JANUARY 2015 VOL. 5, NO. 1

In The Trenches

THE NEWS MAGAZINE OF THE NATIONAL ASSOCIATION OF GEOSCIENCE TEACHERS

Teaching Climate Change

In The Trenches

Editor in Chief: Cindy Shellito
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On the Cover: Students at Maine East High School, Park Ridge, Illinois, learn about Earth's physical and geologic systems and the impact they have on humans and about the impact humans have on the environment in dual credit courses on introductory geology and physical geology offered by Oakton College and taught by science department chair Aida Awad. (Photo courtesy of Aida Awad)

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Establishing an Elementary Foundation for Teaching Global Change

Tapping into students' intrinsic interest in the environment at a young age is the key to promoting lifelong interest and awareness of climate change.

Visitors to Chicago's Field Museum marvel at "Sue," the tyrannosaurus, and other natural wonders. [Photo by J. Nguyen, licensed under CC-By-SA-3.0]

I became smitten by the wonders of the universe viewed through the lens of science while in elementary school. In second grade, a fascination with dinosaurs opened my mind to deep time. My fourth grade class took a field trip to a power plant where coal brought by trains from Wyoming was burned to make steam to turn turbines to generate alternating current. The scale and scope of the plant, the massive turbines, smoke stacks and piles of coal waiting incineration were intimidating and impressive. Around the same time, while exploring near the mouth of a canyon my friends and I found a beautiful little oasis and waterfall on an intermittent creek. We were livid when one day not long afterward we discovered that a bulldozer constructing roads for a new mountain subdivision had deliberately destroyed our oasis. Children of the Space Race and Cold War, we had no doubt that humans had become a force of nature capable of altering, if not destroying, the planet. These experiences planted the seeds for my love of science and my career path.

In the years since I was in elementary school, we have learned to measure changes on the Earth in ever greater detail. Consequently, we know much more about humans as a force of nature.

The population of the planet has more than doubled since the 1960s. Not only that, but humans

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are now consuming massive amounts of fossil fuel-derived energy, transforming the world on a geologic scale. We fix more nitrogen for fertilizers than the combined effect of all bacteria on the planet and cause more soil erosion than all natural processes. We move freshwater large distances to meet our needs, and with 80 percent of it going to agriculture, we contribute to further erosion and water pollution.

We are also substantially altering the climate system. Reports by the Intergovernmental Panel on Climate Change (2013) and the National Climate Assessment (Melillo 2014) suggest global average surface temperature will rise modestly or substantially by 2100, depending on whether and how society responds. At the present exponential rate of change, human activities will increase radiative forcing of the climate system from ~2 to over 8 W/m^2 by the year 2100, causing massive changes in ecosystems and societies. Mitigation and adaptation to these changes will require a massive transformation of society by means of education, beginning in elementary school, to minimize climate impacts and maximize resilience and options.

Educational research used in the development of the *Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), confirms that the primary grades from kindergarten through fifth grade are important and appropriate venues to establish foundational understanding of science and develop thinking and innovation skills. Born investigators, elementary students can observe weather, seasonal change, and how organisms respond to changes. They can study microclimates around the school, explore how energy flows through ecosystems and food webs, examine how the energy we consume in our lives is generated, and develop strategies and tools to minimize human impacts on the environment. By learning the essentials of climate and energy early on, they can be prepared in middle school to tackle the topic of human-caused climate change and to delve into causes, effects, risks, and responses in more detail in high school.

As with any sensitive subject, educators obviously need to handle with care how such discussions are framed. Pondering a future that will be radically different from the world of their parents and grandparents could be understandably distressing to students. This can trigger avoidance and

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denial. One way exemplary teachers have found effective in addressing topics of this nature is to emphasize that while the challenges are substantial, there are also exciting opportunities for creativity and innovation. Technologies and jobs that don't exist today will need to be developed to help tackle the climate, energy, food, and water problems that we are already facing. Inspiring learners to come up with their own innovative ideas and strategies grounded in reality and checked against solid science can help counter the urge to disengage and tune out. If properly nurtured, primary school students can be inspired to explore new territory and carry their motivation and momentum with them into secondary school and beyond.

