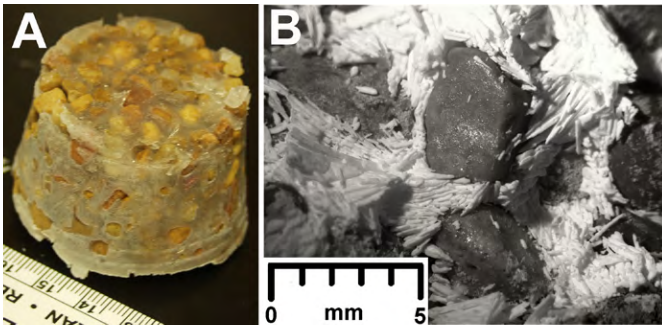

Figure 4a and 4b. Synthetic conglomerate produced by cementation of aquarium gravel with sodium acetate crystals. Photo Credit: James Ebert

Metamorphic Rocks

Modeling the formation of metamorphic rocks is challenging owing to the complexity of the changes that occur. It is not practical to model recrystallization or formation of new minerals in a classroom. However, it is possible to model the formation of foliation via directed pressure. A common strategy for modeling foliation uses a ball of Play-Doh that is embedded with pennies, sequins or other planar objects. The ball is pressed between the hands, reorienting the planar particles (Figure 5a). Note that the force is directed horizontally as is the case in the collision of tectonic plates. One should avoid flattening the ball on a tabletop to avoid the misconception that the pressure is directed vertically during metamorphism. A shearing motion of the hands can also achieve reorientation of planar elements (Figure 5b). The

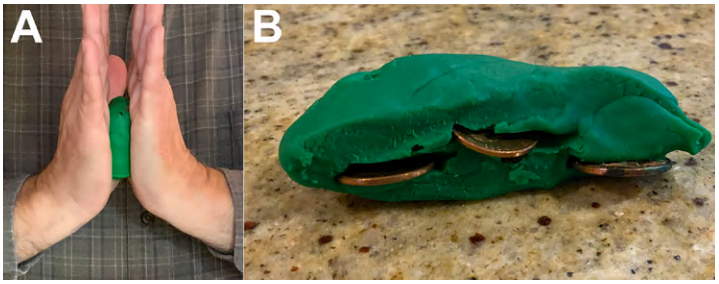

Figure 5a and 5b. Modeling foliation in metamorphic rocks by reorientation of pennies in Play-Doh. Photo Credit: James Ebert flattened ball may be cut open to observe the realignment of the planar elements.

Igneous Rocks – Lava Flows

Paraffin wax (or crayons) provides a much more realistic model of the formation of igneous rocks. They have a low melting temperature and solidifies at room temperature. A dripping candle may be used to produce "lava flows" (Figure 6). Larger "lava flows" can be produced by melting a larger quantity of wax in a double boiler. This avoids burning the wax. The solidified wax is analogous to igneous rock because it formed from a hot, liquid state that mimics magma.

The crystalline nature of igneous rocks can be modeled effectively through the use of thymol, a crystalline organic compound. Thymol is a skin, eye and respiratory irritant (See MSDS) and should only be used in sealed containers such as flasks with rubber stoppers. Small quantities of thymol are placed in flasks and sealed with rubber stoppers. Flasks are then placed on a hot plate set at a low temperature. Before the last crystals melt, remove the flasks from the hot plate. The effect of different rates of cooling on crystal size can be modeled by using two flasks (Figure 7). One flask of melted thymol is placed on the tabletop and the other is placed in a container of crushed ice. Students should first predict which rate of cooling will produce the larger crystals. The sealed flasks can be passed around so that students can verify or reject the predictions that they made. The sealed flasks of thymol can be re-heated and reused indefinitely.

