Voyager 1 color-enhanced image of Saturn taken on 18 October 1980, 25 days before closest approach. The large violet cloud belt at the center is the North Equatorial Belt. Saturn’s North Temperate Belt exhibits bright storm-like features. The Southern hemisphere, below the rings, appears bluer due to the scattering of sunlight and viewing geometry.

Photo Credit: NASA/JPL-Caltech
The Earth Scientist

From the President

Construction Zone: A New NESTA Website

Aloha, NESTA,

I want to thank everyone who has stepped up to help transition us from our old SERC housed website to our new Wild Apricot housed website. While not yet complete, I am truly amazed at the amount of work that has been done in such a short time. The reason we now have a modern, attractive, and useful website that grows by the hour is due to your efforts.

When asked to contribute, you have, and it is this community involvement that is critical to the success of our organization and to our “image” on the net.

There are no secret membership numbers, sadly all organizations are in a decline. Younger Millennial / Gen Z teachers are the future of the ESS teaching profession, and it is critical to market to them effectively if we want NESTA to flourish. That is something we could do much better.

While I am essentially a luddite when it comes to what makes a website “good” or “useful”, I do recognize that our old website was neither and the new website is. I also recognize that the first impression folks get of our organization is not the E-News, or our Peer Reviewed Journal, The Earth Scientist, it is our electronic presence...our Website, our Facebook and Twitter feeds that not only set us apart as the “go to” for Earth System Science resources etc, but more importantly markets a community of younger teachers to join our ranks. Websites are no longer just depositories of information. They sell who we are and what we do. It is our introduction to them, and often we only get one shot to sell that to those that visit our site before they move on to the other thousands of sites on the internet. And while one quality visit is great, we need to make our site something worth revisiting, fresh, interesting and useful. This cannot be done by a small committee; it needs a FULL group effort. If you do feel inadequate to assist, you are not. You have years of knowledge and experience that does translate, just by a new method.

As we enter the third decade of the 21st Century, NESTA will continue to produce our top-notch Journal and a monthly electronic newsletter. However, we would be remiss if we didn’t do more to market our organizational community of educators and meet the needs of the new generation of educators and sophisticated users who demand high quality resources and useful and meaningful content delivered via the web and a variety of social media platforms.

It is with this need in mind that I ask you to continue to contribute to the development of our new website.

Richard Jones, President 2020-2022
richard.jones@hawaii.edu
Editor’s Corner

This Winter 2020 issue features articles that expand our reach to international avenues for earth science and highlights the importance of understanding the history of our beginnings as a space-faring people. We have been isolated in our pandemic-restricted spaces for the past year and it is refreshing to reconnect to the wider earth science community through international efforts. The work of organizations to support geoscience on a global scale provides myriad ways for U.S. earth science educators to get involved on a larger stage. Our Canadian neighbors have highlighted the need for more trained scientists and science teachers in their northern communities. The Community Science Liaison (CSL) initiative will help to transform Canadian STEM outreach practices and provide new role models for inspiring young people to join the ranks of the science workforce.

Earthquakes are an international phenomena and the Shake and Break module described in this issue allows students to explore different ways of representing earthquake data to better communicate findings and integrate geoscience content with the practices of analyzing and interpreting data.

Earth science educators are always looking for new ways to connect to their students. Several potential strategies are highlighted to develop a deeper understanding about where students are in their science learning journeys. Finally, the interdisciplinary activity about the Voyager 1’s golden record offers many avenues to introduce students to an important milestone of human exploration and about the size and extent of the solar system. The stories of Voyager 1 and 2 are a reminder of the scientists and engineers that have supported solar system ventures over many decades and how students can become involved in future opportunities that reach to Mars and beyond.

25 Years Ago in TES

Twenty Five years ago, in 1995, TES was in its thirteenth year of publication. The focus of the 1995 Winter issue was “Astronomy”, and fittingly, the cover featured an artist’s conception of the Comet Shoemaker-Levy 9, as it crashed into Jupiter, just the summer before. The issue led off with an article about why summers are warm and sun’s angle. The second article dealt with the Pluto Fly-by Mission and ways in which you might involve your students. The next article explored the moons of Mars. The subsequent article explored the Retrograde Motion of Mars. Next was an article about trying Star Photography. The next article dealt with using road maps and LANDSAT maps together. Another article addressed the teacher’s problem of having lots of activities available yet needing to be able to present them in a coherent manner/order. An article was included telling the reader how they might use “email”, which “has the potential to connect you with 25 million users”. And finally, there was an article dealing with the issues of gender, racial and cultural equity among the students in the Earth Science Classroom.

By Tom Ervin
The twin Voyager 1 and 2 spacecraft (voyager.jpl.nasa.gov/mission/) are exploring where nothing from Earth has flown before. They are continuing on their 40+-year journey since their 1977 launches and are much farther away from Earth and the sun than Pluto. In August 2012, Voyager 1 made its entry into interstellar space, the region between stars. Voyager 2 entered interstellar space on November 5, 2018. Both spacecraft are still sending scientific information about their surroundings through the Deep Space Network, or DSN.

The primary mission of Voyager 1 was the exploration of Jupiter and Saturn. After making a string of discoveries at those planets, the mission was extended. Voyager 2 explored Uranus and Neptune, and is still the only spacecraft to have visited those outer planets. The images have powered the curiosity and imagination of students since the start of the missions and educators have worked to bring these wonders to their students. Is there anything more ubiquitous than students building solar system models? Teachers have used craft balls, coins, stakes in the ground, sport balls and fruit; they have all been used in the service of helping young people visualize the size and scale of the solar system.

Each has limitations because of the vastness of space and the small scale we need to use in a classroom or school yard, but we all have a favorite model system that we have employed. An updated version of this activity has been provided online for multiple grade levels at marsed.asu.edu/solar-system-scale-and-size. The activity uses a 5E format with suggestions for NGSS and Common Core alignment.

We can agree that students need to have a concept of the vast distances and movement of celestial bodies in space through solar systems models but perhaps there are some additional aspects that can build spatial thinking. 

Fast Facts: Voyager 1 and 2
- Voyagers 1 and 2 are identical.
- Both launched in 1977.
- They are powered by nuclear sources.
- Both carry a greeting to any form of life.
- Voyager 1 is at a distance of 22.3 billion kilometers (149.0 AU) from the Sun (in 2020).
- Voyager 1 is traveling at a speed of about 3.6 AU per year.
- Voyager 2 is at a distance of 18.5 billion kilometers (123.6 AU).
- Voyager 2 is traveling at a speed of about 3.3 AU per year.
- Both will study ultraviolet sources, fields and particles in the boundary between the Sun’s influence and interstellar space.
- They are expected to return valuable data for two or three more decades. 

Source: voyager.jpl.nasa.gov/frequently-asked-questions/fast-facts/
the K-12 Curriculum was convened to study aspects of spatial reasoning across disciplines and they published a book of their findings in Learning to Think Spatially by the National Research Council (NRC, 2006). The committee started from the premise that spatial thinking is a basic and necessary skill that all students can acquire and that should be formally taught with appropriate instruction. Astronomy was highlighted because of its long history of careful systematic observations of the heavens and the “intellectual breakthroughs achieved by some of the finest spatial thinkers in the history of science”. The list of worthy spatial thinkers includes Eratosthenes, Ptolemy, Galileo, Copernicus, Newton and Einstein. These past historical figures exemplify what we would like to see in spatially literate students; the ability to use spatial data to construct and defend a point of view in solving problems or answering questions.

The construction of solar system models in school is just the first step to help students think spatially. Depending on the capabilities of your students, encourage them to investigate what data led a historical figure to suggest a new explanation of the movements of the solar system’s planets and moons. Ask them to report on the drawings, the data, and the ideas that led to new understandings about how bodies move in space.

You can also pose the question “Where does the solar system end?” NASA astronomers would say that it all depends on the criteria you are using. If you consider the edge is where the planets end, then it is Neptune and the Kuiper Belt. If you consider the end is the edge of the sun’s magnetic fields, then the end is the heliosphere. If you consider the edge is the stopping point of sun’s gravitational influence, the solar system would...
end at the Oort Cloud. (svs.gsfc.nasa.gov/12639) Ask students to take a position and then defend it with evidence and reasoning.