Moving Forward

On occasion I have run into individuals who feel climate change shouldn't be taught in school, that it is too complex, too emotionally and politically wrought for young people to learn about. Such attitudes baffle me. Every one of us is, whether we know it or not, already being impacted in some way by climate change and will be more so in the future. As individuals and communities, we all deserve to know how to make informed climate choices to reduce risk and maximize resilience.

The historic reasons for the omission of climate change in the curriculum are numerous: In addition to the emotional toll and resulting resistance the topic can engender, climate and energy are complex and technical topics that fall into the cracks between traditional disciplines. There has also been a legacy of deliberately manufactured doubt and confusion on the part of business or ideological interests threatened by the implications of the science. This has led to a tendency to avoid the issue even among those who accept the science.

Given that most of the 1.6 million elementary teachers in the U.S. lack a background in science and, due to testing, are often under pressure to emphasize mathematics and language arts in their classrooms, this may sound like a tall order. But there are simple and practical steps that can be taken to weave these topics into elementary school classrooms.

Observing daily and seasonal changes, contemplating the upstream and downstream flow of our food, water, and energy systems, and exploring ways to reduce waste and negative impacts of human activities are all part of the Next Generation Science Standards for elementary students. Field trips to visit power plants might be more difficult to organize now than it was when I was in school, but even a visit to the school's boiler room, guided by someone who can describe how it works and when it is used for heating or cooling, can provide a powerful "teachable moment."

Some schools are being transformed into living laboratories that are climate-smart and energy efficient. Ideally all schools can become interactive hubs of creativity for learners and their communities. At the elementary school level, however, establishing the foundation for understanding general principles of climate and energy is more important than having students do detailed carbon footprint or energy audits, which are more appropriate for middle and high school. As the NRC *Framework for K-12 Science Education* lays out, planting the seeds of inquiry and investigation should begin early on, starting with everyday experiences and a problem-solving attitude, which will help set the stage for further, deeper learning in the years that follow.

College educators, especially those involved with pre-service and professional development for teachers, can play a vital role—by giving elementary teachers in particular the support and guidance they need to give their learners foundational knowledge and skills that they can build on in decades to come.

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THE CAM PROJECT

Tools for Bringing Student Media Production into Climate Change Education

Climate change education offers many challenges and opportunities that may not be encountered in other geoscience subdisciplines. In the cognitive domain, challenges include the inherent complexity and dynamic nature of climate change, as well as the prevalence of misconceptions, or faulty mental models, about the climate system (Forest and Feder, 2011). Additional challenges include psychological, affective, and social responses to information about climate change that can impede both discussion and learning (e.g., CRED, 2009). For example, Leviston et al (2013) describe the effect of "pluralistic ignorance," in which people who believe that human-induced climate change is occurring are reluctant to share that view with others because they mistakenly think they are in the minority.

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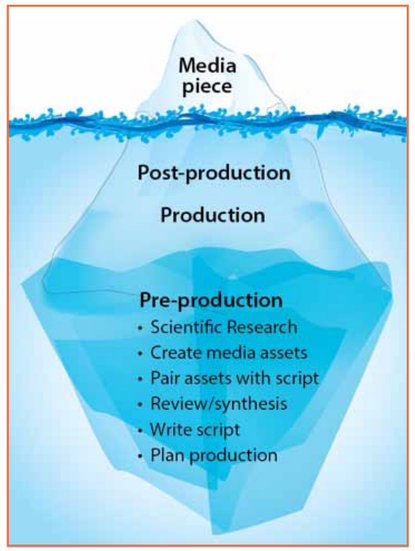
The Climate Education in an Age of Media (CAM) Project (http://cleanet.org/cced_media) provides geoscience teachers with resources to bring student media projects into climate change education. We have found that these can be a powerful way to meet the challenges mentioned above while simultaneously fostering 21st century literacy skills, using active learning approaches, and empowering students to have a voice in societal discourse about a topic that will disproportionately impact younger generations (Rooney-Varga et al. 2014).