Figure 6. Wax model of "lava flow." Photo Credit: James Ebert

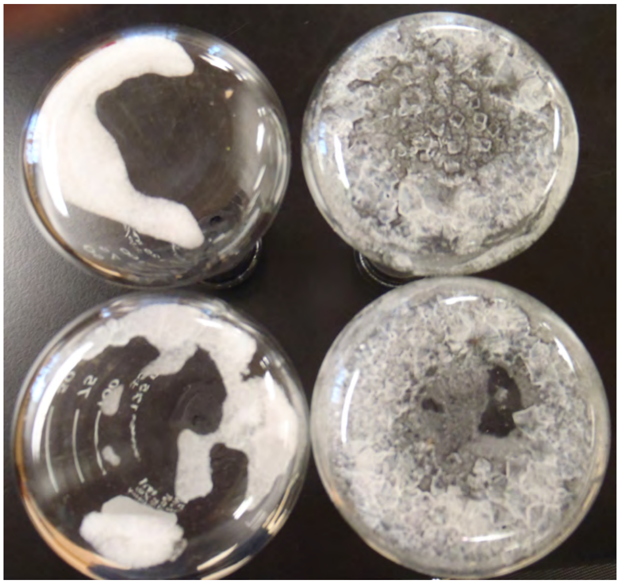

Figure 7. Small (left) and large (right) crystals of thymol produced by differing rates of crystallization from melt. Photo is of the bottoms of sealed flasks. Photo Credit: James Ebert

Limitations of Models for Rock-Forming Processes

All models, including those presented here, are imperfect representations of their targets (Gilbert and Ireton 2003). As simplified representations, models emphasize certain aspects of the target and obscure or omit other aspects. Therefore, it is important to discuss with students the limitations of each model.

In the lithification model described above, the crystals of sodium acetate that lithify the gravel do not always nucleate on the surfaces of the grains (Figure 4) as is the case when cement crystals precipitate from groundwater (Figure 1). The rapid rate at which the sodium acetate crystallizes is a poor analog for the gradual growth of cements in pore spaces over the long periods of time available with geologic processes.

The foliation model described above only addresses the formation of foliation by reorientation of pre-existing planar crystals. It does not illustrate foliation by growth of new planar minerals (e.g., micas in schists) or the formation of mineral banding (e.g., gneiss). Recrystallization and the formation of new minerals that result from the heat-induced mobility of ions are not represented in this model. Further, the model is very small in scale compared to the immense volumes of rock metamorphosed in collisional mountain systems. The scale of this model may reinforce students' misconceptions regarding how did this *particular* rock form rather than how did this *type* of rock form.

Use of a candle to model lava flows may lead younger students to believe that fire is necessary to melt rock, so using a double boiler is preferable. Although thymol clearly models the formation of crystals from a melt, the model suffers from the fact that only a single type of crystal is formed.

In magmas, multiple mineral crystals (e.g., feldspars, quartz, micas, amphiboles, etc.) form as the melt cools.

Conclusion

Each of the models presented illustrate the formational processes of each of the major rock families. They do not show the complete rock cycle in which any type of rock can be converted to any other type by the appropriate processes operating on an initial rock. Despite this shortcoming and the limitations of the individual models, these are starting places for middle and high school students to better understand the complexities of the rock cycle.

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About the Author

Dr. James Ebert is Distinguished Teaching Professor, emeritus at the State University of New York at Oneonta (SUNY Oneonta), where he taught for 36 years. Throughout his career he has been actively involved in pre-service teacher preparation and professional development of in-service teachers. He is the founder and moderator of the ESPRIT (Earth Science Peer Resource for Improved Teaching) listserv. Dr. Ebert is also the founder of SUNY Oneonta's Earth Science Outreach Program which offers dual credit geoscience courses in high schools across New York State. His research includes sequence stratigraphy, the use of microfossils and volcanic ash beds in calibrating the geologic time scale and the use of models in geoscience education. He is a Fellow of the Geological Society of America and member of several other geoscience professional societies. Dr. Ebert was on the writing team for the Earth Science Literacy Principles and has been a facilitator for the National Association of Geoscience Teachers (NAGT) Traveling Workshops program. He is a recipient of the NAGT Eastern Section's John H. Moss Award for Excellence in College Teaching. He can be reached at James.Ebert@oneonta.edu.

Expand the Focus on Your Community with Environmental History Trail Signs

Dr. Michael J. Passow

Abstract

We describe an example of a community-based science education project consisting of signs for an environmental history trail. Using a combination of local social history and local geological history, we created the text for fifteen signs, plus longer descriptions on the city's web site of a natural area in New Jersey. Such a project fosters place-based learning and pride in the home community. Students can help create a contribution to their local community which can last for decades.

Introduction

Every community is the result of a series of natural and engineered events. As science teachers, we want our students to gain understanding of the geological events that created their community's appearance. But why stop with your students? Why not help educate the entire community through environmental history trail signs? Why not teach about your community to everyone in town and build a sense of pride, along with greater knowledge of Earth science?