Humans have sent spacecraft to the edges of the solar system and one article in this issue, “Golden Record – an Integrated STEAM Project,” provides additional ideas to engage your students in developing a global time capsule for the present time using images of things that are relevant to them. The exploration of space brings together many disciplines and when science is presented in a social context, students may be more engaged to learn about the history and impact of scientific discoveries. After all, they are now part of a interstellar space-faring people.

Reference

About The Author
Peg Steffen is an NGSS Curriculum Writer for the Illinois Mathematics and Science Academy. For more than a decade, she was the education coordinator for the Communications and Education Division of NOAA’s National Ocean Service where she led a development team that provided web-based products, professional learning, and educational games in ocean, coastal and climate science. Her 26 years of classroom teaching included biology, physics, and astronomy/geology at the high school and university levels. She received a National Board for Professional Teaching Standards Certificate for Adolescent and Young Adult Science and many teaching awards in her 40 years of work to bring science education to teachers in the United States, Mexico, Europe and Asia. She can be reached at peg.steffen@gmail.com

Project Atmosphere and Project Ocean are unique graduate-credit experiences offered by the American Meteorological Society. These combination online and in-residence professional development courses offer K-12 teacher participants one-of-a-kind opportunities to learn and experience meteorology and oceanography, become earth science leaders in their community, connect with outstanding teachers from across the country and earn graduate credits from California University of Pennsylvania. Travel costs and stipends included!

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ametsoc.org/ProjectOcean

Abstract

Inspired by the EarthScope outreach and education programs, the Community Science Liaison (CSL) initiative will transform Canadian STEM outreach practices by guiding long-term two-way relationships between K-12 schools and scientific programs such as EON-ROSE (Earth-System Observing Network – Réseau d’Observation du Système terrestre). The CSL concept developed from the EarthScope-inspired pan-Canadian EON-ROSE research program will monitor entire Earth Systems across the Canadian land mass. Starting in northwestern Canada, due to the presence of 36 EarthScope Transportable Array (TA) stations, local citizens interested in science will be recruited as the CSL for their community/region. EON-ROSE (and other scientific program) scientists will design training workshops, provide mentorship, and enable CSLs to lead community consultations while designing and guiding hands-on, place- and curriculum-based K-12 Citizen Science (CS: Citizen = non-scientist such as CSL K-12 groups) projects to address community concerns, questions and/or curiosity. School groups will be welcome at the annual EON-ROSE conference, completing the research cycle experience for these students. EON-ROSE (Earth-System Observing Network – Réseau d’Observation du Système terrestre) is the combined effort of Canadian universities, government agencies, industry, and international collaborators. The vision for EON-ROSE is to install a network of ~1400 telemetered observatories across the Canadian land mass to monitor solid Earth, environmental and atmospheric processes to provide real-time, openly available data. These observatories will include sensors to address community interests as determined by CSL consultations.

Challenges Facing the Science Community in Canada

A recent 3M survey (14,000 participants - July to September 2018) revealed that while science skeptics in Canada are rare, 44% of those surveyed perceive scientists as being elitist. Furthermore, 1/3 thought that scientists had corporate agendas, 1/3 believed that scientists were influenced by government agendas and only 30% believed science that aligned with their personal beliefs (Weber, 2019). John Smol (ecologist at Queen’s University, Kingston, Ontario; in Weber, 2019) observed that “There’s a real disconnect between what scientists do and what is the perception in the public.
We have a real responsibility to make (science) accessible. We’re still doing a relatively poor job of translating the data—by and large paid for by taxpayers—and passing it to the public.” The NSERC (National Science and Engineering Research Council of Canada—science funding agency in Canada) operating budget for 2019 was $1.2 billion; yet most non-academic Canadians do not know what NSERC is or what the significant outcomes are from NSERC-supported research.

There are critical gaps in the Canadian STEM (science, technology, engineering, and mathematics) workforce, including a growing need for a new generation of trained geodesists across North America. Many northern communities in Canada lack access to scientists and many even lack qualified science teachers; the consequence is that these communities lack the role models capable of inspiring youth to become the scientists of the future. Research indicates that effective teaching is supported when disciplinary knowledge development is authentic in the discipline (i.e. acting like a scientist), and learning tasks are designed to inform disciplinary knowledge (i.e. engage with real scientists/experts; Friesen, 2009).

**Community Science Liaison Program with Citizen Science Research – One Possible Solution**

One of the main goals of the Community Science Liaison (CSL) program is to address these challenges facing science in Canada. Some of the relevant goals for the CSL program include: i) making scientists household names across Canada (e.g. Figure 1), ii) providing young Canadians direct access to scientists, iii) changing Canadian attitudes towards STEM by involving Canadian youth in hands-on, place- and curriculum-based K-12 Citizen Science research programs to address community interests and curiosity.

**Support for this approach: Wood Street School Grade 11 Experiential Science Program**

One of the most successful high school programs for promoting enrollment into post-secondary STEM disciplines is the Wood Street School Grade 11 Experiential Science Program in Whitehorse, Yukon Territories. All students from this program graduated from high school with 60% pursuing post-secondary STEM disciplines and 10% completing graduate school or professional programs such as Medicine (O’Connor & Sharp, 2013, 2014).

In 1989, Robert (Bob) Sharp, then Coordinator of Curriculum Development, and Superintendent with Yukon Education was tasked by the Yukon Minister of Education to design a program to improve high school graduation rates. Sharp developed the integrated experiential approach organized around place-based Citizen Science research projects (Tables 1, 2).

### Table 1: Courses Integrated into the Experiential Science Grade 11 Program

<table>
<thead>
<tr>
<th>Course</th>
<th>General Description</th>
<th>Relevant Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology 11</td>
<td>Survey Course</td>
<td>Population Ecology, classification</td>
</tr>
<tr>
<td>Geography 12</td>
<td>Earth systems</td>
<td>Atmospheric dynamics, geomorphology, resource utilization</td>
</tr>
<tr>
<td>Chemistry 11</td>
<td>Quantitative Chemistry</td>
<td>Environmental chemistry</td>
</tr>
<tr>
<td>Art 11</td>
<td>Visual arts</td>
<td>Scientific illustration; landscape</td>
</tr>
<tr>
<td>Field Methods 11</td>
<td>Applied Studies</td>
<td>Environmental Monitoring Protocols</td>
</tr>
<tr>
<td>Physical Education 11</td>
<td>Physical, mental fitness</td>
<td>Well-being; Outdoor Education</td>
</tr>
</tbody>
</table>
Students completed two full day labs each week in facilities at Yukon College. Thirty-to-forty days of field studies a semester exposed the students to a wide variety of scientists associated with a range of environmental and geographical topics (e.g. Table 2). Students collected field data and analyzed various aspects of environmental study issues before developing strategies to address community concerns (O’Connor & Sharp, 2016; Sharp, 2017). Enrollment was open to students who felt experiential approaches that addressed real problems spoke to their interests (representing a cross-section of the Yukon population, including Indigenous students). The success of this program for engaging students in STEM disciplines speaks to the powerful nature of place- and curriculum-based hands-on Citizen Science research projects, consistent with the design of the Community Science Liaison program.

### Community Science Liaison (CSL) Program Description

The target audience for the proposed Community Science Liaison program is K-12 school groups for place- and curriculum-based Citizen Science projects led by a local CSL. These hands-on Citizen Science activities will guide students and their teachers through the entire scientific process, from project design to data collection, and analysis to presentation of results (remotely to their scientist mentors or in-person at conferences). Some Citizen Science projects will address community questions, curiosity and/or concerns determined through community consultations lead by the CSLs. Scientists such as those associated with the EON-ROSE research initiative will design training workshops for the CSLs, provide mentorship for the CSLs, teachers and school groups, and visit the schools’ groups whenever possible (these will also include remote interactive discussions with scientists). A CSL speaker series will have the scientists visiting schools where the school groups will present their project results to the scientists first, before the scientist gives their presentation; intended to promote two-way conversations between the school groups and scientists. School groups will also be welcome to present their results at the annual EON-ROSE annual meetings (starting with late September, 2021 in Banff (delayed due to COVID 19) in Whitehorse). With permission, K-12 Citizen Science research projects will be featured on the CCArray website that is under development (ccarray.org).

