Big Data

In this issue:

• Thinking big
• Harvesting a sea of data
• A day in the field

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DEPARTMENTS

6 Editor's Corner
Big Data

8 Science 2.0
Start Your App Search With a Question

10 The Green Room
Air Pollution in the Developing World

12 Health Wise
Debunking Health-Related Myths

20 Headline Science
• No Lotion Needed: Many Animals Produce Their Own Sunscreen • Drinking-Age Laws Affect Teen Accident Rate • Teachers Need a Solid Grounding in Evolution • Walk (on Water) Like a Mosquito

50 Call for Papers

60 Career of the Month
An Interview With Data Analyst Dean Judson

62 Safer Science
Heightened Risks

70 NSTA Recommends

74 Authors’ Guidelines

75 Index of Advertisers

76 Right to the Source
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Big Data

When the Sloan Digital Sky Survey started work in 2000, its telescope in New Mexico collected more data in its first few weeks than had been amassed in the entire history of astronomy. Now, a decade later, its archive contains a whopping 140 terabytes of information. A successor, the Large Synoptic Survey Telescope … will acquire that quantity of data every five days (Cukier 2010).

It’s a Cambrian explosion of data. Ever-increasing volumes of information from sensors, satellites, cell phones, telescopes, global information systems, and social media provide unprecedented opportunities for scientists, citizens, and students to investigate complex systems. This has led to what has been called the Age of Big Data (Lohr 2012).

Scientific progress doesn’t result from simply accumulating data. But there’s no doubt that big data is revolutionizing fields as diverse as astronomy, marketing, genomics, climate science, oceanography, social science, and health care.

Data collected from millions of cell phones helped track the 2009 swine flu pandemic and fight the recent Ebola outbreak. Geospatial big data is growing by at least 20% each year (Lee and King 2015). Vast Google user databases have improved the software programs that check spelling, recognize speech, and translate languages.

Discovering the Higgs boson required both big data and big connectivity: 10,000 scientists and engineers from 600 institutions in more than 100 countries analyzed the hundreds of millions of particle collisions generated every second by the 27 km–long collider at CERN.

Gigabytes (10^9 bytes) and terabytes (10^12 bytes) are out; petabytes (10^15 bytes) and exabytes (10^18 bytes) are in; zettabytes (10^21 bytes) are on the near horizon. From science to sports to advertising to public health, big data is transforming the way we think about, interpret, and interact with the world.

Big data has the potential to transform science teaching and learning as well. Educational researchers can now track student achievement in online courses, where monitoring the progress of masses of students in real time can make research more conclusive. In our physical classrooms, students can engage in the higher-order thinking involved in analyzing and interpreting large science datasets and designing their own inquiries to discover patterns and meaning in mountains of accessible data, as authors in this issue of The Science Teacher illustrate.

The Cambrian explosion of life forms, though relatively short in evolutionary terms, still lasted 25–30 million years. Is it possible that the big data revolution will produce similarly dramatic changes, this time in our understanding of the world, in just a matter of decades?

References


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Field Editor
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Start Your App Search With a Question

At this writing, online stores offer nearly 2.5 million apps for Apple and Android devices. Narrow that down to educational apps, and they still number a hefty 80,000 for Apple devices alone, and that doesn’t count non-educational apps that may serve an educational purpose. So, how do we swim in this ever-growing sea of apps?

Begin with a question

So often, we see apps being used in education simply because they’re popular (as evidenced by their ranking or rating in the app stores). Typically, teachers will download an app, then look for a way to fit it into the curriculum. This is backward. We should think first about what we want our students to be doing, and then curate the available apps to find those that most closely meet the need.

Taking notes

So, we may ask: “Which apps allow my students to take better notes and do it collaboratively?” This frames the search not just to replicate what students already may do in a paper notebook but to find a tool to make the task more effective. Consequently, we find some great note-taking tools like Evernote, Penultimate, Skitch, neu.Notes, and neu.Annotate (see “On the web”). In each of these tools, students can pen their own notes, mark up documents, add their own graphs, images, or data tables, and even use the onboard webcam or microphone while doing so.

Annotating videos

Another question we hear is “How can students use pictures and video more creatively and effectively?” Coach My Video and Coach’s Eye, though not categorized as educational, are good tools allowing teachers to mark up students’ videos collected, say, in a lab or field study and allowing students to annotate scenes in the video. Fotobabble allows students to personalize the still images they collect, adding voice-over narrations, while Skitch lets students mark up digital images to better explain what the observer is seeing.

Creating concept maps

In another phase of scientific inquiry, we may want students to show their understanding of the evidence collected during a lab. This time, the question might be: “How can my students create and share concept maps to brainstorm and generate visual representations of their thoughts?” This question leads us to concept-mapping apps—Groupboard, iBrainstorm, Mindjet Maps, and Lucid Chart—many of which allow for simultaneous creation and collaboration.

Finally, we sometimes hear teachers ask: “How can my students best tell the ‘story of science’ that is occurring during their investigations?” Digital storytelling is a great way to elicit creativity and imagination from students, and a number of good apps allow students to do just that, including StoryKit, Strip Designer, and Toontastic. All of these help students tell the grand story of their lab experience or engineering marvel in the form of a comic strip, cartoon, or storybook.

Other questions

We’ve outlined several more themes of instructional design questions and provided links to apps that address these needs on our website, http://bit.ly/1mFSAte. Be sure to think about the instructional design question before you make your next app selection for student use.

On the web

Coach’s Eye ($4.99): http://apple.co/1FxNRIx
Coach My Video: http://apple.co/1JSLkzo
Evernote: http://apple.co/1bDBONU
Fotobabble: http://apple.co/1JAN4Jh
Groupboard: http://apple.co/1GFirMI
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neu.Notes ($1.99): http://apple.co/1bezex6
Penultimate: http://apple.co/1KWP3f
Skitch: http://apple.co/1GFqTq0
StoryKit: http://apple.co/1Inruq0
Strip Designer ($2.99): http://apple.co/1HZimEp
Toontastic: http://apple.co/1bezT1x

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Air Pollution in the Developing World

Recent reports of dangerous air pollution in China don’t surprise scientists. In this rapidly industrializing nation, much of the air pollution comes from coal-burning power plants. As economies like China’s move from agriculture to industry, “environmental quality deteriorates at the early stages . . . and improves at the later stages,” according to the Environmental Kuznets Curve (EKC) hypothesis (Dinda 2004).

Air pollution in less economically developed countries (LEDCs) differs from that in more economically developed countries (MEDCs). LEDCs often lack good waste disposal options and may resort to open waste burning. Also, MEDCs generally have stronger environmental regulations. In the United States, for example, the Environmental Protection Agency (EPA) enforces air quality standards, and coal-burning plants must install pollution-control technology. Sources of air pollution in LEDCs, however, go largely unmonitored. For example, Delhi, India, monitors air pollution in only five places across the sprawling city (see “On the web”).

Classroom activities

For general resources about air pollution, start at the EPA’s teacher resource site (see “On the web”) with lesson plans and links to many activities. One EPA link takes you to the teacher resource section of AirNow, where your class can investigate your local air quality. The Air Quality Index toolkit for teachers provides resources for teaching about the connections among air quality, health, and weather, as well as actions students can take to reduce air pollution.

The lessons at the Delaware Department of Natural Resources and Environmental Control (DNREC) website answer the question: “Why study air pollution?” Students study possible solutions and the responsible agencies (see “On the web”). The University of Northern Iowa offers air-quality activities such as “Particulate Matter Matters!” and “To Burn or Not to Burn,” addressing coal-burning power plants. The College Board offers several laboratory activities designed for Advanced Placement Environmental Science students. In one such lab, students monitor air quality after designing and building an air scrubber. To focus on the human health impacts of air pollution, look to the National Institutes of Health air quality unit, which uses the Tox Town website developed by the National Library of Medicine (see “On the web” and Levin et al. 2012). This unit addresses the following essential questions: How does air pollution affect human health? What human activities affect air quality?

Many students have probably witnessed brown smog hanging over cities. Increasingly, children in the U.S. are suffering from asthma, according to the Centers for Disease Control and Prevention (see “On the web”). And we are not alone. Countries in every stage of development around the world are experiencing air pollution. Educating your students about the sources, environmental and human health effects, and potential solutions for air pollution is crucial.

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On the web

AirNow teacher resources: http://1.usa.gov/1FxBSLa
CDC asthma data: http://1.usa.gov/1JS818
China’s air pollution: http://nyt.m/i/1Fc4ex6
Clean Air Act: www.epa.gov/air/caa
College Board air quality monitoring lab: http://bit.ly/1aVS100
Delhi’s air pollution: http://nyt.m/i/eA8pYB
EPA lesson plans and activities: http://1.usa.gov/1DUq6ki
Tox Town unit: http://1.usa.gov/1yTKXMR
University of Northern Iowa air quality activities: http://bit.ly/1Do7HRE

References

The Master of Science in Education: Science/Math Education is a 36 credit hour program designed for Science and Math teachers in grades 7 through 12 who are interested in becoming better teachers. Students may choose their 12 credit hour major emphases from either Biology, Chemistry, Math or Physical Science/Physics. All coursework is available online and includes both content and pedagogy.

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Debunking Health-Related Myths

Too many Americans ignore science. A recent study quantified the problem (Pew Research Center 2015), showing large gaps between scientists’ understanding and the public’s beliefs:

- 88% of AAAS [American Association for the Advancement of Science] scientists think eating genetically modified foods is safe, while only 37% of the public does.
- 68% of scientists—but only 28% of citizens—think eating foods grown with pesticides is safe.
- 87% of AAAS scientists say climate change is mostly caused by human activity (another source cites 97% consensus among scientists [Cook et al. 2013]), while only 50% of the public agrees.
- 98% of scientists say humans have evolved over time compared with 65% of the public.

The cover of a recent National Geographic cites these viewpoints as evidence of a War on Science: “Climate change does not exist. Evolution never happened. The Moon landing was fake. Vaccinations can lead to autism. Genetically modified food is evil” (Achenbach 2015).

The public’s mistrust of science has grown so deep that science educator Bill Nye started traveling the nation a few years ago to battle deniers of evolution and climate change. You can join the fray on the health front by making sure your students aren’t falling for these fallacies:

1. Germs can’t attach to food that falls on the floor if you pick it up within five seconds (“the five-second rule”).
2. Feed a cold; starve a fever.
3. Coffee stunts your growth.
4. Spicy foods can cause ulcers.
5. Swallowed gum stays in your stomach for years.
7. Reading in dim light damages your eyes.
8. Too much TV is bad for your eyes.
9. If you cross your eyes, they might stay that way.
10. Tanning gets rid of acne.
11. You need to wait an hour after eating before swimming.
12. You can tell the gender of a fetus by the shape and height of a pregnant woman’s belly.
13. Cats can steal the air from a baby’s mouth.
14. Dogs’ mouths are cleaner than people’s mouths.
15. You can catch a cold from being outside in cold or wet weather.
16. Cracking knuckles causes arthritis.
17. People only use 10% of their brains.
18. You lose most of your body heat through your head.
19. Fluoridated water causes health problems.
20. Vaccines can cause autism.

Assign one myth to each of your students and have them use credible sources to research and write a brief explanation of why the myth is false. Or, you can read the myths aloud and ask students to raise their hands to show whether they believe each statement is true or false, before revealing that all are false.

Also, have your students read the Harvard Business Review article, “Why Debunking Myths About Vaccines Hasn’t Convinced Dubious Parents,” which offers evidence-based explanations of why it can be difficult to debunk myths (see “On the web”). Then you can lead a classroom discussion about what scientists can do to boost their credibility and communicate more effectively with the public.

Michael E. Bratsis is senior editor for Kids Health in the Classroom (kidshealth.org/classroom). Send comments, questions, or suggestions to mbratsis@kidshealth.org.

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THE NEXT GENERATION SCIENCE STANDARDS

Where are we now and what have we learned?

Stephen L. Pruitt

The Next Generation Science Standards (NGSS Lead States 2013) were released almost two years ago. Work tied to the NGSS, their adoption, and implementation continues to move forward around the country. I am most frequently asked about the pace of adoption by states, the implementation of the standards, and how the NGSS will be assessed. In this article, I will discuss where we are now and what I have learned during the process so far. As we implement the NGSS, it is important to remember that education is a journey, not a destination.

Where are we now?

As of April, 12 states and the District of Columbia—encompassing about 30% of the nation’s public school population—have adopted the NGSS. Other states and districts continue to consider adoption. Additionally, a growing number of districts in non-adopting states are embracing the NGSS as the best way to move scientific literacy forward. Many of these are large districts that see the need to significantly change how they approach science education regardless of the state-level politics. As a result, the NGSS are significantly influencing science education throughout the country. The excitement around the NGSS I saw at the NSTA national conference in Chicago this year was palpable. Yes, the conference was in an adopting state, but many teachers attending from non-adopting states were also excited and eager to learn more about the standards.

From the beginning, adoption needed to proceed at a pace befitting each state, occurring when, and if, it made sense. Each adopting state, even those who were not lead states due to their undertaking long reviews and public comment periods, can lay claim to owning the NGSS. As such, they can and should choose their own timing. A host of issues face states beyond adopting and implementing new science standards. These issues include developing timelines for adopting instructional materials, revising science standards statutes, and building the will within a state’s education community to make the changes called for in A Framework for K–12 Science Education (NRC 2012) and the NGSS.
Any teacher will tell you that adopting and implementing the NGSS cannot be done without a way to assess. Given the political climate around assessments, the conversation can be harrowing. As a key first step, the NGSS adopter states are committed to building classroom capacity. The focus has been, and must be, on classrooms first rather than building a test. The more we focus on educators and how to make the NGSS real in classrooms before developing an assessment, the better. Assessments that support classroom practice will come as we learn more from classroom experience.

The way the NGSS outlines how students show proficiency makes sense, so teachers are embracing it. That doesn’t mean everyone is an expert. (Research from various places, including The Cambridge Handbook of Expertise and Expert Performance [Ericsson et al. 2006], show that it takes many hours of practice before expert thinking is acquired.) But it does mean that change is in the air, and we must learn more to do better for our students.

It’s time to move from valuing what we measure to measuring what we value. In Kentucky, for instance, the state department of education has hired a “thought partner” before awarding assessment contracts to ensure that any new assessment fully assesses the NGSS. California is using a similar structure with two different groups as they consider new science assessments. So, I am encouraged with the direction and pace of implementation. A thoughtful and deliberate approach has always made the most sense. It is tough to have the courage to be patient, but it is a necessity, not for the adults but for the students.

What have we learned?

My presentation at NSTA’s national conference focused on the top 10 things I learned in 2014 through working with educators and state staff on the various issues we confront. Here are the 10 things, in no particular order:

1. Eliminating the black box is tough.

A black box is created when current science learning is predicated on future science learning. This means that when you say to your students, “You will not understand this until next year,” you create a mystery rather than understanding. The NGSS provides an opportunity to look at science instruction coherently by connecting the different disciplines to better understand a phenomenon, removing the black box. Understanding the role of photosynthesis in the cycling of matter, for example, means you must understand a little about physical sciences in terms of matter and Earth science in terms of distribution of matter.

2. Teaching topics vs. understanding phenomena.

Teaching science is about helping students understand the world around them, both natural and designed. Teaching topics like gas laws, volcanoes, or photosynthesis without connecting them to core ideas that help students explain the world provides no reason for them to learn or retain that information. Gas laws describe part of the structure and properties of matter. The deeper understandings of gas laws are found in the NGSS, but they are couched in explaining the bigger picture of structure of matter. The understandings needed for gas laws are spread throughout the years and across three core ideas in high school physical science. Understanding forces, energy, distribution of energy, and interactions of particles is far more powerful in explaining the world than simply calculating Charles’s law.

3. Simply reading the NGSS does not lead to NGSS expertise.

In our work with the Educators Evaluating the Quality of Instructional Products (EQuIP) rubric, we have seen that professional development that dwells only on the NGSS does not help educators see the innovations required in the NGSS. So, having educators engage in EQuIP, curriculum design, task design, or even an intense discussion of standards that preceded the NGSS stimulates greater understanding. Professional development should also push educators to think outside their grade band and discipline when considering the NGSS (see numbers 9 and 10).