This is one example, based on what we did in my home community of Englewood, NJ, where I serve on our Environmental Commission and as a member of our local historical society. However, you do not need official connections to conduct a project like this. You can begin with just an idea and the drive to make it happen. It can be done as an individual or as a class/group project, depending on who is interested and locally knowledgeable. I was able to create most of the Englewood projects as a solo act, although I confirmed some of the social history with our local historians, worked with the city manager on the signage, and the city web manager on the photographs of local geologic features, and references that were posted on the city web site at (http://www.cityofenglewood.org/filestorage/9306/11306/11308/Englewood_Environmental_History_Trail_Overview.pdf).

Partial financial support for our project came from a grant from ANJEC (Association of New Jersey Environmental Commissions) and private donations. Funds can also be raised through local Rotary Clubs or other service organizations. The main expense is for the signs and posts. We worked with a local sign company, who recommended use of aluminum signs on tubular posts set in concrete. These have withstood several winters and an unknown number of hands small and large, testing the resilience of the signs.

Text can include only simple facts, such as the location's geography and geology.

Figure 1. Basic geographical facts. This sign is in a well-trafficked area in the center of town. Photo credit: Dr. Michael J. Passow

Figure 2. Regional Bedrock Geology
Photo credit: Dr. Michael J. Passow

Figure 3. Nickname for the features on the main road of the eastern side of town Photo credit: Dr. Michael J. Passow

The eastern side of our city is called the East Hill. It gets its topography from the more resistant basaltic rock of the Palisades sill, compared with softer sedimentary rocks on the western side. There are various levels to the slope, which early settlers imaginatively called the "Seven Sisters," so this combination of geological and social history were combined in a sign.

Today, Englewood is a suburb of New York City, but in the early 20th century, there was a small traprock (stone) quarry about two miles from where the George Washington Bridge was built a few decades later.

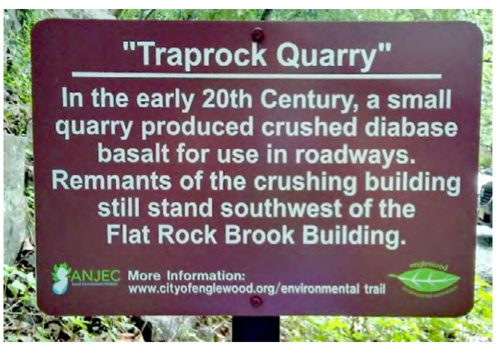

Figure 4. Traprock (basalt) quarry
Photo credit: Dr. Michael J. Passow

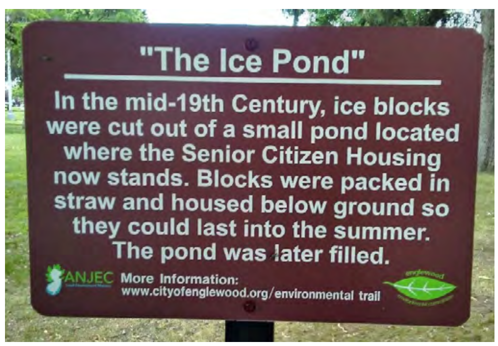

Figure 5. Near the site of the ice pond
Photo credit: Dr. Michael J. Passow

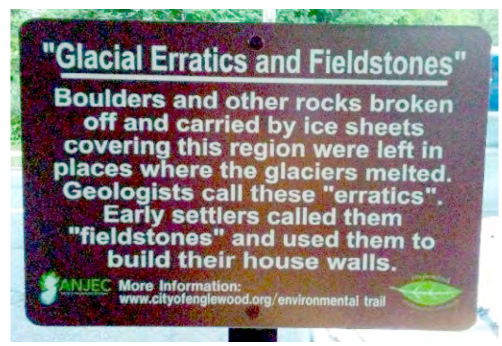

Figure 6. Glacial erratics and 'fieldstones'
Photo credit: Dr. Michael J. Passow

Your community probably has a local history section in its library where you can learn interesting examples of science-related events For, instance, another combination of geoscience and social history is commemorated in the sign near where one of the local ice ponds was located.

Englewood lies just north of the terminal moraine of the Wisconsin ice sheet. As such we have a lot of glacial erratics, many of which were used in building walls of the earliest homes. In many communities, such erratics were also used to construct stones walls.