While still relatively uncommon in geoscience education, falling technological and cost barriers, the rapid growth of video as a communication medium, and an increasing emphasis on active, project-based learning all suggest that student video projects can be effective as pedagogical tools. Many of us rely on video sources for educational content as a means to "flip classrooms" or a way to enrich our own learning. Similarly, media literacy—the ability to learn from, critically evaluate, and use media to communicate with others—is considered an essential 21st century literacy (Mioduser et al. 2008). The ability to communicate through video is increasingly demanded of scientists (who often lack media literacy skills; Olson, 2009) and is likely to grow in importance as our students move into careers of their own. Lastly, a growing number of young people use video as an expressive form (Lenhart, 2012).

The CAM Project has brought together a team of scientists, science educators, media artists, and media instructors to create curriculum materials and resources that give geoscience educators the tools they need to bring student media production into their own climate change education work. The CAM approach has been successfully adopted in a wide range of instructional settings—from fourth grade science curriculum to high school science projects, middle and high school after-school programs, and undergraduate and graduate courses (Conway, 2013; Rooney-Varga et al. 2014). CAM Project resources include curriculum, materials, and student exemplars for animation projects, person-on-the-street and expert interviews, public service announcements, and video mash-ups, as well as examples of student-produced music videos, mock game shows, and film essays.

The Process of Media Production: Opportunities for Learning, Assessment

The media production process is typically viewed as having three phases: pre-production (including planning, research, and writing); production (where assets and resources are created and/or gathered); and post-production (where everything is brought together, integrated, synthesized, assembled, and edited into a single coherent informative and aesthetic piece of communication). While we tend to focus on the media piece itself, the work needed to generate that piece provides many opportunities for learning and assessment. The end product is analogous to an iceberg, consisting of a small portion that is easily evident, while the vast majority of work and learning is "below the surface," during its creation.



While we tend to evaluate media projects based on the media piece itself, the bulk of the work, learning, and assessment opportunities are "below the surface," occurring during the pre-production phase especially. [Illustration by by Valerie Martin (graphic) and Juliette Rooney-Varga.]

For science education, the pre-production phase is especially important. Curriculum and assignments during this phase can easily be adjusted to meet specific educational needs and course goals. Students may do an original research project, collecting their own data. They may research the primary literature or other sources to see what they can find. Or they may be given explicit reading assignments or lectures that deliver science content for their project. For example, in the CAM Project resources for middle and high school grades, we have included short descriptions of feedback loops in the Earth-climate system. Assignments for more advanced undergraduate students require them to conduct their own review of primary literature sources. What is essential during the pre-production phase is that students gain sufficient mastery of the content to not only explain it to others, but to create a compelling piece that harnesses language (i.e.,

writing skills), as well as visual and audio representations of concepts in an integrated, fluent communication piece.