4. If you can eat it, it’s probably not a model.

Understanding the science and engineering practices takes time. There are traditional “models” in classrooms across the country of which I imagine about 80% are edible. Models that students construct and use for the NGSS classroom are quite different. Students need to use models to explain or predict phenomena using evidence. Most “edible” models do not allow for that experience. Scientific and engineering practices are what students do, not teaching strategies. Students should be
able, for example, to identify the components of a model, articulate the relationship of those components, and explain or predict future phenomena based on the model. For more information, see the Appendix of the Evidence Statement (www.nextgenscience.org/ngss-high-school-evidence-statements).

5. Crosscutting concepts are still the third dimension.

The NGSS have three dimensions: scientific and engineering practices, crosscutting concepts, and disciplinary core ideas. Crosscutting concepts are still the hardest dimension to implement but also incredibly powerful. This dimension helps students connect what they learn to the world around them in a meaningful way. It’s hard, but clear instruction about how crosscutting concepts fit with the other dimensions will change science education.

6. Phenomena are underplayed and underappreciated.

The Framework and the NGSS are very focused on phenomena. We need to bring the wonder back to science classrooms, which can be done through studies of phenomena. We have found this is tough to do because of our conditioning, but it is essential to making science real to students.

7. Bundling is not easy.

Bundling performance expectations in the study of phenomena is critical to painting a coherent science picture for students. There is no single correct way to bundle, rather it must make sense to the teacher. So, pick a phenomenon and look at all the standards to find a way to better explain the world. Discuss it with colleagues. Bundling will only get easier with discussion and practice.

8. Communicate, communicate, communicate and then communicate some more.

The NGSS represent a lot of what we want science classrooms to be, but they also depart from how most of our parents were taught. We must make every attempt to be clear about purposes, development processes, and how the NGSS will better prepare our students for the world.

9. Leadership makes the difference.

Teachers make the difference in classrooms. It is time we realize that our profession also makes a difference in society. Teachers are leading the way to our future. What we see in states and districts that are effectively implementing the NGSS is that teachers and administrators are assuming greater leadership roles. Yes, there is more to learn and, yes, it is not easy, but the early implementers have shown us that quality leaders make the difference.

10. 3-D Learning is hard. We do not help teachers or students by pretending it’s not.

If anyone claims to know everything about the three-dimensional learning embodied in the NGSS, be skeptical. This is hard. But, like other professions that deal with hard changes, we will surmount these challenges, too. Learning how to create a 3-D culture in our classrooms takes time and effort.

As was mentioned earlier, achieving expertise (thinking like an expert) takes many hours. We teachers should, as engineers do, give ourselves time to learn and room to grow. We will not get it right the first time, and that is okay. We will get better at NGSS instruction, but we must first acknowledge that it will take time and we will have varying degrees of initial success. The NGSS represent a great opportunity for students and science education. To me, they also represent a great opportunity for teachers to teach science the way we know we should and to be real leaders as we prepare our students for the future.

References


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No Lotion Needed: Many Animals Produce Their Own Sunscreen

Researchers have discovered why many animal species can spend their whole lives outdoors with no apparent damage from high levels of solar exposure: They make their own sunscreen.

The findings, published in the journal *eLife* by scientists from Oregon State University (OSU), found that many fish, amphibians, reptiles, and birds can naturally produce a compound called gadusol, which among other biologic activities provides protection from the ultraviolet, or sunburning, component of sunlight.

The researchers also believe that this ability may have been obtained through some prehistoric, natural, genetic engineering.

The gene that provides the capability to produce gadusol is remarkably similar to one found in algae, which may have transferred it to vertebrate animals. And because it’s so valuable, it has been retained and passed along for hundreds of millions of years of animal evolution.

“Humans and mammals don’t have the ability to make this compound, but we’ve found that many other animal species do,” says Taifo Mahmud, a professor in the OSU College of Pharmacy and lead author on the research.

The genetic pathway that allows gadusol production is found in animals ranging from rainbow trout to the American alligator, green sea turtle, and a farmyard chicken.

“The ability to make gadusol, which was first discovered in fish eggs, clearly has some evolutionary value to be found in so many species,” Mahmud says. “We know it provides UVB protection; it makes a pretty good sunscreen. But there may also be roles it plays as an antioxidant and in stress response, embryonic development, and other functions.”

In their study, the OSU researchers found a way to naturally produce gadusol in high volumes using yeast. With continued research, it may be possible to develop gadusol as an ingredient for different types of sunscreen products, cosmetics, or pharmaceutical products for humans.

A conceptual possibility, Mahmud says, is that ingestion of gadusol could provide humans a systemic sunscreen, as opposed to a cream or compound that has to be rubbed onto the skin.

The existence of gadusol had been known of in some bacteria, algae, and other life forms, but it was believed that vertebrate animals could only obtain it from their diet. The ability to directly synthesize what is essentially a sunscreen may play an important role in animal evolution, and more work is needed to understand the importance of this compound in animal physiology and ecology, the researchers say.

(Oregon State University) [http://bit.ly/1IvUGMX](http://bit.ly/1IvUGMX)

Drinking-Age Laws Affect Teen Accident Rate

Legal-drinking-age laws in Canada can have a major effect on young drivers, says a new study from the University of Northern British Columbia. Drivers just older than the legal drinking age had significantly more motor vehicle crashes than those immediately below the legal drinking age.

In the study, published in the *American Journal of Preventive Medicine*, Russ
Callaghan and his research team looked at Québec motor vehicle collision statistics between 2000 and 2012 that involved young drivers. They found that, compared to those just under legal drinking age, drivers at or above the age had an abrupt increase of 6% in their number of collisions. This increase was even more marked at night, when collisions increased by 11% immediately at the minimum legal drinking age.

“As soon as youth are given legal access to alcohol, there are immediate effects on the road,” says Callaghan, the study’s lead author and an associate professor at the university. “The number of collisions involving both male and female drivers who have just reached legal drinking age rises dramatically, which illustrates the impact that alcohol-related legislation can have on population harm and injury prevention.”

The legal drinking age is 18 in Alberta, Manitoba, and Québec and 19 in the rest of Canada. Recently, the Canadian Public Health Association and a national expert panel working group have recommended that the legal drinking age be raised to 19 years across the country.

“Our research provides current information for both Canadian and international policymakers to draw on when considering alcohol policy...
reform,” Callaghan says. “Drinking-age laws can have major consequences on driving safety.”

According to the research, raising the drinking age to 19 years in Québec would prevent 337 police-reported collisions per year that involved at least one 18-year-old driver. Raise the drinking age to 21, and approximately 583 police-reported collisions per year could be prevented for drivers from 18 to 20 years of age.

Callaghan’s research is part of a larger series of studies he is pursuing over the next several years that investigates the effects of alcohol-related legislation on a variety of harms, including mortality, hospital emergency admissions, in-patient admissions, injury, and crimes, such as sexual assaults and disorderly conduct. (University of Northern British Columbia) http://bit.ly/11qZujd

Teachers Need a Solid Grounding in Evolution

Discussing the relationship between science and faith, rather than avoiding the discussion, may better prepare future high school biology teachers for anticipating questions about evolution, according to Penn State political scientists.

In a series of focus group meetings with biology students at four Pennsylvania institutions—three universities and a college—students from a Catholic college appeared to be more reflective when talking about issues of faith and science.

Students at religious colleges often receive instruction in theology and attend lectures that integrate discussions about faith, says Michael Berkman, professor of political science. While this may help ease anxiety if religious issues arise in future high-school class discussions and talks with concerned parents, ultimately knowledge of evolution is what provides biology teachers with the confidence for effective science instruction, he adds.

“If you don’t have confidence in your own knowledge, especially in a controversial topic, your tendency is going to be to shy away from it, to avoid controversy and to not really teach the subject.”

Critics of evolution often take advantage of a teacher’s limited understanding of evolution to foster doubt in the science and make the science seem less settled than it actually is, Berkman says. These critics need only a slight opening to sow that doubt.

 “[Critics] don’t have to necessarily prove an alternate theory, [they] just have to shed doubt on the prevailing scientific consensus,” Berkman says. “This is not an original idea. A variety of people and groups use the strategy of enabling doubt, in terms of doubting evolution, or climate change, or even, in the past, with tobacco research.”

Although many religious denominations now accept the compatibility between religious faith and the science of evolution, students from the non-religious schools in the study revealed that they often experienced tension between the two, according to the researchers, who released their findings in the Annals of the American Academy of Political and Social Science.

Biology students who have not considered the religious implications of evolution may not be prepared, when they become teachers, for questions from skeptical parents and students.

“Some of the [college biology] students felt that they would be supplied with sufficient lesson plans and pedagogical skills when they become teachers so that they could overcome what they don’t quite understand now and answer the challenging questions that might come up,” Berkman says.

Incorporating faith into discussions about evolution at Catholic and other religious institutions may be easier than at public institutions because the fields of science and religion are kept much more separate at the latter.

In an earlier study, Berkman and his colleagues found that high school biology teachers play a critical role in forming public consensus about science. Denying evolution could, then, lead not just to doubts about evolution but also to a broader misunderstanding of science in general, according to the researchers.

“Evolution is fundamental to biology, but more importantly we think that when you are communicating a skepticism about evolution, you’re communicating a skepticism about science generally,” Berkman says.

The researchers conducted focus group sessions at a large research university; a medium-size, state-owned university; a historically black university; and a Catholic, four-year college, all in Pennsylvania. (Penn State) http://bit.ly/1JUKoHF

Walk (on Water) Like a Mosquito

Small, semiaqueous arthropods, such as mosquitoes and water striders, are...
free to go about their waterborne business thanks to their unique leg-based adaptations, which repel water and allow them to float freely on the surface.

By examining the forces that the segments of mosquito legs generate against a water surface, researchers at the China University of Petroleum (Huadong) and Liaoning University of Technology have unraveled the mechanical logic that allows the mosquitoes to walk on water, which may help in the design of biomimetic structures, such as aquatic robots and small boats.

“The current analyses deepen our understanding of the mechanisms of water-walking of these aquatic insects,” says Jianlin Liu, a professor of engineering mechanics at the China University of Petroleum. They describe their current research in the journal *AIP Advances*.

Mosquitoes land on still bodies of water to lay their eggs just under the

**Water striders (pictured) and mosquitoes walk on water.**

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surface, where the embryos hatch and develop into pupae, eventually emerging from the water as mature adults to continue the cycle.

A mosquito leg consists of three segments coated in gridlike, microscopic, hydrophobic scales: A stiff femur juts out from the insect’s abdomen and connects at a joint to an equally stiff tibia, which branches into a long, flexible tarsus. Previous measurements of the ability of water surfaces to support insects had largely ignored the tarsus, however, focusing instead on whole legs.

The researchers measured the buoyant force produced by the tarsus by adhering a mosquito leg to a steel needle, which was attached to an indenter column and microsensor. This in-situ setup allowed them to adjust the angle and force between the leg and the water’s surface, while taking readings with an optical microscope and digital camera.

Liu and his colleagues found that the insect’s ability to float on water—generating an upward force of 20 times its own body weight with its six legs—is owed entirely to the tarsus’s buoyant horizontal contact with the surface.

“This finding overthrows the classical viewpoint that the longer the mosquito leg, the more efficiently it produces buoyant force,” Liu says.

By reducing the total surface area of the leg in contact with water, the adhesive force of the water on the insect is greatly reduced, which assists in takeoff.

Understanding the structural ability of the tarsus to achieve such a large supporting force per unit length, however, remains an ongoing research endeavor for the team. Future work for Liu and his colleagues involves studying the microstructures, wet adhesive forces, and dynamic behavior of mosquito legs. (China University of Petroleum) [http://bit.ly/1FiWgA4](http://bit.ly/1FiWgA4)
Data are the foundation of science. Every insight and fact in science textbooks is grounded in evidence based on data. The Next Generation Science Standards (NGSS Lead States 2013) positions “analyzing and interpreting data” as one of eight science and engineering practices, and the Common Core State Standards, Mathematics (NGAC and CCSSO 2010) recognize “Measurement and Data” as one of the domains of mathematics to be fostered at all K–12 levels.

In the past, scientists—such as Galileo, Faraday, or Curie—generally worked with data collected personally or within a small team. Nowadays, scientific breakthroughs are more likely to come from complex data sets larger than one scientist could collect. These data, such as genomic DNA data stored at the National Center for Biotechnology Information (see “On the web”), may come from many individual labs. Or they may be from centrally coordinated instruments, such as the geoscientific EarthScope array (see “On the web”). Either way, the data are usually centrally archived and made available online free of charge.

Such data, now accessible to science teachers and students, are often of a quality and quantity previously seen only at research institutions. Large data sets are also increasingly important in other fields, from real estate to marketing to education to criminal justice to sports.

No matter what careers your students may pursue, analyzing and interpreting big data will be an important skill set.

This article is aimed at teachers already experienced with activities involving small, student-collected data sets and who are now ready to begin working with large, online data sets collected by scientists and engineers. We discuss challenges, instructional strategies, and sources of appropriate lesson plans.

Kim Kastens, Ruth Krumhansl, and Irene Baker
Challenges and changes

Figure 1 shows our framework for thinking about how children mature into skilled, data-using adults. At first, children observe the world in an unstructured way with their senses (domain A). They learn to make predictions and generalizations about phenomena experienced directly, such as: “Water will flow downhill.” Next, as students in school, they work with small, self-collected data sets (domain B). Most traditional school-based investigations, including those described in the *National Science Education Standards* (NRC 1996), fall in domain B. An example is growing plants on a classroom windowsill under differing conditions of hydration.

Later, students work with larger data sets that they did not collect themselves. Most often, these are obtained online. At first, they work on fairly well-defined problems, such as locating tectonic plate boundaries from a database of earthquakes and volcanoes (domain C). Finally, they learn to work with large, complex data sets around ill-structured questions such as whether we should allow hydrofracking in our community or which medical treatment is best for an elderly relative (domain D). Figure 1 shows a trajectory with intervals of gradually increasing proficiency as the learner hones skills within one domain, interrupted by transitions involving big steps in learning.

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**FIGURE 1**

Pathway to becoming a skilled data user.

The authors hypothesize that the pathway from child to skilled data user involves several challenging transitions; this article focuses on the transition from small, student-collected data sets to large, professionally collected data sets.

**FIGURE 2**

Changes and challenges in transitioning toward big data.

<table>
<thead>
<tr>
<th>Before</th>
<th>→</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student-collected data</td>
<td>→</td>
<td>Data professionally collected by scientists, engineers, technologists</td>
</tr>
<tr>
<td>Relatively small data sets</td>
<td>→</td>
<td>Relatively large data sets</td>
</tr>
<tr>
<td>Simple empirical observations (e.g., rainfall measured by rain gauge)</td>
<td>→</td>
<td>Complex derived parameters (e.g., precipitation derived from satellite remote sensing data)</td>
</tr>
<tr>
<td>Direct knowledge of context and setting in which the data were collected based on one’s own senses</td>
<td>→</td>
<td>Sparse and abstract understanding of setting from metadata (e.g., date/time, lat./long., location map)</td>
</tr>
<tr>
<td>Participation in design of data plan yields direct knowledge of trade-offs in depth versus breadth</td>
<td>→</td>
<td>Secondhand knowledge of how data were collected</td>
</tr>
<tr>
<td>Aware of some potential data problems from personal experience (e.g., data loss, measurement error, instrument failure, operator error)</td>
<td>→</td>
<td>Must recognize possible data problems from attributes of the data themselves and/or the metadata</td>
</tr>
<tr>
<td>Simple, comprehensible analysis tools: pencil and paper, graph paper, calculator, spreadsheet</td>
<td>→</td>
<td>Powerful but opaque data display and/or statistical software</td>
</tr>
</tbody>
</table>
This article is about the transition from small, student-collected data sets to large, professionally collected data sets, labeled as Transition II in Figure 1. Many challenges and changes happen across this transition (Figure 2). While student-collected data typically have at most a few hundred data points, professionally collected data sets are often measured in gigabytes. Scientists’ data sets are also likely to cover a longer time interval and use a higher sampling rate, more sampling stations, larger population, more conditions, and more data types, or have other forms of complexity. Students typically display their own data in simple tables or graphs but may need to use more complex statistical or visualization tools when using large, scientist-collected data sets (Krumhansl et al. 2012).

