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Charting a course toward *NGSS* alignment

You may have noticed that *Science Scope*'s activity-based articles now include a *Next Generation Science Standards* (*NGSS*) alignment chart that shows the integration of disciplinary core ideas, crosscutting concepts, and science and engineering practices. This chart reinforces the *NGSS* connections made within the text of the articles. The inclusion of this information naturally requires more space, and you may have noticed that activity-centered articles are now longer than they once were. However, it is our view that three-dimensional instruction represents best practice for all teachers, whether or not their state has adopted the *NGSS*.

The *NGSS* alignment chart in *Science Scope* was designed to follow the evaluation criteria outlined in the EQuIP rubric from Achieve (*www.achieve.org/EQuIP*). The chart shows the particular standard and performance expectations (PEs) with which the featured activity aligns. A statement is included to make it clear that the activity alone is not sufficient to have students reach the goal of the PE. Reaching the goal of any PE will take repeated instruction over time. While each of the three dimensions are represented in the *NGSS* alignment chart, the particular dimensions used in the activity might not be the same ones given in the *NGSS* for the indicated PE. Again, it will take many lessons with many combinations of dimensions to reach the goal of a particular PE.

The third column of the *NGSS* alignment chart is the most important section. It contains specific "evidence" that shows how the activity adheres to three-dimensional instruction by making connections to specific tasks and questions from the activity. To keep the chart size reasonable, we include only those tasks deemed most essential to the activity and most directly connected to the dimension. We also provide connections to applicable *Common Core State Standards*, in English language arts and mathematics, when appropriate.

In many of our recent articles, you may have noticed references to "online extensions." These are supplemental materials for articles that we didn't have space for in the print edition of the journal. Online connections can include student directions, handouts, teacher guides, readings, rubrics, answer sheets, photos, and other helpful materials. They are stored on the Online Connections page of *Science Scope*'s website and can be accessed at *www.nsta.org/middleschool/connections.aspx*.

These changes have been made with our readers in mind and we need your feedback. Tell us what you think about the length of our articles, online access to supplemental materials, and the inclusion of the *NGSS* alignment chart and the way it ties specific student tasks to each dimension. I welcome your feedback at *iliftig@gmail.com*.

Inez Liftig
Editor, *Science Scope*

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SCIENCE SCOPE

NSTA's peer-reviewed journal for middle level and junior high school science teachers

This issue's focus:

Science for All

■ denotes thematic content

ON THE COVER

Making science accessible to all students should be the goal of every classroom science teacher. In this issue, we share a variety of lessons you can use to overcome various socioeconomic, physical, and language barriers facing today's students. We hope you can use these activities to help all of your students reach the stars.

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SCIENCE SCOPE

THE JOURNAL FOR MIDDLE AND JUNIOR HIGH SCHOOL SCIENCE TEACHERS

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Looking for an opportunity to affect middle level science education on a national scale?

The National Science Teachers Association is in search of a veteran middle level science educator to serve as the new Field Editor of *Science Scope*.

The Field Editor's responsibilities include:

- Identifying essential topics for our middle school teacher's journal;
- Soliciting articles on these topics from a genuinely diverse mix of engaged educators and columnists; and
- Overseeing the manuscript review process to ensure articles demonstrate good sense, exemplary safety practices, scientific accuracy, classroom usefulness, and alignment with the *Next Generation Science Standards*.

The Field Editor has ultimate responsibility for the journal's content, and therefore must aim high to illustrate best practices while including the everyday activities most likely to achieve our goal of "...excellence and innovation in science teaching and learning for all."

The ideal candidate is a smart, articulate, and effective educator, team player, and communicator who can tap into a network of exemplary middle level science educators. In particular, the successful candidate must have the following qualifications:

- Experience as a classroom teacher of science (middle or junior high);
- A solid science background with a working knowledge of the *Next Generation Science Standards*;
- Insight into enduring objectives and current trends in science education;
- Ability to network in search of suitable content for the journal; and
- Ability to communicate effectively with authors as well as with NSTA members, committees, board of directors, and staff.

This is a part-time, 3-year appointment, renewable for one additional term. Travel required (approximately four trips per year). Stipend and training provided.