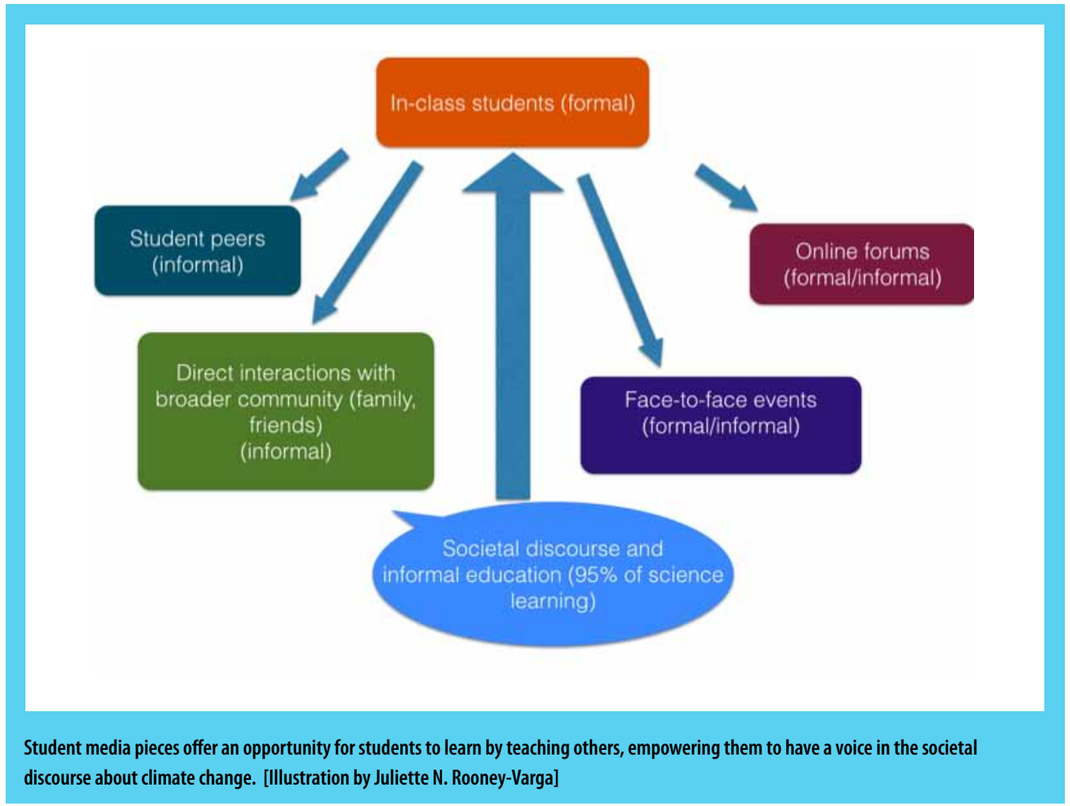
During the production phase, audiovisual assets are created or found. This phase typically involves group work, especially if filming is involved, with at least one team member manipulating the camera while others are being filmed or handling microphones and/or lighting. It calls for extensive collaboration, discussion, problem-solving, and time management.

The post-production phase consists of editing audio and visual products into a coherent, integrated piece as well as disseminating that piece. The iterative process of editing provides an opportunity for learning through continued group discussions, as participants edit their narration and manipulate images, audio, and timing to deliver a message in a compelling manner. As they create their own pieces, students gain insight into the process by which the media they consume is produced and become more sophisticated consumers as a result.

A Sampling from the Cam Project Toolkit: Animation Projects

The CAM Project website provides information and resources for public service announcements, video mash-ups, person-on-the-street interviews, and visual storytelling and animations at http://cleanet.org/cced_media/your_classroom/index.html and samples of projects at http://cleanet.org/cced_media/cam_tv/index.html.

Animation projects are particularly well-suited for communicating abstract concepts about complex, dynamic systems, which are clearly central to climate change. Unlike a writing assignment or a PowerPoint presentation, animation is inherently dynamic, lending itself well to explaining how systems or their components change over time. In fact, in materials developed for the CAM Project, we have integrated systems thinking into animation curriculum materials and found that when we challenge students to use animation to explain how systems work they gain a stronger understanding of how system components



Student media pieces offer an opportunity for students to learn by teaching others, empowering them to have a voice in the societal discourse about climate change. [Illustration by Juliette N. Rooney-Varga]

are interconnected and change over time. Animation projects can be carried out using a range of tools, varying from hands-on, low-tech "paper-mation" or whiteboard animation to more sophisticated software such as Videoscribe or After Effects. While animation software packages continue to become more accessible in both usability and cost, our recommendation for K-12 settings is to start with a low-tech approach so that students focus more on content and less on learning new software. Animation can be easily combined or integrated with other media formats by adding a narration that explains the scientific content, as well as overlaying footage or visual assets to illustrate concepts.