Furthermore, when students collect data themselves, they gain a deeper understanding of the process by which the data were generated and possible limits on data quality (Hug and McNeill 2008). They can develop a personal sense of the circumstances or environment from which the data were extracted and then draw on this understanding in making their interpretations (Roth 1996). All of this is lacking when working with data collected by others.

**Instructional strategies**

The transition from small, student-collected data sets to large, professionally collected data sets is challenging but well within the reach of high school students. Below we offer four, classroom-tested instructional strategies that support students in their first explorations of large, professionally collected data sets (Figures 3–6).

**Strategy #1: Data puzzles:** This approach can be infused throughout your lessons and doesn’t require technology. Seek out activities and test questions where students are asked to interpret data visualizations (for example, graphs or maps) of scientists’ data (Figure 3). In well-designed data puzzles, the data snippets have been chosen because they contain a clear-cut manifestation of an important structure or process and thus offer the student a high insight-to-effort ratio (Kastens and Turrin 2010). In Figure 3, students can see evolution manifested in the beak depths of finches in the Galápagos Islands who did and did not survive a severe drought (Education Development Center, Inc., 2014).

In assessing students’ understanding, begin with basic data-skills questions and be sure that at least some questions require students to reason about processes in the system the data represent (Baker-Lawrence 2013) and not merely to read values off the graph or map. For Figure 3, a question requiring students to decode and describe data would be: “Compare the mean beak size of the two finch populations.” A reasoning question would be: “Based on your knowledge of life sciences and the data provided, suggest a possible explanation for the difference in mean beak size.”
“This was challenging in a good way,” said one teacher who used the finch activity in her classroom. “Some students got it right away and were able to answer the reasoning questions using the data. Others struggled and needed to go back to the data. I asked a few guiding questions to help them understand the connections. Next time I’ll step back more and let students reason longer between the questions and the data.”

Strategy #2: Nested data sets. Students first collect and interpret a small, student-collected data set and then interpret a larger data set (Figure 4). In this example, school groups first gain personal experience with the Hudson River estuary by collecting data near their school. Then they extend their inquiry upstream and downstream by bringing in data from other school groups and across time by bringing in professionally collected data from permanently installed sensors in the river. (For more on this activity, see “A Day in the Field,” pp. 35–42.)

For assessment, combine questions addressing the student-collected data set with questions requiring use of the larger data set. A small data question for the Figure 4 example would be: “How did the salinity at our sampling site change as the tide rose?” A big data question would be: “Suggest three factors that seem to influence the salinity in the river and support your suggestions with data.”

Strategy #3: Predict, observe, explain: This instructional sequence, often used for hands-on activities (Haysom and Bowen 2010), can help students explore large data sets (Figure 5). Based on their understanding of a natural process, students predict what a certain type of data will look like under a certain set of circumstances. In the example of Figure 5, students predict that if a distant star has an exoplanet orbiting it, then an observer on Earth should see the light intensity from the star diminish as the exoplanet passes between Earth and the star (Gould, Sunbury, and Krumhansl 2012). [For a complete description of this activity, see an article in the November 2014 issue of this journal (Gould, Sunbury, and Dussault 2014).] Making a prediction gives the students a stake in the outcome, encourages them to observe more closely, and guides their inquiry through the database.

For assessment, probe students’ understanding of the similarities and differences between the prediction and the observed data. When scientists use models, these similarities and differences reveal which aspects of the model have been successful and which need improvement (Kastens et al. 2013). For the example of Figure 5, you could ask: “In what ways did the data look like you expected?” “In what ways was it different?” “What are some possible causes for the similarities and differences?”

Strategy #4: Hypothesis array: In cases where students may not know enough about a system to make a well-formulated prediction, you can provide them with an array of working hypotheses (Figure 6, p. 30). The students explore and marshal the available data to support one of the
hypotheses. In the example of Figure 6, the hypotheses take the form of sketches of landforms that might be represented in a topography/bathymetry database. Research shows that providing such an array of possibilities helps students explore data in a methodical, productive way (Mayer, Mautone, and Prothero 2002).

To assess well, students must not only choose the correct hypothesis but should also back up their selection with evidence and reasoning grounded in data. In the example of Figure 6, one good question would be: “For each of the hypotheses that you rejected, use data to show why that landform cannot be present in the area researched.”

Sources of data and lessons
Armed with these strategies, you still need lesson plans and data for the specific topics you teach. Fortunately, as data of all types have become more abundant online, and data access tools more user-friendly, data-using lesson plans have proliferated. Figure 7 (p. 31) offers some reliable sources for classroom-tested lessons in which students work with scientist-collected data on a wide range of topics from weather to plate tectonics to evolution to genetics.

Conclusion
With your guidance, plus online data and their newly acquired big data skills, students can find evidence for some of the big ideas of science, rather than having to accept those ideas on authority from a teacher or textbook. They can conduct investigations about places and circumstances where they may never go, such as the bottom of the ocean. They can explore phenomena that are global in scope and span years in time, becoming a part of the community of users of that same data, and perhaps even make important discoveries of their own. Students’ facility with complex data will be useful in a growing array of professions, from auto mechanics to health care, plus a necessary prerequisite for careers in science and engineering.

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Acknowledgments
We thank our colleagues in EDC’s Oceans of Data Institute for sharing ideas and strategies, as well as the classroom teachers who collaborated with us on developing and testing activities for students to learn with data. This thinking has been funded by the National Science Foundation through grants EAR99-07689, GEO06-08057, and DRL11-38616 to Columbia University.
On the web
EarthScope array: www.earthscope.org
EDC's Oceans of Data Institute: http://oceansofdata.org

References

FIGURE 6
Hypothesis array strategy.
Students exploring data from an unfamiliar system seek to support or refute several candidate hypotheses provided to them.
### FIGURE 7

**Sources of K–12 activities using professionally collected data sets.**

<table>
<thead>
<tr>
<th>Source</th>
<th>Sample activities</th>
</tr>
</thead>
</table>
| The Center for Innovation in Engineering and Science Education, Stevens Institute of Technology ([http://ciese.org/realtimproj.html](http://ciese.org/realtimproj.html)) | • Air pollution: What’s the solution?  
• The Gulf Stream voyage  
• Catch a wave  
• Tsunami surge                                                                 |
| Cooperative Institute for Meteorological Satellite Studies, Space Science and Engineering Center, University of Wisconsin–Madison ([https://cimss.ssec.wisc.edu/satmet/index.html](https://cimss.ssec.wisc.edu/satmet/index.html)) | • Satellite winds  
• Weather forecasting  
• Wild weather  
• Satellite images  
• Monitoring the global environment                                            |
| NOAA ([http://dataintheclassroom.noaa.gov/DataInTheClassRoom/](http://dataintheclassroom.noaa.gov/DataInTheClassRoom/)) | • Investigating El Niño using real data  
• Understanding sea level using real data  
• Understanding ocean acidification  
• Drawing conclusions: Weather maps                                              |
• Patterns in ocean currents  
• Comparing regional climates                                                     |
| Earth Exploration Toolbook ([http://serc.carleton.edu/eet/index.html](http://serc.carleton.edu/eet/index.html)) | • Analyzing plate motion using EarthScope GPS data  
• Climate history from deep sea sediments  
• Cool cores capture climate change (ice cores)  
• Detecting El Niño in sea surface temperature data  
• Water availability                                                             |
| Evolution and the Nature of Science Institutes ([www.indiana.edu/~ensiweb/lessons/p.tut.db.html](http://www.indiana.edu/~ensiweb/lessons/p.tut.db.html)) | • Investigating evolutionary questions using online molecular databases  
• Footsteps in time: Analysis of Laetoli footprints  
• Varve dating: Dating sedimentary strata  
• Cytochrome-C Lab (amino acid sequences in several different animals)           |
| Northwest Association for Biomedical Research ([http://bit.ly/1xXoAWw](http://bit.ly/1xXoAWw)) | • How bioinformatics is applied to genetic testing  
• How bioinformatics is used in genetics research                                |
• Medical problem solving: What is the cause of the seizures?  
• Eye color: Is blue really blue?  
• DNA surveillance unit: Is that an endangered whale you’re eating?  
• Bear evolution                                                                 |
What Science Teachers Are Reading This Summer

Teaching for Conceptual Understanding in Science
Grades K–12
This book is a rich source of ideas to make you consider science teaching from a whole new perspective. Teaching for Conceptual Understanding in Science is a collaboration between Richard Konicek-Moran and Page Keeley. The book is a fascinating combination of deep thinking about teaching and learning for understanding; field-tested, classroom-ready strategies that support conceptual understanding in all grades; and personal vignettes with lessons for all educators.

Book: Member Price: $27.16 | Nonmember Price: $33.95
E-book: Member Price: $22.07 | Nonmember Price: $25.46
Book/E-book Set: Member Price: $35.31 | Nonmember Price: $44.14

Introducing Teachers and Administrators to the NGSS
A Professional Development Facilitator’s Guide
Grades K–12
This book is full of activities and useful advice for guiding teachers and administrators as they put the standards into practice in the classroom. It introduces the vocabulary, structure, and conceptual shifts of the NGSS; explores the three dimensions of the Framework and how they’re integrated in the NGSS; provides classroom case studies of instructional approaches; and covers curricular decisions involving course mapping, designing essential questions and performance assessments, and using the NGSS to plan units of instruction.

Book: Member Price: $29.56 | Nonmember Price: $36.95
E-book: Member Price: $24.02 | Nonmember Price: $27.71
Uncovering Student Ideas in Physical Science, Volume 2
39 New Electricity and Magnetism Formative Assessment Probes
Grades K–12

This new volume in the bestselling Uncovering series offers 39 new formative assessment probes focusing on electric charge, electric current, and magnets and electromagnetism. These physical science probes work with everything from demystifying electromagnetic fields to explaining the real reason why balloons stick to the wall after you rub them on your hair. By helping you detect and then address misconceptions with sound science, this new volume has the potential to transform your teaching.

Book: Member Price: $30.36 | Nonmember Price: $37.95
Book/E-book Set: Member Price: $39.47 | Nonmember Price: $49.34

NGSS for All Students
Grades K–12

NGSS for All Students shows you how to teach diverse students and connect your lessons to the Next Generation Science Standards (NGSS). The emphasis is on show. At the core of the book are case studies that vividly illustrate research- and standards-based classroom strategies to engage seven diverse demographic groups. The book also includes additional chapters on how to design a unit with the NGSS and diversity in mind, apply a rubric to examine and improve teaching the NGSS with diverse students, and use the case studies in teacher study groups.

Book: Member Price: $27.96 | Nonmember Price: $34.95
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Book/E-book Set: Member Price: $36.35 | Nonmember Price: $45.44

The BSCS 5E Instructional Model
Creating Teachable Moments
Grades K–12

The BSCS 5E Instructional Model can help you deliberately structure and sequence your lessons so you experience more teachable moments in your classroom. Created in the late 1980s by a team led by author Rodger Bybee, the popular BSCS 5E Instructional Model includes five phases: engage, explore, explain, elaborate, and evaluate. The book elaborates on how the model connects to the Next Generation Science Standards (NGSS), STEM education, 21st-century skills, and real classrooms. The BSCS 5E Instructional Model addresses every teacher’s concern: how to become more effective in the classroom—and enjoy more of those teachable moments.

Book: Member Price: $25.56 | Nonmember Price: $31.95
E-book: Member Price: $20.77 | Nonmember Price: $23.96
Book/E-book Set: Member Price: $33.23 | Nonmember Price: $41.54

Argument-Driven Inquiry in Chemistry
Lab Investigations for Grades 9–12

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Book: Member Price: $35.96 | Nonmember Price: $44.95
E-book: Member Price: $27.17 | Nonmember Price: $33.96
Book/E-book Set: Member Price: $46.51 | Nonmember Price: $58.14

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http://careers.nsta.org
Data and data analysis are central to science and the complex world in which we live. Students need to practice working with data—addressed in the *Next Generation Science Standards* (NGSS Lead States 2013) (Figure 1, pp. 37–38)—starting with small, self-collected data sets and moving on to larger, remotely collected data assemblages. Small data sets are the foundation, and firsthand data-gathering experiences are the building blocks, for working with data collected by others, known as secondary data sets. Making a strong connection between self-collected and secondary data sets improves student understanding.

This article describes “A Day in the Life of the Hudson River Estuary,” a field-based, collaborative, multischool project designed to be a stepped entry to data analysis and meaning making. The project begins with students gathering their own data in a complex estuarine system. They use...
their observations to analyze this authentic data, recognizing patterns and identifying the association to specific Earth processes and interactions. Examples include an increase in salinity connecting to a rising tide from the ocean or a spike in dissolved oxygen—despite the increase in temperature—correlating with a midday sun and increased photosynthesis (Figure 2, p. 39). Students then add their results to the larger “Day in the Life of the Hudson River Estuary” collaborative project, extending the data coverage spatially and allowing them to examine variability in a larger system. Finally, students use local and global real-time data portals to compare their understanding to a much larger set of processes.

**Why start with field sampling?**

On field day, students from three high schools arrive via bus at a pier on the Hudson River at 8:30 a.m. The day starts with an introduction to field techniques, locating on a map the other participating school groups, and a review of the day’s goals. Our sample site is home to one of 10 sensors that provide continuous readings on the 153-mile Hudson estuary. Students will use data from these sensors and from other student groups on the estuary and data they collect themselves with test kits and handheld meters. By 2 p.m., the students have rotated among five different stations, posting results as they sample. This provides a time series of data on a range of parameters, which they begin to examine and discuss before making the 30-minute ride back to their schools.

A field experience adds layers of understanding and complexity that can’t be replicated in a laboratory setting. It also helps students transition to larger data sets where teasing apart subtleties, interactions, and meaning in the data can be challenging. Field sampling brings:

- Active and dynamic learning, not a canned lesson, involving interaction among tides, currents, weather conditions, biology, and other environmental systems.
- A larger sense of scale.
- Problem solving and critical thinking. “People often underestimate the role that experience and real-world problem solving can have on what a student learns,” says one AP biology teacher.

Like professional scientists, students should plan carefully for sample collection and recording before going into the field. For students to collect accurate results that can be analyzed by their classmates, other students from the wider project, and students participating in future years, they need:

- A clear understanding of each parameter being collected, its expected range, and overall role and importance in the larger system;
- specific sampling protocols and recording protocols; and
- ancillary information that is to be recorded to assist in data analysis.

Figure 3 (p. 40) shows the project collection options. Each section of measurements represents an interesting and important part of the larger system; together they highlight the complex nature of a dynamic, reactive, and interactive estuary. Participating high schools select which type of data they will collect from this list, with each teacher assessing their students’ capabilities and available equipment and field time.

Because the data will be integrated into a larger data set, schools are encouraged to measure a few basic parameters to facilitate comparison across sampling sites: dissolved oxygen, pH, air and water temperature, salinity, notation of tidal cycle, and, if possible, fish catch. These parameters are particularly relevant to a large tidal estuary subject to diurnal cycles and habitats; other systems would have somewhat different key parameters.

**Introducing students to field work**

Students should be prepared for field work with proper dress and field supplies. Teachers must prepare by visiting the sampling site beforehand to check for safety issues; accessibility for all students and vehicles, including ramps or other accommodations for any students with special needs; restrooms; and any special equipment needed at the specific site. Trip supplies should include safety items such as protective gloves, goggles, and waste bottles for disposing of sampling waste. Approved personal flotation devices may be required if you are working off a pier or working where water depths would require this. Students should help label and organize all supplies and directions by sampling station.

**Quality data collection for the larger community**

Collecting data seems more important to students when they realize their results will be shared and analyzed by a wide community of users. This is part of the larger practice of science. No individual can collect all the measurements needed to understand Earth’s systems. Scientists rely on other scientists to accurately collect and record data that they can access in their own research.

Teachers should reinforce with students how recording data carefully by following established data collection protocols is essential for the data to be useful. Teachers can discuss their responsibility to the larger community of users and how each piece of data contributes to our larger understanding when results are combined.