To apply, e-mail a concise vita and a letter that specifies related experience and background to the Publisher, David Beacom (*dbeacom@nsta.org*), by **October 15, 2015.**

Chameleons reorganize nanocrystals to change colors

Many chameleons have the remarkable ability to exhibit complex and rapid color changes during social interactions. A new study unveils the mechanisms that regulate this phenomenon, demonstrating that the changes take place via the active tuning of a nanocrystal lattice present in a superficial layer of dermal cells called *iridophores*. The study's researchers also reveal the existence of deeper iridophores with larger and less ordered crystals that reflect infrared light. Inside iridophores, these nanocrystals are arranged in layers that alternate with cytoplasm. This structure allows a selective reflection of certain wavelengths, which contributes to the vivid colors of numerous reptiles. The organization of iridophores into two superimposed layers constitutes an evolutionary novelty and allows the chameleons to rapidly shift between efficient camouflage and spectacular display, while providing passive thermal protection.

Male chameleons are popular for their ability to change their color depending on their behavior. Some species, such as the panther chameleon, are able to carry out such changes within one or two minutes to court a female or face a competing male.

"We discovered that the [panther chameleon] changes its colors via the active tuning of a lattice of nanocrystals. When the chameleon is calm, the latter are organized into a dense network and reflect the blue wavelengths. In contrast, when excited, [the chameleon] loosens its lattice of nanocrystals, which allows the reflection of other colors, such as yellows or reds," explain physicist Jérémie Teyssier and biologist Suzanne Saenko, co–first authors of the study.

A male panther chameleon (*Furcifer pardalis*), photographed in Madagascar.

The scientists also demonstrated the existence of a second, deeper layer of iridophores. "These cells, which contain larger and less ordered crystals, reflect a substantial proportion of the infrared wavelengths," states Milinkovitch. This forms an excellent protection against the thermal effects of high exposure to the Sun's radiation in low-latitude regions.

In their future research, the scientists will explore the mechanisms that explain the development of an ordered nanocrystals lattice within iridophores, as well as the molecular and cellular mechanisms that allow chameleons to control the geometry of this lattice.

Université de Genève

Wandering Jupiter accounts for our unusual solar system

Jupiter may have swept through the early solar system like a wrecking ball, destroying a first generation of inner planets before retreating into its current orbit, according to a new study. The findings help explain why our solar system is so different from the hundreds of other planetary systems that astronomers have discovered in recent years.

"Now that we can look at our own solar system in the context of all these other planetary systems, one of the most interesting features is the absence of planets inside the orbit of Mercury," says Gregory Laughlin, coauthor of the paper. "The standard-issue planetary system in our galaxy seems to be a set of super-Earths with alarmingly short orbital periods. Our solar system is looking increasingly like an oddball."

The new paper explains not only the "gaping hole" in our inner solar system, he says, but also certain characteristics of Earth and the other inner rocky planets, which would have formed later than the outer planets from a depleted supply of planet-forming material.

Laughlin and coauthor Konstantin Batygin explored the implications of a leading scenario for the formation of Jupiter and Saturn. In that scenario, proposed by another team of astronomers in 2011 and known as the "Grand Tack," Jupiter first migrated inward toward the Sun until the formation of Saturn caused it to reverse course and migrate outward to its current position. As Jupiter moved inward, gravitational perturbations from the giant planet would have swept any inner planets (and smaller planetesimals and asteroids) forming at that time into close-knit, overlapping orbits, setting off a series of collisions that smashed all the nascent planets into pieces.

The resulting debris would then have spiraled into the Sun under the influence of a strong "headwind" from the dense gas still swirling around the Sun. The ingoing avalanche would have destroyed any newly-formed super-Earths by driving them into the Sun. A second generation of inner planets would have formed later from the depleted material that was left behind, consistent with evidence that our solar system's inner planets are younger than the outer planets. The resulting inner planets—Mercury, Venus, Earth, and Mars—are also less massive and have much thinner atmospheres than would otherwise be expected, Laughlin says.

"This kind of theory, where first this happened and then that happened, is almost always wrong, so I was initially skeptical," he adds. "But it actually involves generic processes that have been extensively studied by other researchers. There is a lot of evidence that supports the idea of Jupiter's inward and then outward migration. Our work looks at the consequences of that. Jupiter's 'Grand Tack' may well have been a 'Grand Attack' on the original inner solar system."