Learning Outcomes and an Invitation

External evaluation of the CAM Project approach has indicated its potential to foster intrinsic motivation, engagement, critical thinking, social learning, an interest in climate change beyond the classroom, and a sense of empowerment and agency (Rooney-Varga et al. 2014). Findings from surveys, student reflections on their experiences, and focus groups have provided evidence for gains in communication skills, teamwork and interpersonal skills, conceptual and analytical abilities, students' understanding of climate change science concepts, and their commitment to addressing climate change. As for the undergraduate student media projects we studied, audiences who viewed student pieces online or at face-to-face "meet-the-filmmaker" screenings also showed gains in climate literacy and viewed students as trusted messengers about climate change science. We have found that screening events provide a forum for students to lead discussions about climate change science that engage their peers, families, and broader communities, offering opportunities for students to play the role of informal educators. In summary, we see strong potential for student media projects to engage students in learning about climate change science while simultaneously empowering them to have a voice in the societal discourse. We invite you to leverage CAM Project tools and bring student media projects into your own climate change education work.

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RESOURCES TO PREPARE STUDENTS FOR CLIMATE CHANGE

Weather and climate figure prominently in the Next Generation Science Standards (NGSS) for both elementary and secondary students. For example, curricula informed by NGSS would challenge elementary students to make weather observations and begin to see connections between life and climate. In middle school, they would be expected to explore the evidence for rising temperatures in the past century. In high school, the NGSS recommend that students analyze climate data and climate model output to make forecasts for the future and discuss the relationships between various Earth systems and their responses to climate change. NGSS also offers many opportunities to integrate climate change with studies of other sciences. Many of the NGSS Disciplinary Core Ideas (DCIs) in the physical and life sciences (e.g., conservation of energy, electromagnetic radiation, and ecosystem dynamics) relate directly or indirectly to understanding climate change. (The full set of standards is available online at: http://www.nextgenscience.org/) While students now enrolled in secondary and college-level courses have not benefited from curricula shaped by NGSS, instructors at these levels have wealth of online resources to draw upon to provide thems with key conceptual knowledge and skills that will enable them to make choices about climate and the environment as fully informed citizens. The following set of resources may provide inspiration and some useful starting points for lessons, activities, and articles related to climate change.

Teaching-specific ideas, activities, and resources that are ready-to-use

- **CLEAN/Climate Literacy and Energy Awareness Network** (http://cleanet.org) If you are planning to introduce climate into your course soon, this should be your first stop. You'll find resources, guidance, and a network of other professionals dedicated to improving climate literacy at all levels.
- **Earthlabs** (http://serc.carleton.edu/earthlabs/index.html) is a set of rigorous, online Earth science labs (with a focus on climate) that aids educators in developing Earth science as a high school capstone course. Most of the materials are also appropriate for introductory college level courses.
- **Interdisciplinary Teaching about Earth for a Sustainable Future/InTeGrate** (http://serc.carleton.edu/integrate/index.html) Many of the modules and instructional resources in this collection of classroom-tested resources for teaching about the Earth from an interdisciplinary perspective integrate some component of climate or environmental change.
- For a good example of a project that gets students to develop videos about climate change, see the article on page 4 by Juliette Rooney-Varga. If you would like to create your own videos to introduce students to new material, to reinforce old material, or to use in a "flipped classroom," see: **Using Videos in Teaching** (http://serc.carleton.edu/NAGTWorkshops/video/index.html)

Reading material, instructional resources and real-time data available at federal agencies

- **The National Oceanic and Atmospheric Administration/NOAA** (http://climate.gov) is a good starting point when having students use current climate data to analyze current climate data and answer questions about climate change. In addition to news on climate, the main page features an interactive Global Climate Dashboard with quick access to current data. A map application allows students to view more detailed and local data. For students working on more advanced projects that might require detailed or local data, **NOAA's National Climate Data Center** (http://www.ncdc.noaa.gov/) is the place to look.
- **NASA's Global Climate Change** (http://climate.nasa.gov/) website has news, background reading, fantastic visuals, and current data. (If you want your students to move beyond the Earth to explore other planets, don't miss **NASA's Eyes on the Solar System** (http://eyes.nasa.gov/), an interactive online tool for a virtual exploration of the solar system.