The area was also covered by a glacial lake for more than two thousand years.

In its earliest days, Englewood was linked with neighboring cities by muddy roads. In the 1850s, plans were being developed to build a canal by utilizing an existing stream that flowed through the center of town and acted as the local sewer. However, the Civil War and the coming of a rail-road brought such plans to an end. The last remnant of the canal is a channeled ditch next to our main park.

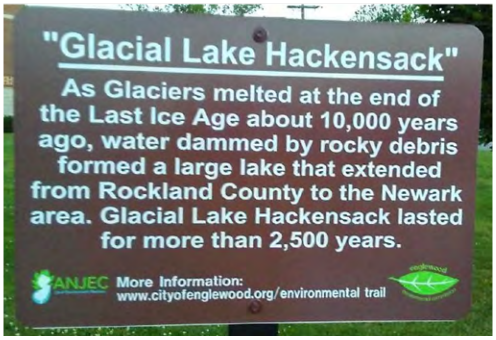

Figure 7. Glacial Lake Hackensack
Photo credit: Dr. Michael J. Passow

Figure 8. The Englewood canal
Photo credit: Dr. Michael J. Passow

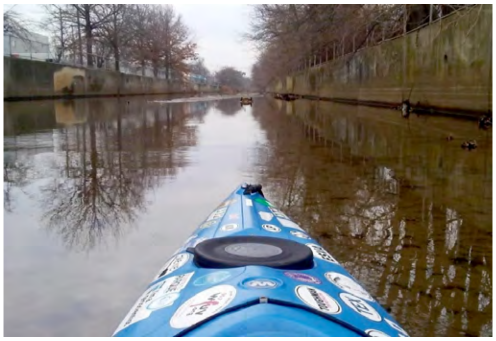

Figure 9. Remnant of the channelized stream that was to become the Englewood Canal
Photo credit: Dr. Michael J. Passow

Altogether, there are fifteen signs on the environmental history trail. Others describe the water supply and wastewater systems; the primordial Eastern Woodlands forest that covered the area before the coming of the European settlers; use of brownstones (locally quarried sandstones used for some churches and other prominent buildings); and the largest local stream system. One sign of special significance marks the Northern Railroad.

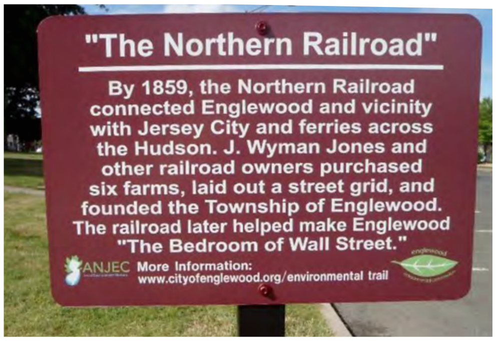

Figure 10. The Northern Railroad
Photo credit: Dr. Michael J. Passow

Its construction, beginning in 1859, led to the founding of Englewood and transformed six farms into what became known as the "bedroom of Wall Street." Many mansions were home to prominent New York City bankers and stockbrokers, especially in the J. P. Morgan company (including Dwight Morrow and Thomas Lamont), and the deforestation of the original Eastern Woodlands Forest for railroad ties and building materials.

If appropriate, students can be encouraged to find examples of environmental injustices, such as waste disposal sites in poorer sections of town. Each community has its own story that deserves wider dissemination through presentations to PTAs, service organizations (such as Rotary Clubs), and public programs, such as Library talks. Funding for signs should be available through grants or local fund-raising efforts. A program like this can lead to a variety of interdisciplinary efforts in the classroom, such as creating signs in languages other than English. Students can work as individual investigators or work in teams to develop important skills for later job skills.

Student understanding can be assessed by having students select one of the signs, learn more about the topics, and give a short presentation to their classmates or students in lower grades. Since there is only a limited number of signs, students can develop presentations about other aspects of the local community environment and the populations that have lived in the area.

Finally, a local environmental history program can empower students to develop deeper connections with their community and create a contribution that can last for decades.

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Table 1. The chart makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely.