Accuracy and documentation of equipment and techniques are important when data is collected over several years and compiled into an online database. For example, concerning fish data, a total catch of fewer than a dozen fish at one site compared with several hundred fish at an-
Connecting to the Next Generation Science Standards (NGSS Lead States 2013).

The materials/lessons/activities outlined in this article are just one step toward reaching the standards listed below. Additional supporting materials/lessons/activities will be required.

### Standard: Life Sciences HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

<table>
<thead>
<tr>
<th>Disciplinary Core Ideas</th>
<th>Aligned activities from Hudson River Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS2.A: Interdependent Relationships in Ecosystems</td>
<td>The complex interdependent relationship in an estuary ecosystem is at the core of the project; examining the dynamic nature of the physical system, the biology and the chemistry is a unique part of working within an estuary. The sampling, and the following analysis of the results through graphing parameters by site, by system and through time, identifies the interdependence in the system resources.</td>
</tr>
<tr>
<td>LS2.C: Ecosystem Dynamics, Functioning, and Resilience</td>
<td>The ecosystem is examined through related impacts and responses to the effect on the chemistry and biology from the weather, the tidal cycle and other parts of the physical system. Temporal cycles are identified both through the course of a sampling day, expanded through the available years of student collected data, and then through adding the instrumental record. Data compared over several years highlights the effect on the estuary from the flooding from Hurricane Irene and Superstorm Sandy in low D.O. levels from loss of aquatic plants to a drop in juvenile fish.</td>
</tr>
<tr>
<td>LS2.D: Social Interactions and Group Behavior</td>
<td>Fish catch is used to identify which are schooling species, leading to a discussion on the behavioral advantage to this. Students evaluate the function of features such as the rotated eye of a benthic flounder, the fused pelvic fin that anchors a naked goby, the benthic behavior of an American eel, or the swimming capability of blue crab to assess the role of each in species survival.</td>
</tr>
</tbody>
</table>

### Standard: Earth & Space Science HS-ESS3: Earth and Human Activity

<table>
<thead>
<tr>
<th>Disciplinary Core Ideas</th>
<th>Aligned activities from Hudson River Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESS3.A. Natural Resources</td>
<td>Collected data includes potential human impacts on the system through hardscaping, channelizing, removing plant material, rip rap addition and a range of other alterations, including the introduction of invasive species.</td>
</tr>
<tr>
<td>Science and Engineering Practices</td>
<td></td>
</tr>
</tbody>
</table>
other site might be related to a difference in habitat or fish schooling behavior; however, it could also result from the collection technique and equipment used, such as setting a fish trap instead of pulling a seine net through the water. Likewise, a very low dissolved oxygen result might mean poor water quality following a rain event that introduced contaminants into the water, or it may mean the use of low-resolution sampling equipment. Without supporting information, recognizing equipment-related differences becomes impossible.

Sampling in the field introduces many environmental factors that can influence the data. Deciding what supporting environmental information to record can be daunting and should be discussed in class. At a minimum, record a careful site description, including an assessment of the built and natural environment; the stage of the tide and current cycle; and weather, including temperature highs and lows, wind speed and direction, and rain amounts for the day itself and the previous few days. Also record the latitude and longitude, sampling date, collection times, and a unique identifier for the samplers, in case clarification is needed when the data is combined. Such an ID might be “PP_2_10AM_Hall” for Piermont Pier, station #, rotation, and group leader.

Developing students’ data-analysis skills
Data analysis is about pattern recognition, which can be enhanced and developed through practice. When scientists analyze and interpret data, they “use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data” (A Framework for K–12 Science Education; NRC 2012, p. 51). The famed Fibonacci sequence was based on patterns from nature, including tides and seasons; using natural processes to develop analysis skill is a logical start for data users.

Encourage students to begin examining their data as the results are collected. As students chart results in the field and make a first pass through the data, they can immediately look for patterns, discussing any change in readings or apparent relationships, while making note of the specific times and results. Their observation of a variation in salinity during the course of the day might allow them to connect it to a changing tidal cycle, a small current or eddy that
A Day in the Field

This assessment should continue in the classroom as students move their results into a spreadsheet for further review and analysis. This spreadsheet can become the base for adding results from the wider regions’ sampling locations as they become available. (We post our project results online to encourage a wider look at the estuary; they could also be shared through e-mail or via Google Docs.)

Comparing data from different collection sites in the estuary introduces students to working with secondary data, using an intimately familiar data set with consistent sampling protocols. Creating a spreadsheet chart allows students to map different parameters against each other, for example fish catch throughout the estuary against variables such as salt levels in the water (Figure 4, p. 40). Worksheets and activities developed around the data can further strengthen data analysis. Students have created their own data visualizations (see “On the web”) using the salinity levels collected throughout the estuary. The overall pattern is not surprising, but subtle nuances in the data hold deeper stories of density changes at depth, tidal variability, and variations in annual weather patterns (Figure 5, p. 41).

Moving to larger data sets

Moving students to the next level—continuously recorded sensor data—poses bigger challenges. These large nodes of “big data” are provided through organizations such as the National Oceanic and Atmospheric Administration (NOAA), the United States Geological Survey (USGS), and the Great Lakes website (see “On the web”). The Hudson estuary has a network of sensor stations called the Hudson River Environmental Conditions Observing System (HRECOS) placed near some of our student sampling sites; they collect many of the same parameters our students do. With any of these larger data sets, the volume and presentation of the data may be challenging for students.

Gather students in groups of two to four to help them decode the data graphs and charts of several related parameters. Scaffold their learning, starting with describing the data to build their confidence and asking basic questions, such as: What parameters are plotted in the graph? What is the sampling timeframe? What happens to the parameters over the sampling time?

Next, move beyond description to analysis. Students’ limited familiarity with the parameters can make it difficult for them to begin their analysis. To help, give them probing questions that increase in difficulty as they become familiar with the data. Questions that offer a good starting point include: You described the behavior of this parameter, now consider: Would this involve other pa-
rameters for which you have data? How do the other parameters react? Is there an apparent relationship? Considering the parameters, could there be a relationship between them? Could the relationship be causation or more likely a correlation? What additional data could you look at to check this?

Small group discussion helps students become more comfortable with looking at the data and using it to make inferences about processes and the wider estuary system. It also builds their confidence for exploring the data further on their own. Using a recording worksheet can be useful in building the data analysis (Figure 6, p. 42).

Reminding students that they have collected and looked at some of these same parameters with their own sampling, such as salinity increasing with a rising tide, helps them connect with this larger volume and new format in the data (Figure 7, p. 42).
Conclusion
This article discussed a model for data use and analysis that involves students collecting data from the field, then analyzing and sharing it as part of a larger integrated data project. The project serves as a stepped entry to working with a large suite of professionally collected data on a similar system. This same approach can be used on a much smaller scale with schools working with different classes to share data or even comparing data collected by other students in the same classrooms over different events or times of the year.

Teachers can contact the USGS or their local county or state stream-testing agency as a first step in locating sensor data being collected on Earth or environmental systems. Students can use complex data sets independent of the field activity to practice making predictions, to develop and test hypotheses, and to identify additional data that would be useful. The worksheet in Figure 6 (p. 42) will help.

There are vast amounts of data being collected every day. As teachers we are always looking for opportunities to strengthen our students’ data analysis skills and exploration in science. This activity is designed to do that.

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Acknowledgments
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**A Day in the Field**

**Data-recording worksheet.**
A sample worksheet for guiding students through the description, analysis, and interpretation of big data sets. The worksheet can be completed in small groups to encourage discussion and critical thinking.

**Identify:**
- Title: Is there a title? What is it?
- Parameters: What is being measured and displayed on the graph?
- Axes: Identify what X represents and what Y represents.
- Time period: What is the sampling time period covered in the data?

**Consider:**
- Describe what you noticed about this image.
- What is the shape?
- What is the "action"? What is happening to the parameters being looked at over the period shown?
- The Cause: What do you think is causing this to happen? Pose a hypothesis.

**Analyze:**
- Other parameters: Consider your hypotheses, could the changes involve another parameter for which there is data available?
- React: How do the parameters react?
- Relationship: Is there an apparent relationship between parameters?
- Think carefully: Given the parameters is it likely there would be a relationship between them?
- Causation or correlation: If there is a relationship would it be more likely to be causation or correlation? Why?
- Additional data: What additional data would you look at to check this?

**Discuss:**
- Unfamiliar: Describe anything you see that is unfamiliar or that you cannot identify.
- Unexpected: What did you notice that you didn’t expect?
- Can’t explain: What did you notice that you can’t explain or that was confusing to you?

---

**FIGURE 6**

**Data display from observation sensors.**
This HRECOS sensor display shows parameters and a process the students should be familiar with from their own data collection: the relationship between the tidal cycle and salinity in the system.

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**On the web**
NYSDEC website for Day in the Life: [www.dec.ny.gov/lands/47285.html](http://www.dec.ny.gov/lands/47285.html)
Developing your own data visualization:

“Big data” resources for environmental monitoring systems:
Hudson River Environmental Conditions Observing System: [www.hrecos.org/joom](http://www.hrecos.org/joom)
National Weather Service: [www.weather.gov](http://www.weather.gov)
NOAA Tides & Currents: [http://tidesandcurrents.noaa.gov](http://tidesandcurrents.noaa.gov)
USGS: [www.usgs.gov](http://www.usgs.gov)

**References**
Harvesting a Sea of Data

Using authentic data to investigate marine migrations

Amy Busey, Ruth Krumhansl, Julianne Mueller-Northcott, Josephine Louie, Randy Kochevar, Kira Krumhansl, and Virgil Zetterlind

A baby elephant seal on the Valdes Peninsula, Argentina.
“My students were hot on the trail of a giant elephant seal,” says Julianne Mueller-Northcott, a science educator at Souhegan High School in Amherst, New Hampshire. “They saw it leave the shoreline south of San Francisco, dive 700 meters, and then head north toward Alaska.” The students weren’t on a research ship but thousands of miles away in a marine biology classroom, following elephant seals and other marine animals virtually, via laptop.

With data from the Tagging of Pelagic Predators research program (see “On the web”), the students navigated the terrain of the ocean floor using Google Earth, following a bright red line tracking the elephant seal (Figure 1) as it circled off the coast of the Aleutian Islands. Adding tracking data from other elephant seals, they looked for patterns across multiple animals—notice, for example, that some seals traveled north while others went directly out to sea. “I prompted them with such questions as: ‘Where is the animal going?’ ‘What would motivate the seal to migrate like this?’ ‘Why is it circling in the one area—mating? feeding? avoiding a predator?’” Mueller-Northcott says. “My students were hooked! They had questions and access to a wealth of scientifically collected data and were ready to try to find answers.”

Ocean Tracks

Ocean Tracks: Investigating Marine Migrations in a Changing Ocean (see “On the web”) is an innovative program that provides students free access to authentic data collected from migrating elephant seals, white sharks, albatross, tuna, drifting buoys, and satellites, as well as customized analysis tools modeled after those used by scientists. Ocean Tracks allows teachers and students to use large, professionally collected data sets to investigate scientific questions of current, real-world importance: What do marine animals’ movements tell us about areas of the ocean that are critical in supporting biodiversity? In what ways are human activities affecting these areas?

Big data in the high school classroom

Scientific research is undergoing a “big data” revolution, as probes deployed in oceans, the atmosphere, and outer space provide near real-time data streams. As more and more data sets such as Ocean Tracks become available online, opportunities to engage students in the Next Generation Science Standards (NGSS Lead States 2013) practice of “analyzing and interpreting data” are blossoming (Figure 2). Students and teachers have unprecedented access to weather and climate data, images of stars and galaxies, seismic recordings, and more—data that take them not just outside the classroom but to the edges of our planet and beyond. With such abundant new data, students can ask and answer their own questions, perhaps identifying patterns that have yet to be discovered by scientists.

While large scientific data sets can potentially transform teaching and learning (Barstow and Geary 2002; Borne et al. 2009; Ledley et al. 2008; Marlino, Sumner, and Wright 2004; NSF Cyberinfrastructure Council 2007; Rainey et al. 2013; Slater, Slater, and Olsen 2009), access to data often comes with a catch: Data portals meant for scientists can be unintelligible to students and teachers due to cryptic labeling, unintuitive navigation structures, unfamiliar data visualizations, and complicated analysis tools. There is a need for critical scaffolds, including customized interfaces, guiding curricula, and tools that allow teachers to assess students’ progress (Edelson, Gordin, and Pea 1997; Krumhansl et al. 2012; Quintana et al. 2004; Sandosval 2001).

To tackle these challenges, Oceans of Data, a National Science Foundation–funded project, set out to find and summarize what is known about designing data interfaces and
Connecting to the Next Generation Science Standards (NGSS Lead States 2013).

The materials/lessons/activities outlined in this article are just one step toward reaching the standards listed below. Additional supporting materials/lessons/activities will be required.

<table>
<thead>
<tr>
<th>Disciplinary Core Ideas</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESS2.E: Biogeology</td>
<td>The Ocean Tracks interface and curriculum engage students in thinking about how Earth and ocean processes influence life in the oceans. For example, students use tracking data to identify areas of the ocean heavily used by marine life and investigate the oceanographic processes that create these biologically productive areas. (Curriculum Module 2)</td>
</tr>
<tr>
<td>ESS3.C: Human impacts on Earth systems</td>
<td>The Human Impacts overlay uses data on a variety of activities and processes (e.g., pollution, shipping) to show the intensity of human impacts in different regions of the Pacific Ocean. Students use this overlay to describe human impacts on areas of the ocean that students have determined to be of importance to the Ocean Tracks species. (Curriculum Module 4)</td>
</tr>
<tr>
<td>LS2.A: Interdependent relationships in ecosystems</td>
<td>Students use tracking data to identify the coast of California as an area heavily used by the Ocean Tracks species. To understand why, students learn how the process of upwelling creates productive areas for the prey of the Ocean Tracks species. Students must then understand the link between the Ocean Tracks species and the prey. (Curriculum Module 3)</td>
</tr>
<tr>
<td>LS2.B: Cycles of matter and energy transfer in ecosystems</td>
<td>Students investigate the behavior of elephant seals by taking measurements from their tracks and linking these to a chlorophyll overlay to generate a map of where the elephant seal prey are likely to be found. Students construct a food web to illustrate the levels of energy transfer between these two groups of organisms. (Curriculum Module 2)</td>
</tr>
<tr>
<td>LS2.C: Ecosystem dynamics, functioning, and resilience</td>
<td>After generating support for hypotheses about how the Ocean Tracks species are influenced by environmental conditions, students make predictions about how human impacts may affect marine species. (Curriculum Module 4)</td>
</tr>
<tr>
<td>LS4.C: Adaptations</td>
<td>As students investigate the tracks of the Ocean Tracks species, they make discoveries about the habits of these animals. They examine how deep elephant seals can dive, the trans-Pacific journeys of the bluefin tuna, and the Laysan albatross's ability to fly incredible distances over short periods of time. Resources in the Ocean Tracks library help students understand how adaptations enable Ocean Tracks animals to accomplish remarkable feats. (Curriculum Modules 1–4)</td>
</tr>
<tr>
<td>LS4.D: Biodiversity and humans</td>
<td>The Ocean Tracks “Hot Spot” tool measures the density of track points in a particular area of the ocean. Using background information on biodiversity from the Ocean Tracks Library, students consider whether the hot spots they identify are species hot spots or biodiversity hot spots. Using the Human Impact overlay, students see how extensively human activity affects their hot spot. With this information, students construct a plan to mitigate the effects of overexploitation, pollution, and other factors on their hot spot. (Curriculum Modules 3 and 4)</td>
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</table>
### Science and Engineering Practices

<table>
<thead>
<tr>
<th>Practice</th>
<th>Example</th>
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</thead>
<tbody>
<tr>
<td>Practice 4: Analyzing and Interpreting Data</td>
<td>Students take measurements from tracks of Elephant Seals (speed, depth, and track curviness), and interpret this data to generate support for hypotheses about where the animals are displaying feeding behavior. (Curriculum Module 2)</td>
</tr>
<tr>
<td>Practice 6: Constructing Explanations</td>
<td>Students use animal tracking data and oceanographic data overlays to identify habitat hotspots in the Pacific Basin. They then construct explanations for these phenomena, which requires them to integrate their measurements and observations with their understanding of the underlying mechanisms that create productive ocean habitat. (Curriculum Module 3)</td>
</tr>
<tr>
<td>Practice 7: Engaging in Argument from Evidence</td>
<td>Students make a case for the design and location of a marine protected area. Engaging in this debate requires that students provide data supporting why some areas of the ocean are more important than others for marine species, what human activities may affect those areas, and whether the location of these areas changes over time. (Curriculum Module 5)</td>
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</table>

### Crosscutting Concepts

<table>
<thead>
<tr>
<th>Concept</th>
<th>Example</th>
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</thead>
<tbody>
<tr>
<td>Patterns</td>
<td>Students describe and quantify patterns in the tracks of elephant seals, white sharks, bluefin tuna, and Laysan albatross. They then make quantitative comparisons between the migration patterns of these four species to determine the species that travels the fastest and farthest. (Curriculum Module 1)</td>
</tr>
<tr>
<td>Cause and Effect</td>
<td>Students observe patterns in habitat use by large marine animals and use data and background information to identify the underlying causes of these patterns. (Curriculum Modules 2 and 3)</td>
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</table>

### Ocean Literacy Principles (Ocean Literacy Network 2013)

<table>
<thead>
<tr>
<th>Principle</th>
<th>Example</th>
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<tbody>
<tr>
<td>Principle 5: The ocean supports a great diversity of life and ecosystems.</td>
<td>Students observe the ocean in four dimensions as they follow the individual animals across the surface, down to the seafloor, and examine environmental factors that vary across space and time. Through an in-depth investigation of the Ocean Tracks species, students gain an appreciation for the remarkable adaptations of these animals to their ocean environment. (Curriculum Modules 2 and 3)</td>
</tr>
<tr>
<td>Principle 7: The ocean is largely unexplored.</td>
<td>Ocean Tracks uses data collected by the Tagging of Pelagic Predators research program. Using satellite technology, electronic tags allow us to learn more about ocean inhabitants and their environment than ever before. Students investigate questions of interest to practicing scientists as they examine where these animals live, travel, feed, and breed. (Curriculum Modules 1–4)</td>
</tr>
</tbody>
</table>
visualizations for high school students. Guidelines emerged (Krumhansl et al. 2012) that are being implemented and tested in the Ocean Tracks project introduced above.