University of California, Santa Cruz

WIKIMEDIA COMMONS

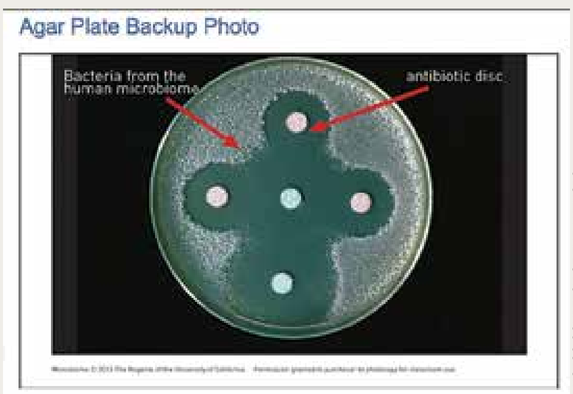
Jupiter may have destroyed a first generation of inner planets in the early solar system.

"What's our three-word claim?": Supporting English language learning students' engagement in scientific argumentation

by María González-Howard, Katherine L. McNeill, and Nicole Ruttan

Middle school students in a sheltered English instruction science class are at the beginning of a unit in which they are learning that organisms that are too small to be seen by the naked eye live on and in the human body. (A *sheltered English instruction class* is an instructional setting in which the teacher attends to students' content learning and English language development.) Specifically, in this lesson students investigate that antibiotics kill bacteria. To start exploring these concepts, their teacher, Ms. Ruttan, asks students to make observations of a photograph of an agar-streak plate test (see Figure 1) to see if they can find evidence of microorganisms living on human bodies. Before students analyze the photograph, Ms. Ruttan informs the class about how the agar-streak plate test was conducted. (Note: This was not done as a hands-on activity because the culturing of any organism is not recommended at the middle school level.) Ms. Ruttan explains to students that a scientist took a cotton swab, grazed it along the palm of her hand, and then streaked the cotton swab along the inside of a petri dish that had been filled with *agar* (a polymer that contains nutrients to allow microorganisms to grow). Afterward, the scientist placed penicillin disks in the agar plate, sealed the plate to prevent contamination, and let it sit undisturbed for a few days. The teacher further explained that penicillin is a type of antibiotic used to kill bacteria.

FIGURE 1 **Photograph of agar-streak plate test that students analyzed (Regents of the University of California 2013a)**



PHOTOS COURTESY OF THE AUTHORS

After explaining how the test was conducted, Ms. Ruttan directs students to individually write and draw observations of the visible colonies of bacteria in the plate, encouraging them to include different types of descriptors (e.g., color, location in the plate). A few minutes after giving these directions, Ms. Ruttan walks over to a table of students (all student names are pseudonyms):

Ms. Ruttan: Where are most of the bacteria growing?

Beatriz: There are black ones and white ones, and the white ones are *más cerca del* (closer to the) antibiotic.

Ms. Ruttan: Okay. But, where are most of them?

Teresa: Aqui. (Here). In the outside.

Ms. Ruttan: Around the outside, right?

Guadalupe: So the black things are the bacteria?

Beatriz: Yeah, and the white.

Ms. Ruttan: All of the things you see are the bacteria.

Once students finish writing and drawing their observations, Ms. Ruttan asks a few students to share what they saw with the whole class. Following this conversation, she asks students to consider whether the observations from the photograph of the agar plate serve as evidence in support of the lesson's guiding claim that antibiotics kill bacteria. In small groups, students spend a few minutes discussing and writing their thoughts with their peers. During this time, the following interaction occurs between Ms. Ruttan and one of her students:

Ms. Ruttan: Soledad, what did you write? Does it support, or does it not support?

Soledad: It support.

Ms. Ruttan: It supports. Why?

Soledad: Because in the middle, next to the umm, this thing—

Ms. Ruttan: The penicillin.

Soledad: —the penicillin, is not a lot of bacteria.

Ms. Ruttan: There are not a lot of bacteria close to the penicillin. So what do you think happened to the bacteria that were close to the penicillin?

Soledad: They die.