Table 1. Connecting to the Next Generation Science Standards (NGSS Lead States 2013)

Performance Expectation

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Dimensions	Classroom Connections
Science and Engineering Practices	
• Constructing explanations and designing solutions using multiple and independent sources of evidence consistent with scientific ideas, principles and theories. • Obtaining, evaluating, and communicating information.	• Students investigate local geologic and historical events to develop explanations that can be shared through signage at important local sites. • Students access a variety of historical, geologic and local knowledge information to develop a signage for a selected site.
Disciplinary Core Idea	
ETS1.B: Developing Possible Solutions • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.	• Students prepare maps of the selected sign placements, considering costs and safety. They will develop a project budget and then plan to find funding for installation and maintenance.
Cross-Cutting Concepts	
• Connections to Engineering, Technology, and Applications of Science.	• Students will learn about how geologic formations and historical events have influenced human activities in their area.

Common Core State Standards Connections: ELA/Literacy

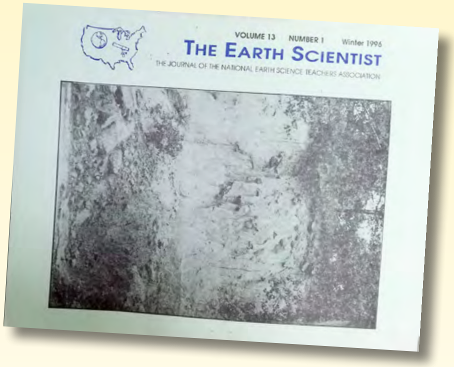
RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. *(HS-ETS1-3)*

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *(HS-ETS1-3)*

About the Author

Dr. Michael J. Passow has been an Earth Science educator for fifty years, and a two-time past President of NESTA. He has taught at the middle, high school, and university levels. Currently, he is a Visiting Professor in the Master of Arts in Teaching Program at the Richard Gilder School of the American Museum of Natural History. He is also the founder and organizer of the Earth2Class Workshops at the Lamont-Doherty Earth Observatory of Columbia University, and Newsletter Editor of the International Geoscience Education Organization (IGEO).

25 Years Ago in TES



Twenty-Five years ago, in 1996, TES was in its thirteenth year of publication. The focus of this Winter issue was Soils. The front cover is a photo showing a Loess bluff near Kansas City. The Winter issue led off with a six-page Guide to Soils. This was followed by an article which dealt with Soil Texture. Then there was an article about the protective role of soil. This was followed by a discussion of soil texture. Next was an article about soil porosity. There was an activity comparing soil porosity to the efficiency of paper towels. Next, there was a summary of NASA's Discovery Program including "Stardust", a mission to Comet Wild-2, to collect comet-dust and return it to earth. [FYI, this mission was successful and the comet-dust samples were returned in 2006. The same spacecraft was recycled for the Stardust-NExT mission, which flew by comet Tempel 1 on Feb. 14, 2011.] There was an editorial positing that America's schools are not designed nor equipped for the 21st century. And finally, there was a concise, one-page article introducing the "new" [Dec. 1995] National Science Education Standards, recently released by the National Research Council, an arm of the National Academy of Science.

By Tom Ervin

NGSS-ESS Working Group

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

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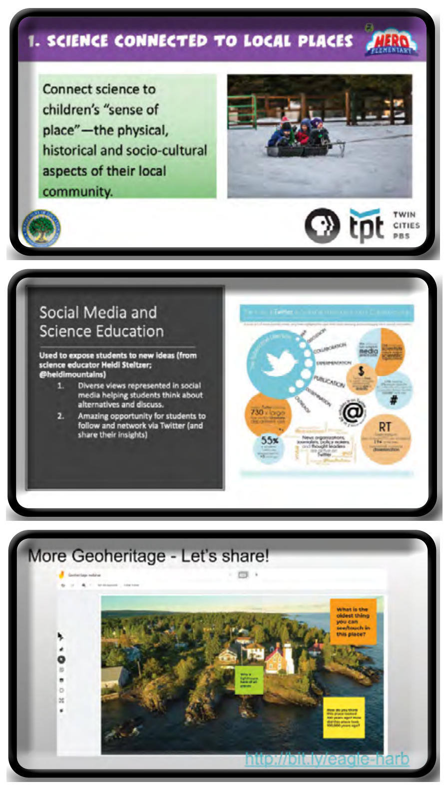

Sample presentation slides from NGSS-ESS Working Group webinars.
Top slide courtesy of Twin Cities PBS, https://www.tpt.org; Bottom: Drone photo by Steve Brimm Photography