**Piloting the data interface**

To develop Ocean Tracks, a team of marine biologists, geoscientists, curriculum developers, web designers, teachers, and education researchers collaborated to generate a web interface and teaching resources and to conduct preliminary research on the program. One of the teachers, Mueller-Northcott, piloted Ocean Tracks in her high school marine biology classrooms in the spring and fall of 2013. Her efforts and experiences, as well as those of the other pilot teachers, have provided insights about the potential of such programs to facilitate learning with big data in high school classrooms.

“After my marine biology students developed ideas about the seal’s behavior based on their observations and background research,” Mueller-Northcott says, “I challenged them to gather and use quantitative evidence to paint a clearer picture of the factors that might be influencing migration patterns.” Working in pairs, the students identified key portions of the track that might support their hypotheses and created plots of the animal’s speed and deepest daily dive (Figures 3 and 4), recording their measurements in a data table. Based on these measurements, along with their observations and the research they conducted using the online Ocean Tracks library, they formed hypotheses that they tested by gathering additional evidence. They added sea surface temperature and chlorophyll concentration overlays and took measurements from these data in areas of interest along the track.

The students looked for patterns consistent with their hypotheses. Feeling confident in their claims, the students moved about the classroom, comparing other groups’ seal track measurements displayed on posters with their own data. At first, some students were alarmed: “Our measurements aren’t the same!” But then they surmised that the different groups may not have chosen exactly the same track intervals to measure and that, in fact, the patterns were similar in all the groups’ data: “The elephant seal’s average speed is lower, and the dives are deeper in the portions of the track where we think they’re feeding,” one student said.

“This was not the kind of discussion that we have very often in my marine biology course,” Mueller-Northcott says. “When confronted with variation in their measurements and conflicting claims, my students helped each other grapple with issues such as what constitutes evidence, what the data (and differences in the data) actually represent, the significance of patterns and the meaning of data that don’t fit those patterns, and how to assess confidence in your own and others’ claims and evidence.” As students delved into the data more deeply, the teacher pushed their thinking further by asking: “What do the data tell you?” “What other information can you use to help you?” “Who can gather the most evidence to support their hypothesis?”
Lessons learned

Teachers’ and students’ pilot work with Ocean Tracks yielded valuable lessons about how to engage students with professionally collected data sets accessible online. The following suggestions are based on pilot teachers’ experiences and reflections (Sickler and Cherry 2011):

- Finding and preparing authentic data can be labor intensive for the teacher, and student experiences with these data are often limited to analyzing and interpreting a single set or type of data. In contrast, easy access to rich data sets can inspire questions, allow for explorations, and spur classroom discussions that are only possible when students explore multiple lines of evidence.

- Even when using a customized data interface, students still need support interpreting data and reading data visualizations, such as sea surface temperature maps or depth plots. Teachers who piloted Ocean Tracks found that students were particularly engaged when working in pairs or small groups and that it’s important to have whole-class discussions and spontaneous debates about data in the classroom.

- Orientation experiences and teacher-support materials (e.g., curriculum guides, suggestions for implementation, content supports) are important, particularly for new teachers, as they help students learn to use scientific data. (Ocean Tracks pilot teachers used a teacher guide and attended a one-day training session on the interface and curriculum materials.) Ocean Tracks plans to offer expanded opportunities for virtual and in-person professional development in future phases of the program.

- To achieve the best results, supplement students’ time on the computer with offline activities that let them practice their new skills.

Male elephant seals can weigh up to 4,500 pounds.
Encourage students to face the challenges of working with scientific data. Many will find it difficult to work without definitive “right” or “wrong” answers, to assess their work on how well data support their claims, and to make claims based on multiple types of data and repeated measurements. Remind students that the data are authentic and that their investigations are similar to the work of real scientists.

Connecting students’ experiences with data to their own lives can motivate them to explore questions related to that data.

Conclusion

Students and teachers today are poised alongside scientists at the frontier of the big data phenomenon. The opportunities for providing better access to big data sets are ripe, and Ocean Tracks is serving as a model. However, much still needs to be learned about what teaching strategies may help students (and teachers) learn to work with and analyze big data. This article can spur further exploration of using big data in the high school classroom. Armed with the right tools and instructional strategies, the possibilities for learning about the world through data are boundless.

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Acknowledgments

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On the web

Ocean Tracks learning modules (a series of investigations); teacher guide, including supplemental activities; and multimedia supports (virtual library and video resources for students and teachers): http://oceantracks.org

Programs, products, and research focused on unlocking the potential of big data in education: http://oceansofdata.org

Tagging of Pelagic Predators (TOPP): www.topp.org

References


Call for Papers

The Science Teacher (TST) is seeking manuscripts that describe new and creative ideas for the secondary science classroom. Manuscripts should provide worthwhile ideas and practical help for teachers as they relate to the themes listed below. TST also always encourages manuscripts outside of the listed themes.

New Tools for Data Collection and Sharing
SUBMISSION DEADLINE: Extended to July 15, 2015
As technology evolves, so do the skills needed for success in the modern world. New tools have radically changed the way we communicate, share information, and collect data. This issue will explore how these new tools can support student learning. Possible topics include ideas for using probeware and wireless data collection in laboratory and field work; social media; online simulations; modeling; mathematics and computational thinking; 3D printers; new presentation and communication tools; YouTube, online lectures, and flipped classrooms; live webcams; cloud computing; and digital graphics, multimedia, and visualization. Please share your teaching strategies involving 21st-century skills.

Constructing Explanations and Designing Solutions
SUBMISSION DEADLINE: August 1, 2015
The central goal of science is constructing explanations. In engineering design, the aim is to develop the best possible solution to a problem. The Next Generation Science Standards therefore identify “Constructing Explanations and Designing Solutions” as one of the core practices of science and engineering practices that students should experience. This issue will focus on activities and teaching strategies that engage students in constructing and critiquing explanations and designing solutions. Please share your ideas.

21st-Century Skills: Critical Thinking, Creativity, and Problem Solving
SUBMISSION DEADLINE: August 15, 2015
Over time, technology and the internet have evolved dramatically, as have the skills required for success in the modern world. As routine work is automated and information made accessible at the click of a digital device, skills necessary for success in work and citizenship have evolved. In addition to core subject knowledge, other skills become increasingly important: critical thinking and problem solving; flexibility, adaptability, and innovation; communication, collaboration and cross-cultural empathy; creativity; information, media, and technology literacy; systems thinking; and others. Have you found a successful way to help students learn these important skills? If so, please consider sharing them with TST readers.

Crosscutting Concepts and Interdisciplinary Projects
SUBMISSION DEADLINE: September 1, 2015
A Framework for K–12 Science Education describes crosscutting concepts as ideas “that bridge disciplinary boundaries, having explanatory value throughout much of science and engineering” (p. 83). These fundamental concepts should be learned in every K–12 classroom, every year. And what better way to include them than creating interdisciplinary units or projects? Have you found ways to cross disciplinary borders by integrating crosscutting concepts into project-based learning? Do you use projects to support the goals of the Next Generation Science Standards? Please share your activities and teaching strategies.

Activities and Investigations
SUBMISSION DEADLINE: Ongoing
Activities and investigations play a central role in all science courses. Do you have a new activity—or a new twist on an old favorite—that engages students in scientific and engineering practices? Have you found ways to integrate technology? What about low-cost alternatives? Have you modified an activity to align it with the Next Generation Science Standards? TST is looking for manuscripts describing interesting, practical investigations that can be incorporated into science classrooms and laboratories.

Commentaries
SUBMISSION DEADLINE: Ongoing
Commentaries of approximately 750 words on any secondary education topic are accepted at any time. Share your thoughts on science education with your peers. Write a Commentary and submit it to TST for review.
When 97% of students choose to play electronic games in their free time (Lenhart 2009), teachers should consider the potential advantages of the “gamification” of learning. Ample evidence shows that science education games can increase students’ conceptual understanding, science-process skills, and understandings about the nature of science (NRC 2011). Games also motivate and challenge students at their own level (Blumberg 2014). When used effectively and scaffolded by other instructional activities, games can improve student learning through the three dimensions of the Next Generation Science Standards (NGSS Lead States 2013): science and engineering practices, disciplinary core ideas, and crosscutting concepts.

Science-based games

The Educational Gaming Environments group (EdGE) at TERC is a not-for-profit STEM education organization in Cambridge, Massachusetts, devoted to increasing science literacy through games. EdGE offers three free games aimed at high school students, available from its NSF-funded Leveling Up project (Asbell-Clarke, Rowe, and Sylvan 2013): Impulse, Quantum Spectre, and Ravenous (see “On the web”). EdGE’s preliminary analysis of 330 students in 31 physics classes has demonstrated higher learning gains for students in classes where gameplay was interwoven with instruction as compared to classes in which gameplay was encouraged without instructional context (Rowe et al. 2014).

Bridging games with classroom instruction

In my honors physics and physical science classes, I (the lead author) used the Impulse and Quantum Spectre games, which require students to apply concepts of force and motion, geometric optics, and light addition/subtraction. During relevant units, students were encouraged to play both during and outside of class on computers or tablets. Gameplay days were interspersed with scaffolded instructional activities. Students were given their own device during class and were encouraged to talk with other students to help overcome difficulties. The physical science class is not typically high-achieving, but students were notably more engaged and excited than in regular instructional activities. These students engaged in authentic scientific discourse as they collaborated to solve game challenges—behavior I do not often observe,
especially among my English language learners. I saw all my students evaluate their strategies and reasoning with at least one other classmate.

**Impulse**
In this strategy-based game, players apply an impulse to move their green particle into a goal, using a limited amount

### Activity 1

<table>
<thead>
<tr>
<th><strong>NGSS Standard HS-PS2 Motion and Stability: Forces and Interactions</strong></th>
<th><strong>Prompting questions for gameplay</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance Expectation</strong> (HS-PS2-1): Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.</td>
<td>• How does applying an equal force to blue, red, and white particles impact the particles’ motions? What does this suggest about the differences between each particle?</td>
</tr>
<tr>
<td><strong>Science and Engineering Practice</strong>: Analyzing and Interpreting Data</td>
<td>• What happens to a particle’s motion after the force has been removed?</td>
</tr>
<tr>
<td><strong>Disciplinary Core Idea</strong>: PS2.A: Forces and Motion Newton's second law accurately predicts changes in the motion of macroscopic objects.</td>
<td></td>
</tr>
<tr>
<td><strong>Crosscutting Concept</strong>: Cause and Effect</td>
<td></td>
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</tbody>
</table>

### Activity 2

<table>
<thead>
<tr>
<th><strong>NGSS Standard HS-PS2 Motion and Stability: Forces and Interactions</strong></th>
<th><strong>Prompting questions for gameplay</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance Expectation</strong> (HS-PS2-2): Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.</td>
<td>• What is the resulting motion of two particles of equal mass that collide head-on at the same speed?</td>
</tr>
<tr>
<td><strong>Science and Engineering Practice</strong>: Using Mathematics and Computational Thinking</td>
<td>• How is the resulting motion different if the masses or speeds of the particles are different, or if the collision is not head-on? Explain.</td>
</tr>
<tr>
<td>• Use mathematical representations of phenomena to describe explanations.</td>
<td></td>
</tr>
<tr>
<td><strong>Disciplinary Core Idea</strong>: PS2.A: Forces and Motion</td>
<td></td>
</tr>
<tr>
<td>• Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. In any system, total momentum is always conserved.</td>
<td></td>
</tr>
<tr>
<td><strong>Crosscutting Concept</strong>: Systems and Systems Models</td>
<td></td>
</tr>
</tbody>
</table>
of energy (Figure 1, p. 52). Players can modify the magnitude and direction of net force applied to any particle on the screen. As players progress, they encounter enemy particles that can explode a player’s particle, ending the game. Enemy particles are associated with various amounts of mass and therefore respond to equal impulses with differing changes in velocity. More challenging levels also incorporate gravitational and electromagnetic forces among the interacting particles (Figure 2, p. 52). As players navigate their green particle to the goal, they must interact with these variable particles, anticipating their motions.

**Bridging Impulse game play with classroom instruction**

Having students play the game before classroom activities gives them background experience. During class, students can play games related to instruction about physics concepts with “teachable moments” as students encounter challenges. Alternatively, teachers can explicitly relate play of specific game levels to other in-class lab experiences. This game can help students to use NGSS science and engineering practices of Developing and Using Models (of the cause of motion), Constructing Explanations (for the motions they observed), Engaging in Argument from Evidence (about why different particles behave differently), and Analyzing and Interpreting Data (which they collect from the particles to derive the law of conservation of momentum). Teachers can also explicitly ask students to reflect on the NGSS crosscutting concepts of Cause and Effect (What makes a particle move or continue moving?) and Energy and Matter Conservation (Is momentum conserved?) related to the physical science disciplinary core idea of Forces and Motion. Figure 3 (p. 53) suggests probing questions for students during or after gameplay.

**Bowling Ball Relay**

Students can play a Bowling Ball Relay (Figure 4) to bridge Impulse concepts to Newton’s 1st and 2nd laws. Using a broom, students push a bowling ball along a designated
path as quickly as possible, avoiding obstacles. Students realize that the bowling ball is not only difficult to move but also to stop (like the massive white particles in Impulse). For comparison, students then repeat the course using a Ping-Pong ball (like the small blue particle in Impulse). The game and related hands-on activity, followed by guided discussion, can help students develop the concepts of balanced and unbalanced systems, inertia, and acceleration.

**Video analysis**

Realistic gaming environments necessarily obey the laws of physics. Students can capture their game play, import it into simple video analysis software such as LoggerPro or Tracker (see “On the web”), and evaluate relative masses and velocities, using an estimated or random screen length as a base distance unit. Students will find that initial momentum of the two interacting particles equals total final momentum, thereby using the game as an inquiry environment to learn about conservation of momentum.