Many of the northwestern communities in Canada have multiple unique Indigenous groups, which require careful and appropriate approaches to guide authentic, long-term relationships. Advice from the Mount Royal University (MRU) Iniskim Centre, the Aurora Research Institute, and connections with Yukon Education and Calgary Board of Education, in addition to the local school boards, will guide development of all aspects of the Community Science Liaison program. One component of the MRU Iniskim Centre’s mission is to raise awareness of Indigenous peoples and their cultures. O’Connor and Sharp (Wood Street School program) have significant experience with the Yukon high

### Table 2: Examples of Citizen Science Projects in Experiential Science Grade 11 Program (modified from Sharp, 2017)

<table>
<thead>
<tr>
<th>Theme</th>
<th>Location</th>
<th>Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquatic Environments</td>
<td>Spook Creek; Whitehorse</td>
<td>Hydrocarbons, e-coli, impacts of human modification to watershed</td>
</tr>
<tr>
<td>Forestry</td>
<td>Haines Junction, Yukon</td>
<td>Seedling growth, regeneration after fire, spruce beetle analysis</td>
</tr>
<tr>
<td>Wildlife</td>
<td>Various</td>
<td>Caribou and road salt, hare census by scat, mice genetics</td>
</tr>
<tr>
<td>Marine &amp; Intertidal</td>
<td>Various</td>
<td>Campbell River Salmon Populations, Anemone and Star Fish Census</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>Various</td>
<td>Air quality, installation of weather stations, lightning strikes</td>
</tr>
<tr>
<td>Snow</td>
<td>Various</td>
<td>Snow profiles, snow as habitat, snow and climate</td>
</tr>
<tr>
<td>Energy</td>
<td>Various</td>
<td>Production (steam vs solar vs wind), conservation (intelligent parking lot controllers)</td>
</tr>
<tr>
<td>Recreation</td>
<td>Various</td>
<td>Trail use and development, ski hill packing, environmental impacts of recreational areas</td>
</tr>
</tbody>
</table>
Clark is a past science curriculum specialist from the Calgary Board of Education, while O’Connor guides the experiential component of the Mount Royal University Bachelor of Education program; these are germane observations because the Alberta curriculum guides the Northwest Territories curriculum. The CSL network will also translate materials into local languages in order to make the website as accessible as possible for these communities.

**Case Study: Geological Bumble Bee Program**

The Geological Bumble Bee (GBB) program (2012 to present; Scherger et al., 2014) involved ~ 800 Calgary grade 2-9 students building and installing ~ 800 Bumble Bee Boxes while concurrently collecting rocks to characterize glacial material deposited ~15,000 years ago. These students return to the field in the fall to collect their boxes and analyze the Bumble bee colonies that occupied their boxes. Mount Royal University Bachelor of Science (Scherger) and Education (Kurila) students have volunteered and assisted with various components of this program. Plans for the CSL program have the GBB expanding across Canada so that K-12 groups can monitor these important pollinators that are under threat from diseases and climate change (Williams et al, 2014).

In 2013, the “Incredibee” grade 2 group won the “Making a Difference Award” at the City of Calgary Mayor’s Environmental Expo (Figure 2). Feedback from this group included, “Yesterday, we built bee boxes! I think that was the best day of my life so far!” “I used to think that bees were mean, nasty...Now I know that bees are helpful to the world.” These quotes speak to the power of these hands-on, place- and curriculum-based Citizen Science research projects. Parent volunteers reported a high degree of satisfaction with the GBB hands-on field study, versus what they have traditionally experienced on field trips around the city where programs were delivered, rather than generated alongside students. Educators (teachers and curriculum specialists) emphasized the strong impact of these authentic, field-based activities versus the traditional didactic pedagogy often experienced in a science program.

**EON-ROSE and Canadian Cordillera Array Research Programs**

The CSL concept arose from multiple discussions within the EON-ROSE (Earth-System Observing Network/Réseu d’Observation du Système terrestre; ccarray.org, Boggs et al., 2018a/b/c, 2019a/b, Eaton et al., 2019, Witze, 2019) collaboration. The 300+ EON-ROSE scientists from across Canada, the USA and Europe represent expertise across all aspects of Earth System Science to support the CSL program. The EON-ROSE network of ~1400 telemetered observatories (Figure 3) will include sensors to address community interests as determined by CSL consultations. The Canadian Cordillera Array is the pilot phase for EON-ROSE; chosen in part because of the 36 USArray stations in northwestern Canada (Figure 4).

The first EON-ROSE observatories were installed in the Yukon Territory and northeastern British Columbia during the summer of 2018, followed by installation of multiple sensors in the “nested” array Mt Meager program 150km north of Vancouver, British Columbia,
that started deployment during the summer of 2019 (locations in Figure 4). While EON-ROSE scientists will provide significant mentoring for the CSLs and K-12 school groups, the CSL team will include scientists from other groups working across Canada.

The Future for the Community Science Liaison Program: Community Relations

The most critical component of the CSL program are strong community relationships, which will expand on existing connections developed by the EON-ROSE collaboration. Careful consultation with the MRU Iniskim Centre and the Aurora Research Institute Coordinator will guide appropriate approaches to these communities. Community relationships started forming during Boggs’ family 2018 epic summer adventure—an 8880km round-trip from Calgary to Tuktoyaktuk. The first CSL team trip to the Yukon and Northwest Territory communities occurred in November 2019, during which the first two CSLs were recruited (with further recruitment planned at a rate of 1-3 per year afterwards).

Community Science Liaison Program Evaluation

Plans are in progress for a mixed methods evaluation of the CSL program including before, during and after questionnaires with closed- and open-ended questions for the scientists, CSLs, K-12 students, their families and teachers. CSLs, teachers and scientists will be guided to journal their experiences, observations and suggestions for improving all aspects of the CSL program. Results from these evaluations will guide improvement of all aspects of the CSL program.

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Humans of EarthScope explores the who, what, where, when, why, and how of being an earth scientist. This new series profiles researchers who use EarthScope data, putting faces to the personal stories that inspired them.

- Why did they choose a career in Earth Science?
- How do they see their research fitting into the bigger picture?
- What advice do they have for future scientists?

The collective expertise, enthusiasm, and findings of the EarthScope community provide a rich and dynamic resource for enhancing Earth Science education at all levels and within all learning contexts.

“I love that my job allows me to directly impact people’s lives.”
—Liz Vanacore

“My research has taken me to Rwanda, Burundi, Ethiopia, Tanzania, Malawi.”
—Cynthia Ebinger

“Field work brings out the thirteen-year old adventurer in everyone!”
—Vadim Levin

Humans of EarthScope
www.earthscope/public/HuofES
**Abstract**

*Shake and Break!* is a 1-week instructional module for core middle school science, developed as part of the National Science Foundation funded *Advanced Manufacturing Integrated to Unlock Potential* (AMP-IT-UP) project (NSF # 1238089). It is aligned with the Next Generation Science Standards (NGSS) and Standards of Mathematical Practice (SMP) and focuses on basic concepts of seismology, spatial and temporal data, and data practices related to data visualization. In this module students explore different ways of representing earthquake data to better communicate findings and integrates geoscience content with the practices of analyzing and interpreting data.

**Introduction**

In 2012, the National Science Foundation funded the *Advanced Manufacturing Integrated to Unlock Potential* (AMP-IT-UP) project through its Math and Science Partnership program to develop a comprehensive initiative to increase student interest and engagement in STEM (NSF #1238089). A central outcome of the project was a series of one-week modules for core middle school math and science instruction, aligned with best practices put forth in the Next Generation Science Standards (NGSS 2013) and the Standards of Mathematical Practice (National Governors Association Center for Best Practices & Council of Chief State School Officers 2010). The modules promote STEM learning by engaging students in project-based inquiry lessons that highlight scientific research and emphasize collecting, representing, visualizing, interpreting, and communicating authentic and compelling data. Though all modules require students to collect, graph, and analyze data, each module also specifically focuses on one of three general data practices—1) Experimental Design; 2) Data Visualization; and 3) Data-Driven Decision Making.