Resources for prompting discussion and generating interest in the intersections between science and society:

- **Yale Project on Climate Change Communication** (http://environment.yale.edu/climate-communication/) explores the public perception of climate change and issues involved in communicating climate change. Explore *Global Warming's Six Americas* to find out where you and your students stand. It might be particularly interesting in a large class to have each student take the *Six America's* quiz at http://uw.kqed.org/climatesurvey/index-kqed.php and compare class results with the national average.
- **The Climate Voices Science Speakers Network** (http://climatevoices.org) will put you in touch with someone who can help can help you connect your students with climate scientists.. The site features profiles and contact information for scientists around the country who are ready to talk to the public about climate change. If it's not possible to bring someone in for a visit, you might consider arranging a Skype Q&A with a climate expert.
- **The Union of Concerned Scientists Global Warming** (http://www.ucsusa.org/global_warming) is a good starting point for discussing the intersection between science and politics. Articles are appropriate for secondary and college-level students and are well cited.
- **Realclimate.org** has been providing commentary on developing stories in climate science for more than 10 years. The blog, authored by working climate scientists, focuses on the scientific issues, rather than the political or economic aspects of climate change. The advantage of having students read excerpts from a blog rather than a published article or other site lies in the fact that students can see the value of discussion in science, as each blog entry is followed by discussion. It provides an opportunity to discuss the importance of scientific discourse in the process of science.

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Abstract Deadline: March 1 /// \\\ Registration Deadline: April 13

THEMES:

- Developing students' higher order geo scientific skills, from data analysis to critical thinking to effective communication
- Increasing the number and diversity of tudents who learn about Earth
- Collaborating with colleagues across the disciplines to situate learning about Earth in a societal context
- Supporting current and future teachers in successfully implementing the Next Generation Science Standards
- Preparing competitive graduates who move easily into and within the broad and changing geoscience workforce
- Pursuing education research that supports our ability to address these challenges

For additional information and to register, visit: http://serc.carleton.edu/earth_rendezvous/2015/

GEOSCIENCE TEACHERS IN NATIONAL PARKS

The Geoscience Teachers in Parks (GTIP) program is a collaborative effort between NAGT and the National Park Service to provide professional development for elementary, middle school, and high school teachers of geoscience, as well as recent grads who are prospective geoscience teachers.

Interns learn from and collaborate with park personnel, local university staff, contracted researchers, and park partners. They conduct public presentations that emphasize park resources. Projects that they have contributed to include:

- mapping newly discovered cave entrances with GPS
- developing self-guided trail guides connecting Karst features to the park's biology and history
- assisting in water monitoring, cricket monitoring, woodrat monitoring, a national bird banding project, and a bat roost monitoring project
- collecting data on trail erosion due to use
- interacting with students through cave tours and the Junior Ranger Program

For more information, visit http://nagt.org/nagt/profdev/GTIP/index.html

To apply to be a part of the Geoscience Teachers in the Park program, complete the online application.

Application deadline: March 15.