For example, if the two particles that have equal mass collide, then simple velocity vectors can be used to model momentum vectors. Even a simple analysis of the particles’ motion demonstrates conservation of momentum (Figure 5). In this case, ball #1, moving at an angle, bumps into stationary ball #2. The individual components of their velocities can be easily tracked and plotted and velocities determined by taking the slopes of the lines before and after the collision. The total change in velocity for the two balls can then be estimated (and should be equal and opposite, thus conserving momentum). Once students have determined that the law of conservation of momentum applies, ask them to use the law to estimate relative mass of different particles colliding with one another. Collisions can be set up to occur in one or two dimensions to differentiate difficulty.

**Quantum Spectre**

This puzzle-style game requires players to shoot laser beams at targets to advance to the next level (Figure 6). As players progress, they are introduced to plane mirrors, convex and concave mirrors and lenses, and beam splitters as tools to help redirect each laser beam to its intended target while avoiding obstacles. Light ray sources and targets are stationary, while players can choose both the location and angle of the tools. Players earn points by minimizing the number of moves they need to make while adjusting the beam’s direction, thereby encouraging students to anticipate how the available tools will influence a beam.

**Bridging Quantum Spectre game play with classroom instruction**

The game Quantum Spectre allows students to see beams of light they otherwise couldn’t in plain air and introduces students to concepts necessary for ray diagramming. In Quantum Spectre, even small variations in focal length suddenly become apparent as the rays extend outward from the mirrors and lenses and can be easily compared—something not directly visible in a laboratory setting. Although geometric optics is not emphasized in the NGSS, this game does allow students to employ science and engineering practices, most notably Using Mathematics and Computational Thinking and Designing Solutions. The game also sets the stage for introducing disciplinary core ideas surrounding wave properties (PS4.A) and electromagnetic radiation (PS4.B) as well as the concepts of reflection, index of refraction, and absorption.

Unlike Impulse, which demands immediate responses to changes in particle motion, Quantum Spectre requires work with a static system; students must anticipate step-by-step solutions to solving the puzzle in the most efficient way. Likewise, the NGSS crosscutting concepts of Scale, Proportion, and Quantity can be explicitly or implicitly addressed as students consider where light rays will be along a grid at near or far positions from a source or point of reflection or refraction. See Figure 7 (p. 56) for bridging examples for the game and classroom.
**Focal length lab**

Most students will never directly modify focal lengths for a single lens unless through simulations that allow students to change the index of refraction of lenses as well as the curvature. Teachers can help students analyze the effects of focal length on mirrors (and, by analogy, lenses) using mirrored paperboard or plastic. By bending a flexible mirror, students can change its focal length and then analyze how that changes image appearance (Figure 8); they can then relate these effects to the light beam behavior they observed in *Quantum Spectre*.

**Filters lab**

An essential part of understanding electromagnetic radiation is how it is absorbed by matter. Students often demonstrate a variety of misconceptions, especially with regard to how white light appears to be colored by filters. Rather, the use of filters is a subtractive process, working much like a colander that strains water from a pot of noodles, allowing some colors to pass through while others get trapped. In *Quantum Spectre*, this is accurately displayed when a magenta light beam shines onto a red filter, and only the red light passes through, while the blue light gets absorbed. This can

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**FIGURE 7**

*Quantum Spectre* gameplay bridging activities.

The materials/lessons/activities outlined in this article are just one step toward reaching the Performance Expectations listed below. Additional supporting materials/lessons/activities will be required.

**Activity 1**

<table>
<thead>
<tr>
<th>NGSS standard HS-PS4 Waves</th>
<th>Prompting questions for gameplay</th>
</tr>
</thead>
</table>
| **Performance Expectation (HS-PS4-1):** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Note: Although wave properties are not explicitly addressed in *Quantum Spectre*, this activity can provide an introductory activity that builds a foundation for students to begin work on meeting the above PE and addressing science and engineering practices and crosscutting concepts related to the disciplinary core idea of Wave Properties (PS4.A).] | • Observe parallel light rays as they pass through a convex or concave lens. What patterns do you notice?  
• Some convex lenses bring parallel light rays together at a “focal point.” What is different about lenses that have different focal lengths? |

**Activity 2**

<table>
<thead>
<tr>
<th>NGSS standard HS-PS4 Waves</th>
<th>Prompting questions for gameplay</th>
</tr>
</thead>
</table>
| **Performance Expectation (HS-PS4-4):** Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. [Note: Although properties of electromagnetic radiation are not explicitly addressed in *Quantum Spectre*, this activity can provide an introductory activity that builds a foundation for students to begin work on meeting the above PE and addressing science and engineering practices and crosscutting concepts related to the disciplinary core idea of Electromagnetic Radiation (PS4.B).] | • Send a red light beam through a blue filter. What happens? Send the red light beam through a red filter. What happens? Why?  
• Send a red light beam through a yellow filter. What happens? Why? |
be easily demonstrated to students by projecting the three primary colors of light—red, blue, and green—on a black background onto a screen (Figure 9, p. 58). Before students look through a red filter, they often incorrectly expect to see an addition of pigments and instead see only the red circle, whose light is the only one to make it through the red filter.

**Ravenous**

Although I did not use *Ravenous* with my own students, it does merit attention for the value it can bring to teachers of life science. *Ravenous* is a side-scroller game about bird flight and survival modeled after real-world ravens. Players must use the raven’s methods to find and use energy efficiently, prove its fitness, and pass on its genes to the next generation. *Ravenous* players control various aspects of flight such as flight speed and wing positions for gliding, ascending, descending, and landing. As such, this game can help teach the NGSS crosscutting concepts of Energy and Matter Flows and Structure and Function, disciplinary core ideas like Interdependent Relationships in Ecosystems, and Natural Selection and Adaptation, and science and engineering practices such as Developing and Using Models (Figure 10, p. 58). The game challenges players to virtually fly like a raven, using available energy in the most efficient manner, finding prey and storing energy so that eventually they can find a mate and reproduce before dying.

*Ravenous* can be scaffolded with a number of in-class activities, including having students sketch a food chain using the biotic factors in the gameplay environment and identifying energy cycles. Teachers can also have students observe birds outdoors so they can see behaviors similar to those in the game, including “backwing” techniques for air braking.
FIGURE 9

Colors predicted and observed by students.

*From left:* Three dots of primary colors of light projected in a dark room; the colors (red, purple, brown) students predict they will see if the original image is viewed through a red filter; and the actual color (red only) viewed by students through a red filter.

FIGURE 10

**Ravenous** gameplay bridging activities.

The materials/lessons/activities outlined in this article are just one step toward reaching the Performance Expectations listed below. Additional supporting materials/lessons/activities will be required.

<table>
<thead>
<tr>
<th>NGSS standard HS-LS2 Ecosystems: Interactions, Energy, and Dynamics</th>
<th>Prompting questions for game play</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance Expectation (HS-LS2-2):</strong> Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.</td>
<td>• What are the producers, consumers, and decomposers in the game? What are the biotic and abiotic sources of energy in the game? • What behaviors should the raven display to use energy most efficiently?</td>
</tr>
<tr>
<td><strong>Science and Engineering Practice:</strong> Developing and Using Models</td>
<td></td>
</tr>
<tr>
<td><strong>Disciplinary Core Idea:</strong> Interdependent Relationships in Ecosystems</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NGSS standard HS-LS4 Biological Evolution: Unity and Diversity</th>
<th>Prompting questions for game play</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance Expectation (HS-LS4-4):</strong> Construct an explanation based on evidence for how natural selection leads to adaptation of populations.</td>
<td>• Work with your class to simulate a species population. Identify some behaviors that you think might help the raven to survive (or have more points before dying). Have some subgroups use different behaviors to model natural selection. Which subgroups earn more points before dying? Why?</td>
</tr>
<tr>
<td><strong>Science and Engineering Practice:</strong> Constructing Explanations</td>
<td></td>
</tr>
<tr>
<td><strong>Disciplinary Core Ideas:</strong> Natural Selection and Adaptation</td>
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<tr>
<td><strong>Crosscutting Concept:</strong> Cause and Effect</td>
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within the game itself could be used to assess skills learned in previous levels, showing mastery of a required skill or strategy. Asking students to narrate their strategies as they play the game can also help reveal their understanding of related science concepts. Diagnostic tools, such as the Force Concept Inventory (Hestenes et al. 1992), can help assess concepts exhibited in the games.

**Conclusion**

Gaming is becoming an effective form of learning and assessment and shouldn’t be overlooked in an increasingly technological world. The games described in this article, entertaining enough to be played by the general public, are also appropriate and useful in a classroom setting.

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**Acknowledgment**

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**On the web**

EdGE at TERC: http://edgeatterc.com/edge
Impulse: http://bit.ly/1BOyRGY
Logger Pro: http://bit.ly/1ID2unbn
Ravenous: http://bit.ly/1by7kwO

**References**


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References


Data Analyst

Data analysts inspect, manipulate, and model data to discover information useful to decision makers. Quantitative data analysis is a more practical, applied field than statistics or data science—it’s for people who want to “get dirty with the data,” says Dean Judson, who has performed this function most recently at the National Center for Health Statistics (NCHS) in Hyattsville, Maryland, a part of the Centers for Disease Control and Prevention based in Atlanta, Georgia. He conducts research that links survey data (comprehensive data on a sample that represents the whole population) with administrative data (sparser data representing a smaller population).

Work overview.

Most of my colleagues are epidemiologists or public health specialists. I help them use data to answer their questions, such as: “Is being overweight really related to future mortality?” “What kinds of people die for what reasons?” “Do they differ by how much money they make?” The questions are never as straightforward as looking up something in a book.

I do a mix of statistical programming (to get the computer to produce relevant numbers), inventing and recommending record-linkage strategies (to find specific people across databases), and analyzing data (looking at results and seeing if they make sense). The record-linkage part of my job involves computation and math, but I also use my sociological training when determining whether the results make sense.

The NCHS has been surveying the public about its health since the 1960s. We look at survey respondents in a given year and try to find them in the National Death Index, which dates to 1979, looking at the causes of death to uncover causal relationships. We address such questions as, “If someone was a smoker in 1987, were they more likely to die by 2007 from causes related to smoking?”

Working with some of the top scientists in their specialties is a joy and a challenge in the best sense, because I can learn from them. I also like being able to invent new analytical techniques.

Career highlights.

When I was working for the United States Census Bureau, a colleague and I were analyzing the results of a simulated census and the real census, and we were the only two people who knew if our simulation had worked. Sometimes being the only ones who know the results of an experiment is deeply heady. I’ve also had the good fortune of inventing a new technique to link data that solves several problems at once.

Career path.

After earning a bachelor’s degree in sociology and psychology, I got a master’s degree and a PhD in sociology. I studied statistical and research methods, demography, and mathematical sociology. Then, I went back to get a master’s degree in math, which I knew I would need to become a quantitative data analyst.

I worked first as a Nevada state demographer, making projections for the state, and then for the U.S. Census Bureau and the Office of Immigration Statistics. I was then a freelancer before going to work for the NCHS.

My job as a state demographer was somewhat political, because the numbers were used to distribute tax money. I had to make 20-year projections about where people in Nevada were likely to be living, so the government could plan for things such as water and housing demand and understand the potential impact for employment. Demographic phenomena—birth, death, and migration rates—are fairly steady, so we used a simple demographic model to get from year to year.

At the census bureau in 2000, my primary job was working on an administrative-records experiment. I and a team of about 30 tried to simulate the U.S. census, primarily using administrative data such as IRS tax forms, the Medicare beneficiary database, and the Social Security number file. Then we compared the simulation to the actual census data. We concluded that the administrative data don’t have enough detail, but they can be useful for making educated guesses when census data are missing from a household.

The Office of Immigration Statistics tries to get data on green-card holders, refugees, asylum-seekers, and unauthorized populations. These numbers are hard to get, and the related public policies...
are hotly contested, so the pressures to produce certain numbers in a certain way trickled down to me. When determining a number using various statistical or demographic techniques, you must make decisions about what data to use, how to use them, and what models to apply to them. There are debates about these models and approaches.

Background needed.

Know the subject matter of the data you’re analyzing, whether it’s demography and epidemiology, the stock market, or something else. Math skills help you reason about the topic, and computer programming helps you implement the results of your reasoning.

Advice for students.

Math, science, and engineering are tough fields when you start out. They’re like sports, for which you constantly practice your skills so that by competition time you’re good enough to be creative. So hang in there. Really research the occupations you might end up in. Check the U.S. Bureau of Labor Statistics’s Occupational Outlook Handbook (www.bls.gov/ooh) to see which occupations are growing or declining and what their work environments are like.

Judson’s education:
BA in psychology and sociology, George Fox University; MA and PhD in sociology, Washington State University; MS in math, University of Nevada.

On the web:

Related occupations:
Statistician, data scientist, artificial intelligence researcher

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Summer 2015
Heightened Risks

Hands-on science activities sometimes place teachers and students in elevated and potentially dangerous locations. Whether students are collecting meteorological data on a school roof, studying aerodynamics by launching paper airplanes from elevated platforms, or dropping parachute designs in stairwells, teachers and school districts can face liability if someone falls.

Safer alternatives

Teachers are legally responsible under their duty of care to perform a safety assessment before implementing any hands-on classroom activity. When completing a safety assessment, teachers should go through an activity step-by-step and determine what parts of the activity could be dangerous and what could go wrong in these situations. A dry run of the activity without students is also recommended. Teachers should then think of alternative actions that could make the activity safer. This may include elimination of the activity from the curriculum.

In the paper airplane and parachute activities, for example, teachers should note that they and students need to wear eye protection during testing, given that flight patterns may be unpredictable. Teachers should also be aware that students are at risk of falling from elevated areas. A device called a grabber can be used during testing instead. It has suction cups or tongs at one end and a hand-grasp system at the other and comes in a variety of lengths.

Also, a parent volunteer, instead of a student, could fly models from an elevated platform that has fall protection in place, such as railings. In the case of the weather unit, under no circumstances should students be allowed on the roof of the school. There are relatively inexpensive electronic sensors for weather data gathering that can be read from the safety of the laboratory.

As for the teacher standing on elevated platforms, the Occupational Safety and Health Administration (OSHA) requires that employees receive prior training for working with such surfaces (see “On the web”), including walking-working surfaces (1910.23), portable wood ladders (1910.25), metal ladders (1910.26), and scaffolding (1910.28). In other words, if the teacher is to work on an elevated surface, special training is required.

Teachers must also be aware of child labor laws. Although students are not school employees, teachers should follow the United States Department of Labor’s Prohibited Occupations for Non-Agricultural Employees, which prohibits individuals ages 15 and under from working with ladders, scaffolds, or similar equipment. Additionally, the regulations stipulate that individuals ages 17 and under should not be working on a roof (see “On the web”).

Another danger is flying objects or projectiles damaging someone’s eyes. Activities should meet state goggle statutes for students and the OSHA Personal Protective Equipment standard for the teacher.

Conclusion

Make sure you complete a safety assessment before having students reach new “heights” in their education. Also check local, state, and federal safety standards for both students and the teacher as an employee.

Ken Roy is Director of Environmental Health and Safety for Glastonbury Public Schools in Glastonbury, Connecticut, and NSTA’s Chief Science Safety Compliance Advisor. If you have questions or an issue dealing with safety that a future column might help address, send an e-mail to Royk@glastonburyus.org. Follow Ken Roy on Twitter: @drroysafersci.

On the web

OSHA standards for working on elevated surfaces: www.osha.gov/SLTC/fallprotection/standards.html
Prohibited Occupations for Non-Agricultural Employees: www.dol.gov/elaws/esa/flsa/docs/haznonag.asp
For more information, visit: www.nsta.org/conferences
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☐ Chemistry
☐ Physics
☐ Environmental Science
☐ Physical Science
☐ General Science
☐ Other

Position

(check all that apply)

☐ Teacher  ☐ Scientist
☐ Professor  ☐ Student
☐ Dept. Head/Chair  ☐ Consultant
☐ Principal
☐ Supervisor/Coordinator
☐ Administrator
☐ Professional Develop. Provider
☐ Other

Grades

(check all that apply)

☐ Pre-K  ☐ 8th Grade
☐ 1st Grade  ☐ 9th Grade
☐ 2nd Grade  ☐ 10th Grade
☐ 3rd Grade  ☐ 11th Grade
☐ 4th Grade  ☐ 12th Grade
☐ 5th Grade  ☐ College
☐ 6th Grade
☐ 7th Grade

Institution

(check all that apply)

☐ Public School  ☐ 2-year College
☐ Private School  ☐ 4-year College
☐ Laboratory  ☐ Graduate School
☐ Business  ☐ Retired
☐ Informal Education
☐ Home School
☐ Library
☐ Other

Program/Ticket Information

☐ P-1: I would like to GO GREEN and PAPERLESS and receive an electronic version (PDF) of the final conference program. This PDF will be sent via e-mail approximately two weeks before the conference. (See reverse for details.)