All modules also strive to promote, to the extent possible, the integration of the STEM content, incorporating science and engineering contexts and data collection investigations into activities that also require that students analyze data using both grade-level appropriate and foundational mathematics skills. Three of the science modules are contextualized within earth systems, challenging students to collect and analyze data regarding earthquakes, volcanoes, and weather. The earthquake module, a middle school science module entitled *Shake and Break!* is presented in detail below. All other modules are also available for free download at ampitup.gatech.edu.
Overview

Shake and Break! is a week-long science module that focuses on basic concepts of seismology, spatial and temporal data, and data practices related to data visualization—i.e. how data can be represented in different ways to communicate various messages to an audience. During this investigation, students analyze earthquake data to help the Buzztech company decide where to build its new manufacturing plant. The module was designed for middle school science classes but also connects to math concepts such as coordinate systems and mapping. Like all AMP-IT-UP modules, it follows the BSCS SE instructional model that is based on the constructivist theory of learning and allows for students to construct their own knowledge based on experiences (Bybee et al. 2006).

Background Information for Teacher

The instructional materials, which are all available for free download at resources.ceismc.gatech.edu/amp/earthquake, were created and revised based on years of classroom implementation through the AMP-IT-UP project. The student materials include a student edition text that guides students through the experience and the accompanying student worksheets that students use to showcase what they are learning. The materials also include teacher instructions to help educators implement the modules successfully. The teacher edition is the student text that has been annotated with tips and suggestions to help guide students through the module. The annotations include sample answers that students might give to questions, reminders to prepare materials ahead of time or additional content to explore. The teacher preparatory guide is intended to help teachers plan their lessons. It contains information that might be required in lesson plans such as relevant standards, essential questions, and key terms; provides a synopsis of each section of the module; and visually maps the module content onto the SE learning model (bscs.org/bscs-5e-instructional-model/). The main activity in Shake and Break! uses maps and different colored stickers that are used for plotting the location and magnitude of earthquakes.

Preparation

During this activity students work with temporal and spatial data and discover the importance of data visualizations. Each group of 2-3 students is given one section of a larger map, earthquake data for their particular section, and multicoloered stickers for plotting the data. For the initial activity students are given 10 years of earthquake data to plot on their maps and analyze. Later, students are given 40 years of data to plot and analyze. Since each group receives only one section of the entire map, they need to combine their map sections after all data has been plotted to create the larger map and reveal the complete data profile.

It is recommended that group size is limited to two students, three at a maximum. There is plenty of work to divide among a pair of students but a third student might get restless. Two different groups can be given the same section maps to plot if class size warrants it. To accommodate students with special needs, the map sections can be enlarged, the dataset size can be increased or decreased, and the sticker colors or textures modified. Adaptations for online learning are also included on the curriculum materials website, as described below.
Engage

The Engage phase is designed to capture student interest and connect them with a real-world problem. The module text introduces students to the BuzzTech company, a cell phone and tablet manufacturer that wants to open a new plant in northern California. BuzzTech has selected three possible sites for consideration and students are challenged to assist BuzzTech with selecting the winning site. Students are given highway maps and relief maps to familiarize themselves with the area. Making a recommendation will not be straightforward as students have to evaluate the advantages and disadvantages of each location including land costs, the availability of employees for commuting, transportation options for manufactured goods, and perhaps more significantly, earthquake activity.

Figure 2. Section map displaying 10 years of earthquake data.

Explore

In the Explore phase students actively investigate the problem by analyzing ten years of earthquake data. The map of the area that BuzzTech is considering has been divided into 9 sections. Students, working in groups of 2-3, are assigned a section of the original map on which to plot their earthquake data. The materials that students use for this activity are their map section print out, a set of green, yellow and red sticker dots, and a copy of the United States Geological Survey (USGS) earthquake data for their assigned section. Students use the stickers to plot the location of earthquakes on their maps, and the colors of the stickers represent the earthquake magnitude according to the Richter Scale: green (0.0-3.0), yellow (3.1-6.0), red (6.1-10.0).

After students plot their data, they engage in a class discussion reflecting on their map sections and consider, based on their information so far, whether their map sections would be a good choice for the plant location.

Shake and Break! stresses the skills and concepts associated with data visualization. Therefore, in this module students take the earthquake data given to them in charts, which includes location and magnitude, and they find different ways of representing the data to better communicate a message. The stickers quickly communicate the earthquake location while the use of color communicates the strength of the earthquakes on the Richter scale in that area.

Explain

During the Explain phase, learners connect what they have done so far with the required science standards that include plate tectonics and large-scale system interactions, analyzing and interpreting data, and stability and change. The student text includes an “Add to Your Understanding” section that introduces disciplinary content relevant to the challenge (earthquake basics, and how earthquakes are detected and measured) and provides links to two videos to support student learning. The first video, Earth Without Water, simulates the removal of water from Earth to show the actual surface of the planet, highlighting the topography of deep trenches and mountain ranges. The second video, Earthquake Samples, contains actual footage of impacts and damage caused by earthquakes, with some of the earthquakes occurring in real time. It features several earthquakes (4.4 to 9.0 on the Richter Scale) to help students visualize the range of earthquake damage and intensity. Students use this content to reflect back on the challenge and what it means for the sites that BuzzTech is considering. Students previously plotted 10 years of earthquake data on their section maps. Now they reflect back on those maps and consider whether the number and magnitude of earthquakes is in a range that BuzzTech can tolerate.
Elaborate
In the Elaborate phase, students extend their understanding of the content they have learned thus far (plate tectonics and data representation) to new experiences, including how researchers use satellites and global positioning systems (GPS) to predict when earthquake activity is likely to occur. However, in order for students to best assist BuzzTech with determining a location for their plant, they need more data. They are therefore given 40 years of data to plot so they can observe differences in seismic patterns over time. Students follow the same procedure as before and use the same colored stickers to represent both the location and magnitude of the earthquakes plotted on their map section. Once students have plotted their data, they again interpret the results, pondering whether the site seems like a good choice for the BuzzTech plant location.

*Shake and Break!* is a data visualization module. While students are learning more about earthquakes and assisting BuzzTech, they are also learning about the value of visualizing data to best communicate scientific findings to other scientists and the public. In *Shake and Break!* students also learn about temporal and spatial data. Forty years of earthquake data (temporal data) give students insight into how earthquake patterns may have changed over time. When students combine their sections to reassemble the larger map of the area that BuzzTech is considering, it shows how the earthquake data changes across a geographic area (spatial data). The larger map reveals clear patterns of earthquake activity, allowing students to make better informed recommendations to BuzzTech.

Evaluate
There are multiple opportunities to evaluate student learning through both formative and summative assessments during this module. The student pages are essentially practice, guiding students in this experience as they plot their earthquake data onto their section maps. For teachers looking for formal grades, the student page *Letter to BuzzTech*, is recommended for a summative assessment. This assignment gives students a scaffolded letter to help them communicate their site recommendation to BuzzTech. When making recommendations, students consider the larger reassembled map showing earthquake activity as well as the chart listing advantages and disadvantages of each site location. There is no straight-forward recommendation to make; students have to weigh all of their available information to make the best-informed decision possible.

Conclusion
This STEM-integrated earth science module connects students with real-world scenarios and uses authentic science, mathematics and social studies data. Although it is intended primarily for 6th grade science classes, the content and student pages can be adapted for students of varying abilities, additional grades, or even different subjects such as mathematics enrichment. This activity can also be used for virtual, online instruction. Students, in lieu of having physical materials, insert images of their assigned map sections into PowerPoint or Google Docs. They then digitally draw green, yellow and red circles onto their maps to identify the earthquakes, save their files as pictures and share the completed files with their teachers. Teachers can then use software such as Adobe
Maps of ancient land and water patterns, based on investigations of rocks and fossils, demonstrate how Earth's plates have moved great distances, collided and spread apart.

Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

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.

The processes have changed Earth's surface at varying time and spatial scales.

Performance Expectation
MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

Science and Engineering Practices

Analyzing and Interpreting Data
• Analyze and interpret data to provide evidence for phenomena.

Constructing Explanations and Designing Solutions
• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own 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.

Disciplinary Core Idea

ESS2.A Earth's Materials and Systems
• 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.

ESS2.B Plate Tectonics and Large-Scale System Interactions
• Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth’s plates have moved great distances, collided and spread apart.

Cross-Cutting Concepts

Scale Proportion and Quantity
• Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Table 1. Middle School History of Earth

https://www.nextgenscience.org/topic-arrangement/mshistory-earth

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Marion Usselman is a Principal Research Scientist at Georgia Tech, and Associate Director for Development and Educational Innovation at CEISMC. She received a B.A. in Physics/Biophysics from the University of California, San Diego and a Ph.D. in Biophysics from the Johns Hopkins University. She was the Principal Investigator on the AMP-IT-UP project and has worked for many years to promote K-12 STEM education and develop robust university-school partnerships. Marion can be reached at Marion.Usselman@ceismc.gatech.edu.