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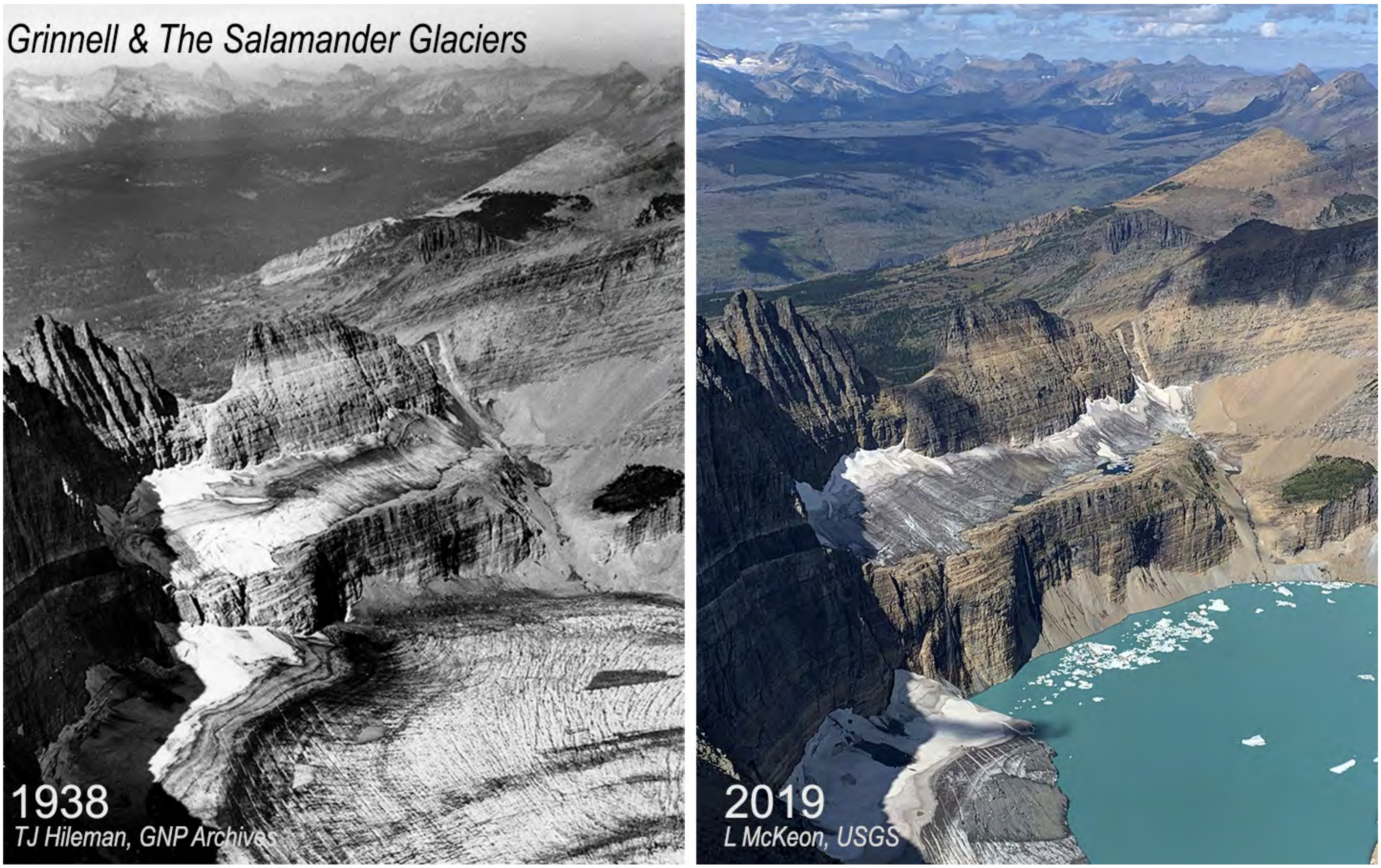

Grinnell and Salamander Glaciers from the summit of Mt. Gould in 1938 and 2019. Repeat photography archives demonstrate glacier change in Glacier National Park. (https://www.usgs.gov/centers/norock/science/repeat-photography-project?qt-science_center_objects=1#qt-science_center_objects) The Upper Grinnell Lake has formed as the glacier has retreated.

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