Ticket information for short courses, field trips, and networking events will be available online in late July.

Payment

Registration Fee $ __________

Spouse/Guest Fee $ __________

NSTA Membership Fee (form attached) $ __________

Total Due: $ __________

I am paying by:

☐ Check #_____ (payable to “National Science Teachers Association” in U.S. funds)

☐ Credit Card: ☐ AMEX  ☐ Discover  ☐ MasterCard  ☐ VISA

Card # __________________________

Expiration Date __________________________

Signature __________________________

☐ School Purchase Order (copy attached):

PO # __________________________
Registration Instructions
This form is for the use of conference participants only. Individuals registering to conduct business should contact Jason Sheldrake, Assistant Executive Director, NSTA Sales, at 703-312-9273 to register as a Non-exhibiting Industry Representative.

Each registrant (except nonteaching spouse) must submit a separate registration form. Do not send duplicate registrations—if you fax your form, do not also mail the form. For complete information on registration, including rates, deadlines, spouse and guest fees, and more, go to www.nsta.org/confreg.

Registration fees cover all nonticketed conference activities and entry to the Exhibit Hall. Fees do not cover ticketed events, meals, lodging, or transportation other than NSTA-contracted shuttle service.

By registering to attend a National Science Teachers Association (NSTA) conference, you grant permission to NSTA to take and use your photo in NSTA marketing and promotional pieces for an indefinite period of time. Marketing and promotional pieces include, but are not limited to, printed brochures, reports, postcards, flyers, and materials, as well as online uses such as postings on the NSTA website, online newsletters, and e-mail blasts. NSTA shall own all rights, including copyrights in and to the photos. You also grant permission to NSTA to use, encode, digitize, transmit, and display the video/audio of your session, presentation, or workshop given at the NSTA conference, singularly or in conjunction with other recordings, as well as to use your name, photograph, biographic information, and ancillary material in connection with such video/audio for commercial, promotional, advertising, and other business purposes. NSTA and its employees are released from any liability arising out of the use of your name, video, photographs, and/or organization name and location.

Earlybird/Advance Deadlines
Registrations submitted online, postmarked, or faxed by the earlybird deadline or the advance deadline have substantially lower fees than those for on-site registration.

You must register by the advance deadline to receive your badge, tickets, and confirmation in advance of the conference. If you submitted your registration before the advance deadline and if by three weeks before the conference you have not received your confirmation packet, call NSTA conference registration at 703-243-7100 or 800-328-8998 or e-mail reg@nsta.org.

If your registration is received online or postmarked/faxed after the advance deadline, you will be charged the full on-site rate and your confirmation may not be mailed to you before the conference. Pick up your confirmation, badges, and tickets on-site at the Conference Services Counter in the NSTA Registration Area.

Ticketed Events
Tickets for short courses, field trips, networking events, and other special events will be available for purchase in late July. You may register for the conference using this Advance Registration Form and add tickets to your registration later by submitting a new registration form (check the box on the new form that indicates that you have already registered for the conference). In late July, details and descriptions of ticketed events will be available on our website (www.nsta.org/conferences). Tickets are nonrefundable.

Refund/Cancellation Policy
Refund requests must be in writing and must be postmarked 10 days before the conference. Badge materials must be returned with refund request. Registration cancellations are subject to a $20 processing fee. Ticketed events are nonrefundable.

Questions?
Contact NSTA conference registration at 703-243-7100 or 800-328-8998, or via e-mail at reg@nsta.org. For general information on the fall conferences or to register online, visit our website at www.nsta.org/conferences.

Submitting Your Registration
Payment for registration and membership (if attaching membership application) must be included with your registration form. Forms received without payment will be returned unprocessed. Payment may be made by check, credit card, or purchase order from your school or school district (attach forms for all registrants). Mail your completed form with check or credit card payment to:

National Science Teachers Association
Conference Department
PO Box 90214
Washington, DC 20090-0214
FAX: 703-243-3924

Become an NSTA member and Save $95* on your conference registration!

Complete the membership application available on the following pages and send it (along with membership fees and your fall conference registration form/payment) to:

National Science Teachers Association
Conference Dept., PO Box 90214
Washington, DC 20090-0214

Or fax to: 703-243-3924. Registration and applications are also available online at www.nsta.org.

NSTA gives you the tools and resources to excel in your career and saves you time and money by equipping you with already vetted resources, research, products and materials, and access to the information you need to apply to your classroom.

Just a few of the many benefits include:
- Access to members-only listservs
- A subscription to one of NSTA’s award-winning journals
- 20% discount on NSTA Press® publications
- Fresh, NEW lesson plans to enliven your classroom

Learn more at www.nsta.org/membership

(*when you register for 2–3 days in advance)
Get Great Benefits All Year Long—Join NSTA Today and Save!

Gain year-round access to the latest news and information affecting science education.

1. **Membership Options** Each membership option listed below includes one journal.
   - Individual Membership—$79/yr.
   - Student—$39/yr. For students enrolled in an accredited college or university with an interest in science education only. Include proof of current registration with your payment. Instructor must sign here:
   - New Teacher—$39/yr. Teachers who are in their first five years of teaching. Send a copy of your teaching certificate or a letter from your administrator.
   - International Regular Membership—$94/yr. (one journal only)
   - International Electronic Membership—$39/yr. (no hard copy journal and no U.S. addresses)
   - Retired—$39/yr. Science educators who are fully retired and have been an NSTA member for at least five years.

   **Available for the 2015 Reno Area Conference**
   - NSTA/NSSTA—$75/yr. includes membership in both Nevada State Science Teachers Association and NSTA (NEV15).

   **Available for the 2015 Philadelphia Area Conference**
   - NSTA/PSTA—$105/yr. includes membership in both Pennsylvania Science Teachers Association and NSTA (PSTA15).

   **Available for the 2015 Kansas City Area Conference**
   - NSTA/STOM—$85/yr. includes membership in both Science Teachers of Missouri and NSTA (STOM15).
   - NSTA/KATS—$90/yr. includes membership in both Kansas Association of Teachers of Science and NSTA (KATS15).

2. **Contact Information** (please print)
   - Name ____________________________
   - Title ____________________________
   - Institution _______________________
   - Home ☐ ☐ Work ☐
   - Address ____________________________
   - City ____________________________ State ________ Zip ________
   - Country ____________________________
   - Work Phone _______________________
   - Home Phone _______________________
   - Fax ________________________________
   - E-mail ____________________________
   - Twitter handle _____________________

   Have you ever been an NSTA member?
   - No ☐ ☐ Yes ID# _____________________

   I am interested in receiving information from NSTA about a leadership position.
   - Please remove my name and postal address from the mailing list NSTA makes available to other organizations.

3. **Membership Journals** Select the journal you would like to receive as part of your membership:
   - Science & Children—9 times a year; grades K–6
   - Science Scope—9 times a year; grades 6–9
   - The Science Teacher—9 times a year; grades 9–12
   - Journal of College Science Teaching—6 times a year; college

   To subscribe to more than one journal, call NSTA Member Services at 800-722-NSTA (6782) or 703-243-7100.

4. **Grades** (check all that apply)
   - Pre-K ☐ ☐ 4th Grade ☐ ☐ 9th Grade ☐
   - Kindergarten ☐ ☐ 5th Grade ☐ ☐ 10th Grade ☐
   - 1st Grade ☐ ☐ 6th Grade ☐ ☐ 11th Grade ☐
   - 2nd Grade ☐ ☐ 7th Grade ☐ ☐ 12th Grade ☐
   - 3rd Grade ☐ ☐ 8th Grade ☐ ☐ College ☐

5. **Disciplines** (check all that apply)
   - Earth and Space Science ☐ ☐ Physical Science ☐
   - Biology/Life Science ☐ ☐ General Science ☐
   - Chemistry ☐ ☐ Computer Science ☐
   - Physics ☐ ☐ Tech Education ☐
   - Environmental Science ☐ ☐ Other ____________________________

6. **Payment Method**
   - School Purchase Order enclosed. PO# ______
   - Check enclosed, payable to the “National Science Teachers Association” (U.S. Dollars)
   - Please charge my credit card: ☐ MasterCard ☐ VISA ☐ Discover ☐ AMEX

   Card # ___________________________________________________________________________ Expiration Date _______________________

   Name on card ____________________________ Signature ____________________________

Four Easy Ways to Join NSTA

1. Visit www.nsta.org
2. Fax your completed form to 703-243-3924
3. Mail your completed form with payment to NSTA, PO Box 90214, Washington, DC 20090-0214.
4. Call NSTA Member Services at 800-722-NSTA (6782) or 703-243-7100.

Membership dues are subject to change without notice.
INSTRUCTIONS
Housing reservations can be made in one of the following ways beginning May 18.

• Internet * Preferred
  For payments via credit card
  www.nsta.org/renohousing
  Please have your credit card and arrival/departure information ready. Accepted credit cards include American Express, Diner’s Club, Discover, Visa, and MasterCard.

• Telephone
  877-352-6710 (toll free)
  801-505-4611 (international)
  Call between 7:00 AM and 6:00 PM Mountain Time, Monday–Friday. Be prepared to provide all the information on this form.

• Fax (Use one form per room request)
  801-355-0250

• Mail (Use one form per room request)
  DO NOT MAIL TO NSTA
  *Mail CHECKS ONLY to:
  Orchid Event Solutions–NSTA/Reno
  175 South West Temple, Suite 30
  Salt Lake City, UT 84101

DEADLINE
Reservations must be made by September 24, 2015.

CONFIRMATIONS
Orchid Event Solutions will send you a confirmation of your reservation. Please review all information for accuracy. E-mail confirmation will be sent if an e-mail address is provided (preferred), or confirmation can be faxed or mailed. If you do not receive a confirmation or if you have questions, call Orchid Event Solutions. You will NOT receive a confirmation from the hotel.

TAX RATE and SPECIAL REQUESTS
All rates are per room and are subject to a 13% sales and lodging tax (subject to change). Special requests cannot be guaranteed; however, hotels will do their best to honor all requests. Hotels will assign specific room types upon check-in, based on availability.

ROOM DEPOSIT REQUIRED TO SECURE RESERVATION
All reservations must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing forms received without a valid guarantee or deposit will not be processed. Check deposits must be mailed with a completed housing form payable to “Orchid Event Solutions.”

CANCELLATION POLICY
Cancellations made after September 24 and prior to 24 hours before arrival date will be subject to a $25 cancellation fee. One night’s room charge and tax will be forfeited entirely if cancellation occurs within 24 hours of arrival.

Please select hotel choices in order of preference and enter their numbers below.
1st ______________________ 2nd ______________________

Room Type Requested: ☐ One Bed ☐ Two Beds

If requested hotels are unavailable, a reservation will be made at the next available hotel. Please select criteria: ☐ Comparable room rate ☐ Proximity to conference site

Submit only one room request per form. Should additional forms be needed, please make copies.

List all room occupants (include yourself):

☐ Check here if you require special services ☐ Nonsmoking request

Special requests: __________________________________________________________

DEPOSIT INFORMATION
All reservation requests must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing forms received without a valid guarantee or deposit will not be processed. Faxed requests must include a valid credit card. Check deposits must be mailed with a completed housing form.

Type: ☐ American Express ☐ Diner’s Club ☐ Discover ☐ MasterCard ☐ Visa

Card number: __________________________ Exp. Date: __________________________

Name on credit card ______________________________________________________

Cardholder’s signature* __________________________________________________

*I hereby authorize Orchid Event Solutions or any one of the hotels to process a charge to my credit card for each room deposit in accordance with the policies provided herein no sooner than September 24, 2015.

☐ One night’s check deposit enclosed and made payable to Orchid Event Solutions. Mail housing forms to Orchid Event Solutions–NSTA/Reno, 175 South West Temple, Suite 30, Salt Lake City, UT 84101. Check deposits must be received by September 24 to be accepted.
INSTRUCTIONS
Housing reservations can be made in one of the following ways beginning May 18.

• Internet * Preferred
  For payments via credit card
  www.nsta.org/phillyhousing
  Please have your credit card and arrival/departure information ready. Accepted credit cards include American Express, Diner’s Club, Discover, Visa, and MasterCard.

• Telephone
  877-352-6710 (toll free)
  801-505-4611 (international)
  Call between 7:00 AM and 6:00 PM Mountain Time, Monday–Friday. Be prepared to provide all the information on this form.

• Fax (Use one form per room request)
  801-355-0250

• Mail (Use one form per room request)
  Do not mail to NSTA
  *Mail CHECKS ONLY to:
  Orchid Event Solutions–NSTA/Philadelphia
  175 South West Temple, Suite 30
  Salt Lake City, UT 84101

DEADLINE
Reservations must be made by October 12, 2015.

CONFIRMATIONS
Orchid Event Solutions will send you a confirmation of your reservation. Please review all information for accuracy. E-mail confirmation will be sent if an e-mail address is provided (preferred), or confirmation can be faxed or mailed. If you do not receive a confirmation or if you have questions, call Orchid Event Solutions. You will NOT receive a confirmation from the hotel.

TAX RATE and SPECIAL REQUESTS
All rates are per room and are subject to a 15.5% sales and lodging tax (subject to change). Special requests cannot be guaranteed; however, hotels will do their best to honor all requests. Hotels will assign specific room types upon check-in, based on availability.

ROOM DEPOSIT REQUIRED TO SECURE RESERVATION
All reservations must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing Forms received without a valid guarantee or deposit will not be processed. Check deposits must be mailed with a completed housing form payable to “Orchid Event Solutions.”

CANCELLATION POLICY
Cancellations made after October 12 and prior to 24 hours before arrival date will be subject to a $25 cancellation fee. One night’s room charge and tax will be forfeited entirely if cancellation occurs within 24 hours of arrival.

CANCELLATION POLICY
For payments via credit card
www.nsta.org/phillyhousing
• Internet * Preferred

DEPOSIT INFORMATION
All reservation requests must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing forms received without a valid guarantee or deposit will not be processed. Faxed requests must include a valid credit card. Check deposits must be mailed with a completed housing form.

Type:  [ ] American Express  [ ] Diner’s Club  [ ] Discover  [ ] MasterCard  [ ] Visa
Card number: ____________________________  Exp. Date: _______________________

Name on credit card _______________________

Check here if you require special services
☐ Check here if you require special services
☐ Nonsmoking request

Special requests: ____________________________________________________________

$228 $228 $248 $268
1. Philadelphia Marriott Downtown
   (Headquarters Hotel)

$199 $199 $209 $219
2. Hampton Inn Philadelphia Center
   City–Convention Center

$214 $214 $224 $234
3. Home2 Suites by Hilton
   Philadelphia–Convention Center

A Philadelphia Hotel Map is available online at www.nsta.org/phillyhousing.

Official Housing Request Form
NSTA Philadelphia Area Conference
November 12–14, 2015, Philadelphia, Pennsylvania

CONTACT INFORMATION
First: __________________________________________ Mi: ______ Last: __________________________________________
E-mail: __________________________________________
School/Company: __________________________________________
Address: __________________________________________
City: __________________________________________ State: _______ Postal Code: __________________
Country: __________________________________________
Phone: __________________________________________ Fax: __________________________________________

HOTEL SELECTION
Arrival Date: __________________________________________  Departure Date: __________________________

Please select hotel choices in order of preference and enter their numbers below.
1st ____________________________ 2nd ____________________________

Room Type Requested:  ☐ One Bed  ☐ Two Beds

If requested hotels are unavailable, a reservation will be made at the next available hotel.

Submit only one room request per form. Should additional forms be needed, please make copies.