Mike Ryan is a 25-year STEM researcher at both Georgia Tech and the University of Kansas, a curriculum developer, and a teacher professional learning leader, with a focus on project-based learning. He is the author of multiple K-12 STEM curricula, including Project-Based Inquiry Science - PBIS (Activate Learning). He currently consults schools, organizations and projects in PBL, inquiry, curriculum development, professional & online learning. Mike can be reached at ryanmike@umich.edu.

Photoshop to create the full map containing 40 years’ worth of earthquake data.

For five years AMP-IT-UP curriculum developers, researchers and educators designed the curriculum materials, piloted them in four diverse middle schools, made iterative changes based on formative data, and conducted extensive empirical research regarding their impact on students and teachers (Alemdar et al., 2018). Shake and Break! and the other AMP-IT-UP modules demonstrate how project-based learning and the implementation of integrative practices related to data science can effectively enable students to master core math and science disciplinary concepts and practices while promoting high levels of student engagement (Newton et al. 2019). All AMP-IT-UP curriculum offerings are available at resources.ceismc.gatech.edu/amp/.

Acknowledgements

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References


Do Your Students Even Like Earth Science? How Knowing that Information Can Benefit Your Teaching

James T. McDonald, Professor of Science Education, Central Michigan University

Abstract

When a teacher gets to know students at the beginning of the school year, it can benefit your science teaching. Using various strategies and techniques, science educators can know the perceptions, misconceptions, past science experiences, and current science knowledge of students.

Introduction

Teachers are responsible for the preparation of courses and each class of students is a new opportunity for learning. Educators need to keep in mind the important effect the students’ backgrounds have on science teaching and learning. Getting to know students and getting to know about their science background, or lack of it, may benefit how you address how to best present earth science content to a variety of students in an effective manner. This is especially true since it is becoming increasingly likely that your students will differ more in their demographics, learning styles, preparation in science, attitudes toward earth science, and interests than just a few years ago.

While we like to think that students themselves are responsible for their learning, good teachers also take into account what their students bring to class with them. K-12 science instruction cannot focus solely on the planning and delivery of content while assigning all responsibility for learning to students. Science teachers and earth science educators can do much to encourage and enhance learning both inside the classroom and out. Teachers who continually try to understand their audiences and to address student interests, learning deficits, and misconceptions will be more successful in helping students to meet their own responsibilities to learn.

Beliefs or preconceived notions about students influence how all of us teach. How we respond to our students will, in turn, influence how they learn. What students believe about science and the way that scientists work affects what they hear, what they believe, how they study, and what they learn. Good teaching means that we must bridge the possible gaps of students’ perceptions, language, backgrounds and assumptions that may impede effective communication and thereby hinder student learning.

Knowledge about students will enable the teacher to refine the presentation of material, class discussions, comments, illustrations, and science investigations so that they are more effective learning experiences. References to student interests, backgrounds, knowledge, and even anxieties can make the class seem more personal and the students’ interest more accessible.
Tips for Finding Out About Your Students

The following are things that I have used in my science teaching successfully in my science teaching to find out more about my students:

- Use name tents at the beginning of the school year.
- Find out about their experiences in other science classes, with the particular subject in the courses you teach, and especially in survey or introductory classes.
- Use pre-tests or science attitude surveys.
- Early in the school year, write personalized comments on assignments that you return and invite students to come to you to discuss their progress.
- Have students write out the answers to some earth science connection questions on a 3 x 5 card to get to know them better.

**Name tents.** I teach three different sections of the same class every semester and I use name tents for at least the first month of the semester since my classes only meet once per week. I use 5 x 8 cards folded lengthwise. I have different color cards for each section of the class so that they can be easily passed out. I have students put their first name with how they want to be addressed. This is much easier than just reading the class list to find out what they prefer. When you have students introduce themselves, you ask them about what aspects of earth science they prefer: oceanography, geology, weather, landforms, or space science for example.

**Earth Science experiences.** Since I teach science methods, including some earth science concepts, to preservice elementary teachers, I ask my students about both their positive and negative K-12 and college science experiences concentrating on teachers and the kind of experiences that they had that promoted or hindered learning. I have them first think about it individually and write out their answers. Then they interview two other students, listening for common themes or answers. We then talk about it as a class since this is a course on how to teach science. We focus on the common answers to use as data and we tie those together as positive and negative ways of teaching science. The answers are used to connect with my themes during the class.

The positive experiences typically include teachers who were passionate and knowledgeable about their content. This also includes teachers who could explain content well using a variety of teaching methods. Answers also discussed include teachers who were personal in their approach, teachers who challenged students to know the course material, and provided detailed feedback on assignments. What do you enjoy doing on your vacations that you can share with students: hiking, collecting rock samples, visiting national parks that include vivid geological features, or have you done research on some earth science concepts? Positive learning experiences included hands-on learning, science investigations that had a real-world connection like stream tables or weather stations, discussing current science events going on locally and around the world (volcanic eruptions, earthquakes, or weather systems) a choice of how to do a project, and lab experiences that had multiple pathways to a correct answer or result.

Negative experiences shared by students regarding teachers, included how their teachers went over content too quickly and not in enough depth and using too much memorization. When asked about how much of that information had been retained, students state that it was forgotten as soon as the test was taken. Corresponding to the positive experiences about teachers, the negative comments include teachers that were not passionate or enthusiastic about the material, did not use a personal approach to teaching, or teachers who did not explain things to students using a variety of methods. Another common answer has to do with just using the book, answering questions at the end of the chapter, and too many PowerPoint slides that students had to copy in handwritten notes.
Pre-tests or science attitude surveys. Another technique for finding out what your students know about the earth science you are teaching is using a pre-test or a survey of some sort. You have a chance to get to know them as learners by what sort of teaching strategies enhance or hinder their learning.

To investigate students’ attitudes toward science, some teachers give a brief questionnaire on the first day of class. Useful information for understanding students includes their perceptions of the process of science, of scientists themselves, and of the concepts and topics to be presented in the course. Students’ perceptions can be surprising. The answers to questions such as those posed below can be used throughout the school year:

- What is earth science?
- What is meant by scientific thinking in earth science? Can you provide an example?
- How is earth science done by scientists?
- How do earth scientists measure the validity of their work?
- How has scientific thought about the earth or space scientific discovery helped society?
- How has scientific information had a negative effect on society and how we understand the earth?
- How do earth scientists help society safeguard against abuses of science or technology?
- What are your favorite aspects of earth science? Why does it interest you? Please provide an example.

Having students respond periodically throughout the course to these questions can lead to more effective teaching. While teaching content or leading discussions, the teacher can refer to responses and perceptions of individual students (without using their names). This gives students the sense that the course content can contain more dialogue and piques their interest because their questions have become reference points in your teaching.

Personalized comments on assignments. In the beginning of the year I establish a dialogue with students through the comments I write on their assignments. I ask them what they think about the approaches to science teaching that they had to read about in the articles that are used for the elementary science methods course. You could do the same thing by asking them to elaborate on a particular point or having them come to talk to you about something that they wrote. Students sometimes respond to me in an email or come up to me prior to the next class. This lets students know that you are interested in their thoughts and opinions and that you genuinely want to get to know them and their thoughts about science.

Connection Questions. On the first day of class I have students write out the answers to 5 connection questions that they write on a 3 x 5 card. I refer to the card throughout the semester as I get to know the students personally. The five questions are:

1. What do I need to know about you?
2. What do I need to know about you as a learner?
3. What do you expect from me as the instructor?
4. Describe your biggest fear (concern) about this class.
5. Describe your expectations for this class. What would help you?

They hand them in at the beginning of the next class so I can start to use them right away.
Earth Science Teaching Example: Erosion

Knowing my students as learners can translate into better science teaching and learning. For example, the concept of erosion is one that can be designed and tailored to the needs of your students. Using the information that I have gathered about my students, I can see what their prior science learning experiences (both positive and negative) to make sure that they have the first experiences needed to observe phenomena, gather information, analyze data, and draw conclusions using a stream table. If my students do not have prior experience observing, I can ask certain types of questions and provide first-hand experiences to focus attention on earth processes. For students that have certain strengths I can provide informational texts for reading, videos to fill to visualize learning, investigations for hands-on learners, and discussion so that students can hear from peers to build and add on to their own knowledge.