Engaging Students Before, During, and After Visits to Informal Science Education Centers

Many of us had classroom field trips to museums and aquariums when we were students in grades K-12, where the typical visit was designed as a scavenger hunt to complete fill-in-the-blank worksheets. Surprisingly, there are very few published suggestions or guidelines that support teachers and university faculty who wish to go beyond the show-and-tell of looking at museum displays. Yet the importance of an effective science learning experience in informal environments is emphasized by the National Research Council (NRC, 2009) and National Science Teachers Association (NSTA, 2012). There exist a wealth of opportunities for student engagement before, during, and after visits to informal education centers. Here, I provide suggestions that are easily adaptable to various grade levels and useful to instructors wanting to move beyond the traditional model of a classroom museum visit. Although I use the term "museum" in this article, I am referring to all types of informal science education centers, such as science and natural history museums, zoos and aquariums, botanical gardens and arboreta, visitor centers of national parks and wildlife preserves, and planetariums.

Faculty can start by fully exploring a museum website to review the current/permanent displays as well as upcoming exhibits, seminars and workshops. Knowing the museum schedule may determine the date of a classroom visit and, perhaps, which topics are covered in a course at a certain time during the semester. Teachers may require students to read magazine articles and/or papers from scientific journals that relate to the content of specific exhibits and the research of the museum scientists. Perhaps there is a book for students to read that connects to museum research or an exhibit. Either strategy activates prior knowledge and primes students for learning.

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Contact the education coordinator for the museum to discuss learning goals for the visit. The coordinator may schedule a phone appointment or face-to-face meeting to share highlights in the exhibits, as well as provide existing education materials developed for exhibits and museum brochures ahead of time. In addition to the education department, some museums have resident scientists who can be most helpful. Museum scientists can provide behind-the-scene tours of collections and may be able to provide a seminar or other presentation in the museum auditorium. If the class will be at a museum over a lunch period, museum scientists may be willing to have lunch with the students for small, informal discussions about science, their career pathways, etc.

Museum scientists can provide behind-the-scene tours of collections and may be able to provide a seminar or other presentation for the class in the museum auditorium. [iStock.com photo © Jui-Chi Chan]

Back on campus after the museum visit, it is important to make every effort to integrate information and displays from the museum in to the course content so that students don't view the trip as an add-on to the curriculum. Teachers may require students to look for additional journal articles relating to the science content presented in the displays. If a museum scientist is not available during the day of a visit, a Skype session can be used as a follow up, to provide students opportunities to ask questions. Finally, instructors can ask museum staff about projects available to students (photographing exhibits, documenting collections, developing outreach materials, etc.) for undergraduate research and internships, not only to continue student engagement with the scientific content, but to assist the informal science center in fulfilling their mission of science, education, and outreach.

In 2009, I taught historical geology at the same time that the original *Tiktaalik roseae* fossil was at the Academy of Natural Sciences in Philadelphia for a limited time. This coincided with the publication of the book *Your Inner Fish* by Neil Shubin. I assigned the book to my students to read as part of the course. I also contacted Dr. Ted Daeschler, one of the vertebrate paleontologists and museum scientists that was part of the *Tiktaalik* expedition, and coordinated a class visit to the museum. The students had a private lecture in the museum auditorium by Dr. Daeschler about the expedition and the significance of limbed vertebrates, and then we had a tour behind-the-scenes and were able to view the actual *Tiktaalik* fossil that the students had been reading about. One of the students was so inspired by her museum visit that she arranged an internship with the museum education department and completed her senior honors thesis with the creation of an online supplement to the museum's bicentennial exhibit in Google Earth with a series of educational activities, targeted for middle school science educators and students (her work is accessible at: http://www.paesta.psu.edu/classroom/academy-natural-sciences-bicentennial).

Life restoration by Zina Deretsky, National Science Foundation, of *Tiktaalik roseae*, a transitional fossil from the late Devonian period of North America. [Public domain]

So, during our visit to the Academy of Natural Sciences, students were able to receive a solid scientific background on a unique fossil specimen, and they were able to hear from one of the expedition scientists about the process of fieldwork and the relevance of the discovery. Although students had time to explore the museum on their own, this structured visit, along with advanced preparation and significant follow-up, allowed for deeper engagement with the science content and educational resources available at this informal science education center. I encourage faculty to consider communicating with museum staff and thoughtfully plan the preparation and follow-up for museum trip with students, in order to have the largest impact on student learning.