List all room occupants (include yourself):
__________________________________________  __________________________________________

☐ Check here if you require special services
☐ Nonsmoking request

Special requests: ____________________________________________________________

Please have your credit card and arrival/departure information ready. Accepted credit cards include American Express, Diner’s Club, Discover, Visa, and MasterCard.

Check deposits must be received by October 12 to be accepted.
Deadline: November 4, 2015

INSTRUCTIONS
Housing reservations can be made in one of the following ways beginning May 18.

• Internet * Preferred
  For payments via credit card
  www.nsta.org/kchousing
  Please have your credit card and arrival/departure information ready. Accepted credit cards include American Express, Diner’s Club, Discover, Visa, and MasterCard.

• Telephone
  877-352-6710 (toll free)
  801-505-4610 (international)
  Call between 7:00 AM and 6:00 PM Mountain Time, Monday–Friday. Be prepared to provide all the information on this form.

• Fax (Use one form per room request)
  801-355-0250

• Mail (Use one form per room request)
  DO NOT MAIL TO NSTA
  *Mail CHECKS ONLY to:
  Orchid Event Solutions–NSTA/Kansas City
  175 South West Temple, Suite 30
  Salt Lake City, UT 84101

CONFIRMATIONS
Orchid Event Solutions will send you a confirmation of your reservation. Please review all information for accuracy. E-mail confirmation will be sent if an e-mail address is provided (preferred), or confirmation can be faxed or mailed. If you do not receive a confirmation or if you have questions, call Orchid Event Solutions. You will NOT receive a confirmation from the hotel.

TAX RATE and SPECIAL REQUESTS
All rates are per room and are subject to a 16.85% tax rate plus $1.75 city development tax (subject to change). Special requests cannot be guaranteed; however, hotels will do their best to honor all requests. Hotels will assign specific room types upon check-in, based on availability.

ROOM DEPOSIT REQUIRED TO SECURE RESERVATION
All reservations must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing Forms received without a valid guarantee or deposit will not be processed. Check deposits must be mailed with a completed housing form payable to “Orchid Event Solutions.”

CANCELLATION POLICY
Cancellations made after November 4 and prior to 48 hours before arrival date will be subject to a $25 cancellation fee. One night’s room charge and tax will be forfeited entirely if cancellation occurs within 48 hours of arrival.

DEPOSIT INFORMATION
All reservation requests must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing forms received without a valid guarantee or deposit will not be processed. Faxed requests must include a valid credit card. Check deposits must be mailed with a completed housing form.

Please select hotel choices in order of preference and enter their numbers below.
1st ____________________ 2nd ____________________
Room Type Requested:  ☐ One Bed  ☐ Two Beds
If requested hotels are unavailable, a reservation will be made at the next available hotel.
Please select criteria:  ☐ Comparable room rate  ☐ Proximity to conference site
Submit only one room request per form. Should additional forms be needed, please make copies.
List all room occupants (include yourself):
__________________________________________________________
__________________________________________________________
☐ Check here if you require special services  ☐ Nonsmoking request
Special requests: __________________________________________

OFFICIAL HOUSING REQUEST FORM
DECEMBER 3–5, 2015, KANSAS CITY, MISSOURI
NSTA Kansas City Area Conference
December 3–5, 2015, Kansas City, Missouri

HOTEL SELECTION

<table>
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<tr>
<th>HOTEL</th>
<th>SINGLE</th>
<th>DOUBLE</th>
<th>TRIPLE</th>
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<td>1. Kansas City Marriott Downtown (Headquarters Hotel)</td>
<td>$159</td>
<td>$159</td>
<td>$159</td>
<td>$159</td>
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<tr>
<td>2. Holiday Inn Kansas City Downtown–Aladdin</td>
<td>$115</td>
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<td>$115</td>
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</tr>
</tbody>
</table>

A Kansas City Hotel Map is available at www.nsta.org/kchousing.
Reviews in this issue:

The World of Endangered Animals: South and Central Asia
By Tim Harris
Engage your students in conservation issues. (Grades 6–12)

Science Surprises
By Lawrence Flammer
Teach your students about the nature of science. (Grades 7–10)

TEACH Science Surprises
By Lawrence Flammer
A handy teacher’s guide to Science Surprises. (Grades 7–10)

Earth Science Success, 2nd Edition
By Catherine Oates-Bockenstedt and Michael Oates
Earth science lessons updated for use with digital tools. (Grades 6–9)

The BSCS 5E Instructional Model
By Rodger W. Bybee
Create teachable moments in your classroom. (Grades K–12)

Pembe Ya Ndovu (Tusk of the Elephant)
Directed by Steve Taylor
A documentary examining the illegal ivory trade. (Grades 9–College)

The Handy Nutrition Answer Book
By Patricia Barnes-Svarney
A colorful book for teaching students about nutrition. (Grades 6–College)

Earth’s Rocks and the Rock Cycle
By Tasa Graphic Arts
A digital tool for learning about the rock cycle. (Grades 7–College)

The World of Endangered Animals: South and Central Asia
By Tim Harris.

This book starts with an overview of the habitats of, threats to, and conservation efforts intended to save endangered species in South and Central Asia. The author examines various species from snow leopards and Asian elephants to spoon-billed sandpipers. Each gets a data panel with information on world populations, habitat, related endangered species, and more. Appendixes list wildlife organizations and more endangered animals. In classifying endangered species, the International Union for the Conservation of Nature focuses on categories of threat: extinct (no reasonable doubt the species is dead); extinct in the wild (survives only in captivity or artificially established conditions); critically endangered (faces an extremely high risk of extinction in the immediate future in the wild); endangered (faces a very high risk of extinction in the near future in the wild); vulnerable (faces a high risk of extinction in the medium-term future in the wild); near threatened (faces a high risk of extinction in the medium-term future in the wild), least concern (does not qualify for preceding categories but is likely to qualify in the future); data deficient (not enough information to assess the risk of extinction); and not evaluated (yet to be assessed).
and a common language to discuss other species globally. I recommend this book as another resource in our never-ending quest to protect and preserve our wildlife.

Diana Wiig

Science Surprises

TEACH Science Surprises

This new textbook and accompanying teaching guide aim to help your students understand the nature of science. Both titles are available as e-books or can be purchased in hardcover format.

I found the e-books easy to navigate. The author states that the student book “can replace the first chapter of a secondary science textbook.” Lessons in the five chapters incorporate the 5E learning cycle, are interactive, and use guided discovery. The lessons focus on what science is, debunking misconceptions, and pseudoscience. Graphics and photographs are current and appealing to students. The text is designed to be used with the nature of science lessons on Evolution and the Nature of Science website (www.indiana.edu/~ensiweb), which was developed by the author.

The text addresses the Next Generation Science Standards and includes STEM-ready lessons. Common Core State Standards are met through the integration of math and reading comprehension strategies. The teaching guide contains pre- and post-testing, formative and summative assessment, teacher references, and additional websites. Both texts were field-tested before publication.

Ruth Rand

Earth Science Success, 2nd Edition

Earth Science Success is a tablet-ready, 55-section potpourri of science lessons that offers an excellent variety of student activities, most of which are enhanced by online resources. The use of the tablet in these lessons does not seem forced or added as an afterthought. Rather, the lessons will be far richer and more productive if your students employ the authors’ suggestions for technology applications.

The father-daughter team of authors begin their volume with two lessons on science versus pseudoscience. Students test the validity of astrology and mind-reading and will learn what it means to subject data to a scientific test. All the lessons in this book encourage active learning, as students predict outcomes and explore through data collection and analysis. The range of topics is wide, and performing all 55 investigations covered here within one school year, as suggested by the authors, would be a challenge.

Nonetheless, an Earth science teacher whose course includes climate and weather, ecology, astronomy, and geology will find stimulating, well-designed labs on these topics with an appropriate infusion of technology. In this case, using a tablet is a means to an end, not an objective in itself, and the discrete, fundamental concepts from the Next Generation Science Standards are treated with depth and skill.

Cary Seidman

The BSCS 5E Instructional Model

How many teachable moments do you capture in your classroom? Rather than waiting for a teachable moment to arrive out of the blue, you can learn how to create these valuable moments with integrated instructional units using The BSCS 5E Instructional Model: Creating Teachable Moments.

Grounded in both historical models and psychological theory, the BSCS 5E instructional model consists of five phases: Engage, Explore, Explain, Elaborate, and Evaluate. For those unfamiliar with this model, Bybee not only explains each phase in the context of a classroom setting but also provides the research to support its use. For those already familiar with this model, Bybee asks you to reflect on and evaluate your practice to push your students further. This includes a comparison of lesson components that are and are not consistent with the 5E model, as well as a question-and-answer section.

The most practical aspect of this book is a series of tools that helps teachers both apply and evaluate the use of the 5E model in the classroom. Bybee specifically addresses how to use this model with the Next Generation Science Standards (NGSS), issues in STEM, and 21st-century skills.
The book makes clear that the 5E model is a natural way to create fully integrated instructional units that translate the NGSS into classroom practice. Whether you are new to 5E or have been using this model for years, The BSCS 5E Instructional Model: Creating Teachable Moments can be a valuable resource for planning and implementing integrated units. I would recommend this book to classroom teachers at any level, as well as curriculum developers and teacher coaches. With this tool in hand, any teacher can extend teachable moments into significant and meaningful learning experiences.

Alexandra D. Owens

**Pembe Ya Ndovu (Tusk of the Elephant)**

Directed by Steve Taylor. $69. The Video Project. San Francisco. 2014.

*Pembe Ya Ndovu*, a documentary on elephant poaching, is suitable for students in grade 9 through college. It focuses on the illegal ivory trade and points out the effects poaching has on a species, ecosystem, and local human population—effects similar to those that occur in the cases of many other endangered species.

This well-made video takes us through many African countries on a journey to uncover serious threats to biodiversity and African wildlife. For example, to meet the growing demand for illegal ivory, elephants are ruthlessly killed for their tusks, and often rangers and wildlife officers trying to protect the animals are also killed. Campaigns against these activities are on the rise as greater awareness is raised around the world.

This video would be a great launching point for a research project on human effects on ecosystems—a topic addressed by the Next Generation Science Standards—and possible solutions to the problems. I would have my students also research successful (and possibly not-so-successful) conservation efforts. From there, they could come up with a plan for extending successful conservation projects.

Charma Glitzke

**The Handy Nutrition Answer Book**


Do you need answers to student questions about nutrition? Presented as a series of nearly 900 questions and answers, *The Handy Nutrition Answer Book* covers nutrition basics, food processing and preservation, how to read food labels, food choices, allergies, diets, and food controversies.

The easy-to-use format allows readers to zero in on a single burning question or to read an entire chapter about a nutrition topic. One section, “Nutrition through the Centuries,” addresses how history has influenced our eating habits, dating back to the earliest humans, a topic rarely seen in textbooks or other resources. Helpful appendices offer a list of nutrition websites, an extensive glossary, and the pros and cons of mainstream diet plans.

This book would be a great resource in any science-classroom library. For classes that focus on the human body or nutrition, this book could spur discussion or debate, addressing concerns about cow’s milk, arsenic in drinking water, and whether people need to take vitamin and mineral supplements.

Alexandra D. Owens

**Earth’s Rocks and the Rock Cycle**

By Tasa Graphic Arts. $7.99. Tasa Graphic Arts. Taos, NM. 2015.

I recommend this app to anybody learning about rocks and the rock cycle.

Amazing pictures are found throughout the app. A series of lessons covers information in chunks easily processed by students. Each chunk has a quiz so you can check understanding. Students can e-mail their quiz results to the teacher, allowing for a formative assessment as they explore the app.

One fault is that students have to complete the quizzes in one sitting, because the app won’t retain partial results. Overall, this app stands up as a viable alternative to a textbook for teaching or learning about the rock cycle.

Charma Glitzke

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<table>
<thead>
<tr>
<th>Advertiser</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carolina Biological Supply Company,  <a href="http://www.carolina.com">www.carolina.com</a>, 800-334-5551</td>
<td>C4</td>
</tr>
<tr>
<td>Educational Innovations, Inc.,  <a href="http://www.teachersource.com">www.teachersource.com</a>, 888-912-7474</td>
<td>21</td>
</tr>
<tr>
<td>Howard Hughes Medical Institute,  <a href="http://www.biointeractive.org">www.biointeractive.org</a></td>
<td>1</td>
</tr>
<tr>
<td>NSTA Conferences,  <a href="http://www.nsta.org">www.nsta.org</a></td>
<td>63–69</td>
</tr>
<tr>
<td>NSTA Member Services,  <a href="http://www.nsta.org/membership">www.nsta.org/membership</a>, 800-772-6782</td>
<td>13</td>
</tr>
<tr>
<td>Royal Society of Chemistry,  <a href="http://www.rsc.org/learn-chemistry">www.rsc.org/learn-chemistry</a></td>
<td>24</td>
</tr>
<tr>
<td>Texas Instruments,  <a href="http://www.education.ti.com">www.education.ti.com</a></td>
<td>C3</td>
</tr>
<tr>
<td>University of Nebraska at Kearney,  <a href="http://www.ecampus.unk.edu">www.ecampus.unk.edu</a>, 800-865-6388</td>
<td>11</td>
</tr>
<tr>
<td>Van Andel Education Institute,  <a href="http://nexgeninquiry.org">http://nexgeninquiry.org</a></td>
<td>23</td>
</tr>
<tr>
<td>Ward’s Science,  <a href="http://www.wardsci.com/conference">www.wardsci.com/conference</a></td>
<td>9</td>
</tr>
</tbody>
</table>

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Thomas Jefferson, Data Collector

In May 1776, Thomas Jefferson arrived in Philadelphia. Soon the young delegate to the Continental Congress was drafting the Declaration of Independence. Somehow he also found time to buy a thermometer and, on July 1, to start collecting weather data. Today, a notebook of Jefferson’s weather records is in his papers at the Library of Congress.

In a 1790 letter to his son-in-law, Thomas Mann Randolph, Jefferson explained that column one in his weather record (shown at right) was for the date; columns two and four, morning and afternoon temperature readings; and columns three and five, weather observations in shorthand: a = after, c = cloudy, f = fair, h = hail, r = rain, s = snow. “Thus c a r h s means, cloudy after rain, hail, and snow,” Jefferson wrote. Column six was for “miscellanies, such as the appearance of birds, leafing and flowering of trees, frosts remarkably late or early, Aurora borealis, &c.”

Later, Jefferson acquired a barometer and hygrometer so he could record atmospheric pressure and humidity, respectively. In June 1778, he expanded his record to 11 columns, adding wind force and direction, and the first and last seasonal appearances of “leaves, flowers, wild fruit,” birds, and insects. In 1799, he noticed that two thermometers on the northeast portico of Monticello had been “artificially heated,” he believed, by a “mound of earth.” In the notebook he drew lines through months of incorrect temperature readings.

The notebook contains not only weather data but also notes, lists, and calculations stretching to 1818. Jefferson included weather data provided by others, a clue to his broader scientific goal of comparing data from different places. He got help from John Breck Treat, an Indian agent in the Louisiana Territory; James Madison; and Thomas Mann Randolph, to whom Jefferson wrote: “I will propose to you to keep a diary of the weather here and wherever you shall be.”

On July 4, 1776, Jefferson took four temperature readings, ranging from 68 to 76 degrees. A heat wave had just broken, and fellow delegate Robert Treat Paine noted in his diary the change in weather and something more momentous: “Cool. The Independence of the States voted & Declared.”

Related Student Explorations

• Human/environment interaction
• Scientific communities
• Scientific instruments
• Scientific notebooks

About the Source

Thomas Jefferson’s weather record (www.loc.gov/item/mtjbib026574/) is part of the Thomas Jefferson Papers (http://1.usa.gov/1E2hgFd) at the Library of Congress. The published editions of Jefferson’s papers, including his correspondence with Randolph, Madison, and Treat, are available at the National Archives (http://founders.archives.gov). Robert Treat Paine’s diary entry (http://1.usa.gov/1D8ESrt) is found at the Letters of Delegates to Congress, 1774–1789. The Massachusetts and New York historical societies have additional Jefferson weather records. Your students can analyze these and other primary sources using the Library’s primary source analysis tool (http://1.usa.gov/1o2XeZe).
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