Ms. Ruttan could have simply told her class that their bodies contain microorganisms and that antibiotics, such as penicillin, serve to kill certain bacteria that invade the human body. Instead, she had students observe a photograph from an investigation that facilitated the development of their own understanding of this concept. Additionally, by asking students to provide justification for the claim with evidence and reasoning, Ms. Ruttan had her students engage in a key science practice: argumentation. This excerpt further shows that the English language learning (ELL) students in Ms. Ruttan's class were capable of engaging in this language-rich science practice, particularly when provided with the appropriate supports for doing so. We worked with Ms. Ruttan over the course of the school year as she enacted and adapted a curriculum focused on argumentation to meet the needs of her ELL students. In this article, we describe the strategies that she used to support her students in this important science practice.

The opening classroom vignette illustrates the rigorous science learning that current education-reform documents, such as the *Next Generation Science Standards* (*NGSS*), describe. Ms. Ruttan did not lecture students about the existence of microorganisms in and on the human body. Instead, through observations, collaborative discussions with peers, and argumentation, her students developed their own knowledge about the topic. Describing science learning across three dimensions, the *NGSS* explicitly promote students participating in science practices as they learn crosscutting concepts and disciplinary core ideas (NGSS Lead States 2013). Science practices in particular are being highlighted because they encourage active learning as students construct and refine science knowledge (NRC 2012). Engaging in science practices, however, requires intensive language use on the part of students (Lee, Quinn, and Valdés 2013). Therefore, ensuring that all students, especially ELL students, have opportunities to engage in such rich science learning requires consideration of how to support their language needs.

Appendix D in the *NGSS* and its seven accompanying case studies address what teachers can do to ensure that all students have access to the rigorous science learning promoted in these reform standards (see "Engineering Progressions in the *NGSS* Diversity and Equity Case Studies" on p. 27 of this issue). This article provides additional strategies that teachers can use to support ELL students' engagement in arguing from evidence, one of eight practices in the *NGSS* (specific information around each of the science practices can be found in Appendix F of the *NGSS*) (NGSS Lead States 2013). This science practice involves students engaging in the process of argumentation as they construct and refine the structure of an argument. The *process* involves the ways that students collaborate with peers as they question and build off of one another's ideas, while the *structure* includes the CER framework of a claim, evidence, and reasoning (McNeill and Krajcik 2012; McNeill and Martin 2011). In this structural framework, the *claim* is a statement answering a question or a problem; *evidence* is data such as observations or measurements that support the claim; and *reasoning* is justification of how the evidence supports the claim, which often incorporates science ideas. For example, Ms. Ruttan was hoping that by the conclusion of this particular lesson students would be able to support the claim that antibiotics kill bacteria in the human body by using evidence from the photograph of the agar-streak plate test. For example, students could observe that the white dots on the outside of the plate were bacteria cultures from the human body, but there were

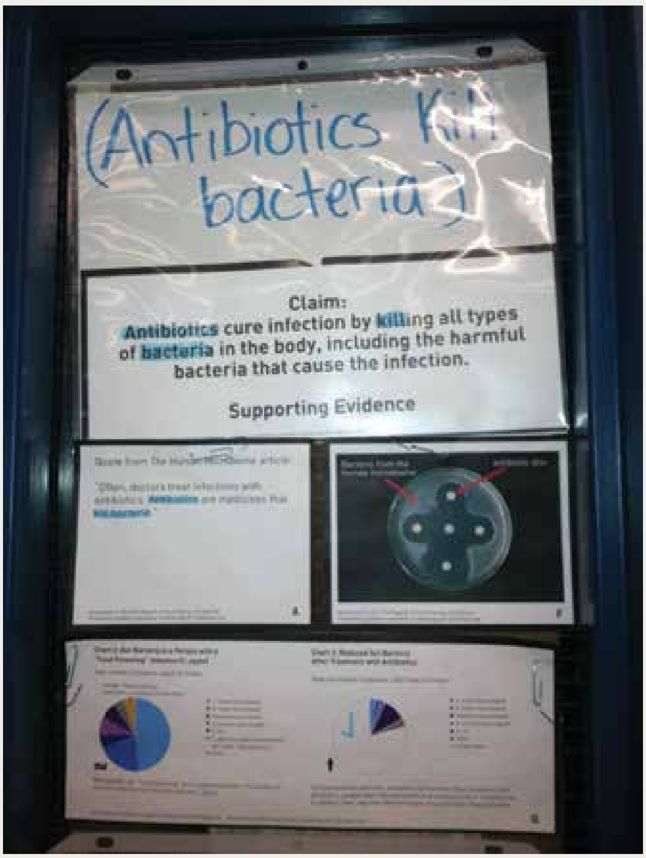
FIGURE 2 Instructional strategies that support students' argumentation engagement