Importantly, take the time necessary to go deeper with students to gather student products to evaluate their understanding and adjust your teaching as necessary. You cannot possibly pre-plan for everything, but you can adjust things as you go along using formative and summative assessments, projects, and learning opportunities to see students grow and succeed.

Overcoming Science Fear

A common misconception of many students is that they believe that the ability to understand mathematics and science is innate. This belief influences how many parents and K-12 teachers have reacted to these subjects, and their attitudes often have conditioned the attitudes of students. It
can be difficult to convince students, who believe that they have no aptitude for science, that they can understand even the simplest scientific relationships. Their belief can serve as a self-fulfilling prophecy, resulting in scientific avoidance.

According to Matthew Shepherd (2019), there are four reasons that people fear science:

- **A perception of conflict with faith beliefs.** Biases associated with our “personal marinades” are strong. What are personal marinades? How we were raised, where we were raised, our faith-based upbringing, political alignment, and our circle of peers. Each of these is important and life-shaping. However, none of them should fundamentally be used to undermine science.

- **It is hard.** A recent book entitled, *Student Attitudes, Student Anxieties, and How to Address Them: A handbook for science teachers* argued that students also bring preconceptions to the classroom about science. They may perceive it is as cold, hostile, or even biased toward certain groups. Many students (and parents) also suffer from “science anxiety.” I am always concerned when I hear a parent say, “I am not a science person nor is my kid.” Such statements train the child to succumb to parental insecurities or biases while setting up a self-fulfilling prophecy.

- **If I do not understand it, dispute it.** There are still a lot of people who do not believe astronauts landed on the moon. However, science denial may be more complicated than we think. The Alfred P. Sloan Foundation supported a conference in 2018 entitled *Science Denial: Lessons and Solutions*. Kari Fischer, one of the conference organizers, summarized 6 takeaways from the conference in The Scientist, and some of them may be surprising. My summary of Fischer’s takeaways:
  
  - The use of the word “denier” leads people to dig in more. Confirmation bias (cherry-picking what we already believe) is a powerful motivator.
  - Scientists need to be sure they have checked themselves, the data, and motivations before engaging with others.
  - Listen to those who challenge you and understand that their core values or stories may resonate more with them than data and graphs.
  - Relevancy is key when talking beyond your science peer group. For example, climate change impacts on the price of cereal may resonate more than discussions about polar bears.
  - Develop a sense of trust with the people you interact with.
  - Resist the urge to play “twitter tennis” (Back and forth) with trolls but try not to ridicule those that “don’t believe.”

- **For Shepherd, human belief about their own relevance is speculative.** Many people have a fear of science and technology innovations. I have had conversations with friends recently about retail self-checkout systems and self-driving cars. Concerns about automation affecting jobs and opportunity are real and should not be ignored. CNBC (2019) reported that 25% of jobs, particularly those with repetitive functions, are at high risk of automation. One comment that Shepherd overheard in a discussion is whether robots will replace us. In that statement, he wondered if part of the fear or skepticism held by some people about science is related to self-preservation.

**Conclusion**

The work of Matthew Shepherd and others can inform our teaching and work as earth science educators. The more we know about our students, the better teachers we can be at any level. Take the time to make connections to your students and you will see it pay off in better learning for the entire school year or semester.
References


About the Author

James T. McDonald is a Professor of Science Education at Central Michigan University in the Department of Teacher Education and Professional Development. His earth science research interests include student misconceptions in astronomy, earth processes, space sciences, and oceanography. Dr. McDonald’s field research experiences include archaeology, paleontology, radio astronomy, volcanoes, national park geology, and oceanography investigations. He can be reached at jim.mcdonald@cmich.edu, @jimscienceguy

Five Little Cave Scientists

by Amy Edwards

Follow five little cave scientists as they use STEM to study caves, both in the cave and back in the laboratory!

Available as Kindle and Paperback
Amazon.com
Abstract

Many teachers across the globe feel isolated in the classrooms and now also in their homes as remote learning becomes more prevalent. Organizations that can connect them virtually are warmly welcomed. For over 30 years, the International Geoscience Education Organization (IGEO) has provided opportunities for earth science teachers to connect with colleagues through its website and newsletters. The website has a wide range of educational resources and links to many useful organizations around the world that may be new to teachers, even the most experienced. The IGEO also conducts the annual International Earth Science Olympiad (IESO), an opportunity for selected high school students to take part in knowledge contests and field experiences and is expanding efforts to provide resources that help teachers and students learn despite the necessity for remote learning.

International Geoscience Education Organization (IGEO)

Understanding how our planet works should be an essential part of everyone’s education. In many places, teaching earth science has been diminished or even eliminated. Yet, in some schools, earth science instruction remains strong. Supporting geoscience education at all levels nationally and internationally at all levels, working to enhance the quality of geoscience education internationally and raising public awareness of geoscience, particularly amongst younger people, are the goals of the IGEO (igeoscied.org).

Efforts similar to the Next Generation Science Standards and its predecessors are not found in all other countries. A comprehensive review of math/science standards around the world was published by TIMSS (Mullis et al, 2016). Some countries have national curricula that teachers are expected to follow to the letter, but in many, such guidelines are absent and it falls on what the teacher knows and has available for hands-on activities. To support earth science teachers across the globe, the IGEO traces back to the 1990 International Union Geological Sciences (IUGS) Commission on Geoscience Education and Training (iugscoge.org).

IGEO monitors geoscience education internationally and fosters communication between geoscience educators worldwide. It liaises with international and national bodies concerned with geoscience education and related concerns, such as the European Geoscience Union (egu.eu), the
International Association for Promoting Geoethics (geoethics.org), IUGS and other international associations concerned with science education.

Every four years, the IGEO sponsors its own Geoscience Education conference. GeoSciEd VIII was in Campinas, Brazil, in 2018 (ige.unicamp.br/geoscied2018/en/). At that meeting, two graduates of the American Museum of Natural History’s Master of Arts in Earth Science Teaching program (amnh.org/learn-teach/master-of-arts-in-teaching-earth-science-residency) described their training and teaching experience (McDonald et al, 2018) in English and Portuguese. GeoSciEd IX will be held in Shimane, Japan, in 2022.

To foster the next generation of geoscientists, the IGEO sponsors the annual International Earth Science Education Olympiads, (IESO) around the globe. The 13th edition took place in Korea in 2019. The theme of IESO 2019 was “Passion for Earth Science...Continued”. (ieso-info.org/)

Almost 450 participants from 43 countries attended IESO 2019. Challenges include a written test, a practical test, ITFI (International Team Field Investigations) and ESP (Earth System Projects). Students demonstrate knowledge and understanding of Earth Systems facts and problem-solving and develop new skills through field experience with teams that include partners from other countries. Although the 2020 version was cancelled due to COVID-19, planning is underway for the 2021 version to be held virtually in Russia.

In the US, support and preparation for the IESO is provided by the US Earth Science Organization (USESO at useso.org/). The USESO seeks to raise student interest in and public awareness of Earth sciences, as well as to enrich Earth science education for students in the United States of America. It has developed an earth systems curriculum to support this mission, promotes the international education and cooperation goals of the International Earth Science Olympiad in the USA and supports efforts to enhance cultural diversity within the earth science community both nationally and internationally. The organization works to increase equal opportunities and reduce implicit bias and provide an assessment of Earth science content knowledge for high school students in the USA. The USESO runs summer training institutes to prepare students to attend International events. It selects the U.S. Earth Science Team to represent the USA at the event, escorts the team to the IESO, and raises money to provide financial assistance to deserving students who cannot afford to attend the USESO training programs or the IESO.

Other efforts undertaken by the IGEO to support earth science education include a newsletter (I am the current Editor), published three or four times a year. It provides opportunities for country councilors to share updates on what is happening in their nations and regions. The U.S. IGEO councilors are Mary Dowse (emerita, Western NM University), Sharon Locke (Southern Illinois University at
Edwardsville), and Steve Anderson (University of Northern Colorado). The IGEO conducts periodic International Surveys on Geoscience Education (UNESCO, 2019).