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NAGT

Stepping into the classroom to teach what some consider to be a controversial subject can be a harrowing experience the first time. The senior education research associate at the Paleontological Research Institution offers a set of tips that may make the experience less nerve-wracking and more effective.

DIVING INTO THE TRENCHES: Rules of Thumb for Teaching Controversial Issues

The Paleontological Research Institution has a long history of nurturing understandings of controversial issues. Our Museum of the Earth is built around the interplay of the history of life and the history of Earth. That is a perspective of Darwinian evolution on a planet billions of years old. We have long worked to teach and help others teach about evolution (Allmon, 2009), climate change (Allmon, *et al,* 2010), and, for the last several years, about hydraulic fracturing ("fracking") and the broader energy system (Duggan-Haas, *et al,* 2013). Importantly, the work related to fracking is done without advocating for or against the practice, both in deference to the promises made to our funders and because it makes good pedagogical sense. Drawing from this work and the related body of research, we have crafted rules of thumb for teaching about controversial issues.

["Arm Wrestling" by Bombadil77 at Wikimedia Commons, CC-BY-SA-3.0-migrated]

1 Be nice (but there are limits). Treating those who disagree as either idiots or evil people is unlikely to convince them that you're correct.

a. **Know your audience.** "Nice" has different meanings with different audiences.

b. **For the most part, people aren't lying.** They largely believe what they say.

c. **Advocacy *may* deepen convictions more than understanding.** Evangelism turns on people who agree with you and turns off many who don't. Being certain and being right aren't the same thing, and they aren't all that closely related. Put more faith in people and institutions that are pretty sure than those that are certain.

d. **Don't let the bastards get you down.** Working on nurturing public understanding of controversial issues will make people angry, and angry people say and do nasty things. Have a support system you can turn to.

2 Complexify the seemingly simple. As educators (and like journalists and politicians), we are driven to simplify the seemingly complex. It's often important, but we do it *too* often. The world is complex.

a. **Move from debate to discussion.** There are often ways to reframe away from false dichotomies.

b. **Controversial issues are always interdisciplinary.** Pay attention to the tools and strategies of the most centrally related disciplines.

c. **Don't forget the importance of the simple.** While acknowledging the issue's complexity is important, there are often simple ideas illuminated within that complexity.

3 Evidence matters, but evidence alone is not enough. All of us hold beliefs for which ample conflicting evidence exists.

a. **Learn about cognitive biases (including your own)** and how to communicate more effectively in light of them.

b. **State evidence clearly and directly, identifying a small number of key points.** Too many different points cloud the issue.

c. **Mathematics matters.** Scale plays a central role in many controversial issues, and understanding really large or really small numbers brings special challenges. "Social math" (National Center for Injury Prevention and Control, 2008) uses familiar examples to show volume, mass, or relative number.

d. **Call out logical fallacies, and hold people accountable for (mis)using them.** There's a taxonomy of problematic argument types. Get to know it and put it to use.

4 Persistence matters. Beliefs related to controversial issues are often closely tied to world views, and such beliefs do not change quickly or easily.

a. **People do change their minds on things that matter.**

b. **Piling on evidence can bring beliefs to a tipping point.** Of course, not always.

c. **Reflect on big changes in your own beliefs.** Chances are, it took either a long time or an immersion in the issue.

d. **Social media may be a better venue for this than classrooms** because connections last more than a semester or a year.

5 Use the local environment as a starting point to engage in critical inquiry of the forces working to shape that place. Climate, energy, and evolution, like most topics in Earth science coursework, play out in a meaningful way just outside the classroom door. Starting close to home will make the issue more relevant to the learner.

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For a full transcript of the presentation upon which this is based, presented in October 2014 at the Geological Society of America Annual Meeting, see: http://bit.ly/controversy2014.

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