Language focus	Type of support	Examples of supports
Comprehension	Supports for listening	• Preteaching argumentation-related vocabulary terms • Referencing a concept wall that highlights key argumentation-related vocabulary terms • Rephrasing a question numerous different ways • Actively interacting with a visual to help make sense of evidence in support of a claim • Watching a video argument numerous times and stopping it frequently to check for understanding of key points (e.g., "What was that person's claim?")
	Supports for reading	• Identifying key concepts in a written claim • Discussing the meaning of a key word or phrase related to argumentation (e.g., persuasive, relevant)* • Annotating written text to identify the structural aspects of an argument (i.e., claim, evidence, reasoning) • Introducing and focusing on one argumentation-related term at a time
Production	Supports for talking	• Doing a think-aloud to model appropriate language to use during a task* • Simplifying a complex claim by identifying key concepts in it* • Providing students with extra time for preparing and practicing an oral argument • Providing oral conversational sentence starters (e.g., "I disagree with your evidence because ____")
	Supports for writing	• Providing students with extra time to complete a writing task • Providing written sentence starters for the various structural components of an argument (e.g., claim, evidence, reasoning) • Verbally modeling a sentence starter for a writing task (e.g., "This evidence supports my claim because ____") • Breaking down and analyzing a model argument with students in order for them to understand student expectations for writing an argument • Providing and going over a writing template that is aligned to a specific argumentation writing task (e.g., Students are persuading an audience of a particular claim) • Changing the activity structure (e.g., going from individual to pairs, or whole class to small group) in order for students to engage in sense-making with their peers • Giving students time to process and talk ideas out with peers before completing a writing task

* Strategies highlighted in examples discussed in the article

no white dots near the five penicillin discs. In addition, she wanted them to articulate their reasoning that antibiotics, such as penicillin, are medicines used to treat infections. Because there were no bacteria around the penicillin discs, this suggests that the antibiotics kill the bacteria that cause the infection. This science practice demands complex language use, as students need command of the English language to understand (through reading or listening) and then critique and refine an argument (through speaking or writing) (Miller, Baxter Lauffer, and Messina 2014). For more information about developing lessons using the CER framework, see McNeill and Krajcik (2012), McNeill and Martin (2011), and the online Argumentation Toolkit (see Resource). For assessments using the CER framework, see Knight and Grymonpré (2013).

FIGURE 3 Completed card sort from microbiome unit (Regents of the University of California 2013)



The strategies discussed in this article occurred in Ms. Ruttan's classroom while she piloted two units, Microbiome and Metabolism (Regents of the University of California 2013a; 2013b), in a life-science curriculum. This curriculum included a specific focus on argumentation and interwove science and literacy instruction (Pearson, Moje, and Greenleaf 2010). During the four-and-a-half-month span that Ms. Ruttan enacted the curriculum, she used many different strategies to support her ELL students as they engaged in argumentation (see Figure 2). These language supports enabled her students, who had varying degrees of English proficiency, to engage in rigorous learning experiences and demonstrate high-quality argumentation.

While the strategies in Figure 2 are by no means exhaustive, they do begin to offer teachers ideas about how to better support their ELL students' argumentation practice as they engage in a range of different activities. In the remainder of this article, we will highlight three language strategies that Ms. Ruttan used in the lesson previously described. Although these strategies were used in the context of a middle school life-science curriculum, they could be used in any science content area across grade levels.

Example 1: Discussing the meaning of a keyword or phrase related to argumentation

Following the discussion of the photograph of an agar-streak plate test, Ms. Ruttan informed students that they should use only relevant evidence in support of the claim in order to make clear and persuasive arguments. Ms. Ruttan recognized that the term *relevant* might be difficult for her ELL students to understand. She also knew how important the concept of relevancy was for students' successful engagement in argumentation, so she took the time to introduce and define the term using an analogy. She first had one of the students ask her "Where are you from?" In response, Ms. Ruttan stated, "I really like to eat French fries." Many students looked around at each other, confused with their teacher's response. However, one student, who seemed to understand why her teacher had answered the way she did, replied, "That is not relevant." Ms. Ruttan smiled and went on to explain to the class why liking French fries was not relevant to the question that had been asked. She clarified, "I'm telling you something that I believe is true. I like to eat French fries. But, it doesn't answer the question you asked. I gave you information about me, but it wasn't connected to the question." Ms. Ruttan used the French fries analogy throughout the lesson to remind her students of both the meaning of the word and the importance of using relevant evidence to justify a claim.