IGEO leaders have created valuable publications, including Earth Learning Ideas (earthlearningideas.com), which are free downloadable pdfs about a wide variety of geology, environmental science, and physical geography topics. System Earth learning units are available in English and German, and online geoscience textbooks, including the Blue Planet modules (archiv.ipn.uni-kiel.de/System_Erde/materialien_Sek2_2.html) are available in Spanish, English, and Chinese. Finally, Exploring Geoscience across the Globe was published in English and Japanese (King, 2019), and “Práticas de geociência na educação básica /Geoscience Practices in Basic Education” was published in Portuguese (Greco, 2018).

IGEO leaders and representatives travel internationally to provide hands-on workshops to improve the quality of teaching, especially in countries where earth science is not a stand-alone subject. These initiatives include support of the European Geoscience Union (EGU) Geoscience Field Officers (egu.eu). In 2019, the EGU began a new initiative to appoint field officers and train them to provide professional development to teachers who have elements of geoscience in their teaching curriculum. After appointing EGU officers in Portugal, Italy, France, Spain, and Germany and IUGS officers in India and Morocco, the EGU is seeking to build on this success by expanding the initiative to three additional European countries and three countries beyond Europe supported by IUGS. IGEO leaders provided teacher-training in India. You can find out more at igeoscied.org/professional-development/teacher-training/july-2015-in-india/. IGEO members are intimately involved in the annual Geoscience Education Workshops for Teachers (GIFT) offered at the EGU General Assembly meetings in Vienna and AGU Fall meeting in San Francisco (education.agu.org/education-activities-at-agu-meetings/gift/).

In recent years, earth science educators in certain regions have banded together to support each other. Across South America, educators have formed the Latin American IGEO (laigeo.cloudaccess.host/), which conducts conferences and field experiences that would otherwise be lacking. Similar efforts are underway in European Countries.

Teachers across the world face a major challenge: teaching through distance learning due to COVID-19 restrictions. To succeed in the post-COVID world, teachers must expand their skills in using educational technology to simulate in-person instruction, and enhance their subject knowledge. For this approach to be successful globally, it will require cooperative ventures, such as the IGEO, to transfer effective methods/knowledge to less-connected, distant colleagues. This collection of geo-websites from many countries (igeoscied.org/useful-links) can provide a wealth of information.

One of the most alluring aspects of earth science education involves field experiences. There are many benefits and challenges to providing quality learning that foster interest and content mastery in earth science through outdoor experiences even during the COVID-19 pandemic. (Sima, 2020) and (Pennisi, 2020). Looking beyond our borders will enhance the opportunities for remote
learning and first-hand experiences and help our students increase their awareness of the larger world of global geoscience.

References


About the Author
Dr. Michael J. Passow taught middle school, high school, and college Earth Science and other subjects for 44 years at White Plains Middle School and elsewhere. He continues to provide support for Science Education through the Earth2Class Workshops at the Lamont-Doherty Earth Observatory for Columbia University, and the American Museum of Natural History Master of Arts in Teaching Program, and consulting. Dr. Passow has served as President of NESTA (twice!), STANYS, and NAGT-Eastern Section. Dr. Passow can be reached at michael@earth2class.org.
Abstract

The Golden Record Assignment is an integrated Science Technology Engineering Art Math (STEAM) project designed for upper elementary through middle grades. Students first learn about space exploration and the scale of our solar system and then create a satellite through a series of specifically designed activities. This leads them to create a global time capsule, the next generation Golden Record. This project not only incorporates all areas in STEAM but also addresses learning cycles like the 5-E model of instruction and engineering by design and also focuses on issues in science, social skills and an emphasis on culturally responsive pedagogy.

Introduction

Science has many opportunities to integrate across the disciplines. The list of what we need or should do as science teachers is extensive. I want my students to learn the science but more importantly I want them to think like scientists. This project is one that I do with in-service and pre-service teachers that integrates all of STEAM into a unit centered on Earth and Space Sciences that focuses on NASA’s Golden Record (Figure 1). Students learn key pieces of information about the planets as well as the scale of them. From there, they design a satellite using an engineering by design process to carry their own Golden Record. Students also examine our global culture to share it with our intergalactic neighbors. Finally, they address issues in science as well as learning how STEM is for all genders and races.

NASA launched Voyager 1 (Figure 2) and 2 in 1977 (Fast Facts, 2018). They left the solar system in 1990 and will likely take 40,000 years before they approach another planetary system. They gave us a lot of information but they each carried something special; a Golden Record (2018). The Golden Record is a type of time capsule that represents the Earth as a whole through images, music, sounds, and greetings. It is important.

Figure 1. NASA’s Golden Record.
Photo Credit: NASA/JPL-Caltech
to note that the record also contains a celestial road map to our planet. Much has changed since then and this project has students create the contents for the second Golden Record. I will highlight one 7-E cycle (Eisenkraft, 2003) which is an expansion of the 5-E cycle (Bybee et al., 2006) and briefly explain the activities building up to it. The 7-E cycle consists of the following stages: 1) elicit, 2) engage, 3) explore, 4) explain, 5) elaborate, 6) extend, 7) and evaluate. This is not necessarily a script, but rather a way I present this activity to my students.

**Elicit**

The Golden Record project can begin with either the planets or space exploration. You can use strategies like KWL charts, think pair share, hook videos, or draw your favorite planet. I start with the mnemonic “My very exciting magic carpet just sailed under nine palace elephants” (Aguilar, 2008). Typically, the students quickly realize that this is a mnemonic and some will say it is for the planets. However, carpet and elephants typically cause confusion. After they learn that carpet stands for Ceres and elephant stands for Eris (the first three named dwarf planets) I talk about how this was actually created from a national competition by National Geographic Children’s Books. I highlight the fact that the winner was an elementary school girl from Montana who used Aladdin as inspiration to help motivate students.

Next, they research a fascinating fact for every planet (Weird Facts, 2018). I form enough student groups to cover the planets and Pluto, give 10-15 minutes to research and 3 minutes to present. The facts could be geographical or just interesting, like some scientists believing Jupiter rains diamonds (Diamond Rain, 2018). One important fact to include in the Engage discussion is how Pluto was discovered by photographs (Pluto Discovered, 2018). Figure 3 shows a very faint object that has moved location from one spot in the photograph on the left to a different spot on the right.

**Engage**

I start this section with discussions about Pluto and how the images we have of Pluto have changed which turns into exploration. I now incorporate an Engineering by Design activity (Voland, 2004) to have them build a satellite (either on paper or with Legos). One such example can be found at jpl.nasa.gov/edu/
First, they think about the job of their satellite (either given or created). Then, they consider what the satellite must do to achieve its goal. They share their satellite with the class to collaborate, research, and then modify their design. This activity addresses the Middle Grades Engineering Design Standard for the Next Generation Science Standards (NGSS, 2013). One important discussion point to tie in the next activity is how fast they travel.

Students have difficulties with very large and small numbers (Jones et al, 2007) which is a critical part of astronomy. I show them a picture (Figure 4, for example) showing planets and ask them “what don’t I like about this?” The image shows the planets circling around the sun typically equidistant and roughly the same size (Jupiter may be twice the size of Earth). They say the scale is wrong but are not sure by how much since they don’t understand the scale. To address this, I give them a mini Earth that’s 1 inch in diameter. They are told to create a model (using clay and the internet) of the Earth Moon system based on that Earth. Students work in small groups to research data. The key is the relationship that one inch on this scale is equal to the diameter of the Earth (7,917.5 miles). One tip to help with classroom management is to refrain from passing out the modeling clay until they have shown their work. With this scale the moon is just under one quarter of an inch in diameter and is slightly over 30 inches away from the Earth. Modeling size and scales are both key components in the Next Generation Science Standards (MS-ESS1-3). You may expand this to include other planetary bodies and the sun (Pluto is over seven miles away from the sun). I finally show a video describing the work of a team who travel to the desert to create an accurate scale model of the solar system (To Scale: The Solar System, 2015, youtube.com/watch?v=zR3Igc3Rhg).

**Explore**

At this point the lesson focuses on information we have received from satellites in space. I introduce the Golden record and that this is science fact not Star Trek fiction. I show them the music, images, sounds and phrases (Golden Record, 2018) on the record. We discuss how this is a welcome to any forms of intelligent life that finds it. Discussing how the Golden Record provides a galactic roadmap to our planet is where the questions start but refrain from further discussion at this point. This is the time to assign the Golden Record project.

The students are charged with making a second Gold Record. The requirements are simple; they need to create a new list which includes 20 images/artwork (images must be included), 20 books, 20 songs, 20 movies, 20 earth landforms and 20 “About our Earth you Should know” (or 20 greatest scientific facts) and 20 of your own categories. 20 items work well because it doesn’t limit their creativity while requiring a reasonable amount of effort. The “create-your-own-category” gives them more freedom. My students have listed speeches, foods (or recipes), video games, inspirational quotes, social media applications, YouTube clips, historical events, memes, and influential people. Part of their instructions remind them that they are representing the entire world not just the United States however they are not deducted points in the rubric if they do not do that (see Table 1). Students are also required to write out their rationale for their choices per section.
For the “Earth Landform” section, they need 20 pictures of landforms along with a correct scientific description on how each landform was made or information about it and statement why they chose each landform. “About our Earth you Should Know” section gives students flexibility in what they feel are the 20 most important facts or pieces of information about our Earth that they feel visitors should know. For example, they could talk about the water cycle and water’s importance. Each item should have a description why it was chosen. These 40 items should reference the Earth and Space Science Standards. Finally, students provide an overall reflection on the project.

This can be a take home project for the students. Students can do half of the project after one week (first four groups of 20 and then the create your own category) and then complete the rest in the second week (the last 2 earth categories and overall reflection). It could also be a collaborative project with your school colleagues. You can work with the art teacher with respect to the images, the English department with respect to the books, foreign languages to ensure global references, and the music department with the songs. Talk with the teachers in advance, describe the project and ask them to have a discussion with the students about popular works in their respective fields.

Students do collect data but in a different way. They research information such as; the most frequently purchased book, the most expensive piece of artwork, the most downloaded song, or the most quoted movie line. Some students researched the greatest Bollywood movies to ensure their Golden Record II was truly representative of the world. Figure 5 shows some examples that are common from students across the categories.

<table>
<thead>
<tr>
<th>Topic</th>
<th>1 point</th>
<th>3 points</th>
<th>5 points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Images/artwork</td>
<td>Less than 20 items are listed.</td>
<td>Listing of images only and reflection included. OR All images shown but no reflection.</td>
<td>Images are shown and there is a thoughtful reflection about the section.</td>
</tr>
<tr>
<td>Books, Songs, Movies (points are per category)</td>
<td>Less than 20 items are listed.</td>
<td>20 items listed but there is no or brief reflection.</td>
<td>20 items listed with a thoughtful reflection.</td>
</tr>
<tr>
<td>Earth Landforms</td>
<td>Less than 20 items are listed.</td>
<td>Listing of landforms only and reflection included. OR All landforms shown but no reflection.</td>
<td>Landforms are shown and there is a thoughtful reflection about the section.</td>
</tr>
<tr>
<td>About our Earth or (Scientific Facts) (2x the pts)</td>
<td>Less than 20 items are listed or copied list verbatim from a website.</td>
<td>20 items are listed without individual description.</td>
<td>20 items are listed with an individual description for each.</td>
</tr>
<tr>
<td>Create your own category</td>
<td>Less than 20 items are listed.</td>
<td>20 items listed but there is no or brief reflection on why they chose the topic.</td>
<td>20 items listed with a thoughtful reflection for choosing their topic.</td>
</tr>
<tr>
<td>Final Reflection (2x the pts)</td>
<td>Reflection is brief and provides little insight.</td>
<td>Reflection focuses either on their enjoyment (or lack of) doing the project or how they would implement it.</td>
<td>Reflection focuses on both the enjoyment (or lack of) from doing the project and how they would implement it.</td>
</tr>
</tbody>
</table>

Figure 5: Sample of Artifacts Students Include in Project

| Mona Lisa – [en.wikipedia.org/wiki/Mona_Lisa](en.wikipedia.org/wiki/Mona_Lisa) |
| Harry Potter and the Sorcerer’s Stone – [en.wikipedia.org/wiki/Harry_Potter_and_the_Philosopher%27s_Stone_%28film%29](en.wikipedia.org/wiki/Harry_Potter_and_the_Philosopher%27s_Stone_%28film%29) |
| Niagara Falls – [publicdomainpictures.wordpress.com/2011/04/10/niagara-falls/](publicdomainpictures.wordpress.com/2011/04/10/niagara-falls/) |
| Martin Luther King Jr. – [en.wikipedia.org/wiki/Martin_Luther_King,_Jr.#/media/File:Martin_Luther_King,_Jr.jpg](en.wikipedia.org/wiki/Martin_Luther_King,_Jr.#/media/File:Martin_Luther_King,_Jr.jpg) |
Explain

Teachers have several options on what to do for the culminating activity of this project. You can have the students share their lists. Students would need to discuss the science in their categories and the reasoning for their decisions. Teachers can then turn the students into a council and have the class decide what 20 items go into every category. These soft skills of dealing with people are critical for student success (Deming 2017) and learning how to negotiate with a group is important. This can be done in the classroom or you can use free online survey tools. If you opted to do a team meeting in class, then aim for three students in each team to discuss their results. Online voting could be extended beyond the one class, depending on teacher preference. Educators could poll colleagues to have a comparison once the students finalize their list. Another option is to turn this into a time capsule and give it to students when they are seniors. A final option could make this a family project where each student talks with their family members to create their record.

The question about what type of image to present to an alien will arise. The movie E.T. could show that we hope aliens are benevolent or that some humans have a high degree of compassion while others do not. This discussion provides an opportunity to discuss the importance of perception and shows that what we do in any field can be viewed from multiple angles.

Elaborate/Extend

One big question is raised for this assignment: if this were real, should we do it in the first place? Ethical and Socio-scientific issues are important in science (Sadler, et al, 2006) and we need to discuss them (Zeidler et al, 2005). How to have this conversation in class may be a pro-con debate format or a general discussion. This discussion can lead into debates on current situations. One situation is how and why funding and support for space agencies has fluctuated which leads to the notion of privatization of space exploration.

The other important conversation is on culturally relevant pedagogy. I introduce Dr. Aomawa Shields whose TedEd lesson (Rising Star Girls, 2018) compares their answers with our discussion. Stephen Hawkins states that it was a mistake to send up this galactic roadmap. After this discussion, we talk about her organization, Rising Stargirls and her research interests (Shields Ted Talk, 2018) on looking for planets that can sustain life.

I developed an approach which involves combining STEM heroes with content we teach (Rosengrant, 2018) because it is important to highlight the role of women and African Americans in science (spcampus.usf.edu/rosengrant-stem-lab/physics-and-stem-heroes/). If teachers highlight and discuss the research of women and minorities in STEM and then relate their work to the basics of what we teach in the classroom, then this serves as a conversation starter to normalize the idea that STEM fields are not just for white males. Dr. Aomawa Shield’s work regarding SETI (Search for Extra-Terrestrial Intelligence) programs provides an extension opportunity to derive the Drake Equation (Maccone, 2012).

Evaluate

There are many ways you can have a summative assessment depending upon what you want to assess. Traditional summative assessments on content knowledge of the history of space exploration or about the planets are an option. Another is to have students prepare a written argument for and against launching the golden record which must include specific facts. Finally, students could work with friends or family and try to convince them that it is a good idea to launch the record.
Closing

What I appreciate the most with this lesson is the breadth of what I can cover. The time frame for the assignment can be tailored from a class or two to an entire week or a semester long project since there is an extensive amount of content, applications and implications. Students learn how to make ethical decisions like scientists. They learn science is for all individuals. They see that science is not separated from other disciplines but intertwined. It reminds students they are in a global society and need to think beyond our country. This integrative STEAM project has been very successful for my classes; a unique experience for the students who will be part of a space-faring civilization.

References

Pluto Discovered, website accessed April 22, 2018. history.com/this-day-in-history/pluto-discovered.
To Scale: The Solar System (2015), video. youtube.com/watch?v=zR3Igc3Rhfg

About the Author

David Rosengrant is an Associate Professor of STEM Education at the University of South Florida St. Petersburg Campus. He teaches undergraduate and graduate science education courses to pre-service and in-service teachers to K-12 educators. His research focuses on educational technologies like AR/VR in the classroom. He was also past chair of the committee of Teacher Preparation for the American Association of Physics Teachers (AAPT). David can be reached at rosengrant@usf.edu.
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