FIGURE 4 **Modeling appropriate language for a card-sorting task**

[*Students are gathered around a table observing their teacher model the task*]

Ms. Ruttan: So, you have seven pieces of information in front of you. With your partner, you're going to evaluate each piece of information and decide whether it is evidence, if it's relevant to supporting the claim, or whether it's information that's not relevant. Make sense? So, this is how; I'm going to model for you how I'm going to evaluate the information. Can you find the card for me that says, "The number of bacteria…"? There it is.

[*Ms. Ruttan grabs the card and reads it aloud to her students*]

Ms. Ruttan: I could look at this card, which says, "The number of bacteria in the microbiome of one human is millions of times greater than the number of people living on Earth." Right? Okay, I'm going to read it carefully and make sure I understand it. So this one is talking about—you guys could look at [card] B—the number of bacteria. This one is talking about how many, right? How many there are. So then I'm going to think about what my claim is about. My claim is about antibiotics and how they cure infection. Yes? So this one is about bacteria, but it's talking about the number. The claim is not about the number of bacteria in the body, it's about what antibiotics do to those bacteria in the body. So this piece of information is irrelevant to supporting the claim. It's about bacteria, but it doesn't tell me anything about antibiotics. Right? This is French fries. You asked me where I'm from, I told you I like French fries. It's not relevant. Makes sense? So I'm gonna put it over here. Irrelevant. B is irrelevant. Does this make sense?

[*Ms. Ruttan places the card under the "irrelevant information" pile*]

Example 2: Doing a think-aloud to model appropriate language to use during a task

After the discussion on relevant evidence, Ms. Ruttan used a card-sort activity to help students develop an understanding of the role of relevant evidence in an argument. Students were provided with an explanatory claim and seven cards. On each card was either data supporting the claim or other information. The task was for students to work in pairs to sort the cards into two categories in relation to the guiding claim: cards that contain relevant evidence and cards that contain irrelevant information (see Figure 3).

Ms. Ruttan knew that in order for her ELL students to successfully engage in this task, they would need to first see it modeled using appropriate language. Figure 4 contains a classroom transcript of Ms. Ruttan modeling the card-sorting task for her students.

By doing a think-aloud of the card-sorting task, Ms. Ruttan not only demonstrated her expectations to students, but also provided them with the language they would need to successfully engage in the task. She also incorporated the French fries analogy in her modeling, reminding students of both the meaning and importance of relevant evidence. As seen in the following example, this modeling was critical for helping her ELL students meaningfully engage in the argumentation activity.

Example 3: Simplifying a complex claim by identifying key concepts in it

A final strategy that Ms. Ruttan used was simplifying the lesson's guiding claim (i.e., antibiotics cure infection by killing all types of bacteria in the body, including the harmful bacteria that caused the infection). As students engaged in the card-sorting task, Ms. Ruttan circulated through the classroom and noticed that some students were having difficulty comprehending the claim. She went up to a table of students and asked them, "If you had to say this claim in three words, what three words would you use?" With some guidance from Ms. Ruttan, her students came up with the words *antibiotics*, *kills*, and *bacteria* (see highlighted words in Figure 3). These three words captured the essence of the explanatory claim and were also more comprehendible for her ELL students. Throughout the card-sorting task, Ms. Ruttan frequently reminded her students, "What's our three-word claim?" Having a richer understanding of the claim in question allowed students to better complete the task. This is exemplified in the conversation that occurred between two students as they engaged in the card sort (see Figure 5).

During the activity, Juanita had a difficult time sorting one of the cards and expressed her frustration to her partner (e.g., "yo no puedo hacer bien la cosa esta" [*"I can't do this thing well."]*). Marina then used her developing English to support Juanita. During this explanation, not only does Marina correctly sort the card as supporting evidence for the claim (using the language of the simplified claim that Ms. Ruttan guided students in identifying), but she also provides some reasoning as to why the evidence supported the claim. The combination of all of the strategies that Ms. Ruttan purposefully used in this lesson allowed her ELL students to better engage not only in the card sort, but also in the resulting argumentation.

The importance of being flexible

In order to best support her students, Ms. Ruttan found it necessary to be very attentive to their participation (and lack thereof) in classroom tasks and to be flexible in the moment of instruction. There were times that she was able to recognize, prior to a lesson, areas that might pose difficulty for her ELL students and purposefully included strategies that would address their needs. However, there were also instances when chosen supports were not working or unexpected challenges arose (e.g., students' difficulty comprehending the claim in the card-sorting task). Therefore, Ms. Ruttan found it important to allow students' needs to drive instruction. She used the strategies in Figure 2 to flexibly meet the needs of her ELL students, which enabled them to successfully engage in argumentation. This resulted in students' developing richer understanding of both the science practice and the disciplinary core ideas. ■

References

Knight, A.M., and K. Grymonpré. 2013. Assessing students' arguments: How strong are their justifications? *Science Scope* 36 (9): 51–59.

Lee, O., H. Quinn, and G. Valdés. 2013. Science and language for English language learners in relation to Next Generation Science Standards and with implications for Common Core State Standards for English language arts and mathematics. *Educational Researcher* 42 (4): 223–33.

McNeill, K.L. and J. Krajcik. 2012. *Supporting grade 5–8 students in constructing explanations in science: The claim, evidence and reasoning framework for talk and writing.* New York: Allyn and Bacon.

McNeill, K.L., and D.M. Martin. 2011. Claims, evidence, and reasoning: Demystifying data during a unit on simple machines. *Science and Children* 48 (8): 52–56.

Miller, E., H. Baxter Lauffer, and P. Messina. 2014. *NGSS* for English language learners: From theory to planning

FIGURE 5 **Students using a simplified claim to engage in a card sort**

Juanita: ¿Irá esta aca? (Does this one go here?) [*Student places card in irrelevant pile.*]

Marina: [*Student reads aloud the card*] "Unfortunately, not all bacteria are helpful. Harmful bacteria can invade the human microbiome through cuts, spoiled food, and even the air we breathe. An invasion of harmful bacteria is called an infection, and infections can make people very sick."

Juanita: [*Student chimes in and finishes reading aloud the card with the other student*] –"make people very sick." I think this here [*student points to irrelevant pile*] because doesn't support the claim.

Marina: Why?

Juanita: [*Student rereads card*] Because *dice* (it says) [*student reads off card*] "unfortunately not all bacteria are helful, helpful. Harmful bacteria can invade the human microbiome through cuts, spoil food, microbiome through cut." I think, yo no puedo hacer bien la cosa esta. (*I can't do this thing well.*)

Marina: Okay, I think here is [*pointing to cards in irrelevant pile*], here are information because they are like not connecting in the claim because they don't have any antibiotics and kills and bacteria [*student points to cards in irrelevant pile*], like [card] B, right? And here [*student points to cards in the "relevant evidence" pile*] they have, we have to see and read if they are [*student points to claim card*] antibiotics killing bacteria. And here this say [*student points to card in relevant evidence pile*] antibiotics kill bacteria; that's why it's here.

to practice. *Science and Children* 51 (5): 55–59.

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts and core ideas.* Washington, DC: National Academies Press.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Pearson, P.D., E. Moje, and C. Greenleaf. 2010. Literacy and science: Each in the service of the other. *Science* 328 (5977): 459–63.

Regents of the University of California. 2013a. *Metabolism.* Filed trial version of middle school science unit developed by the Learning Design Group. Lawrence Hall of Science.

Regents of the University of California. 2013b. *Microbiome.* Filed trial version of middle school science unit developed by the Learning Design Group. Lawrence Hall of Science.

Resource

Argumentation Toolkit—*www.argumentationtoolkit.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

Ericsson, K.A., N. Charness, P.J. Feltovich, and R.R. Hoffman, eds. 2006. *The Cambridge Handbook of Expertise and Expert Performance.* Cambridge, United Kingdom: Cambridge University Press.

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press.

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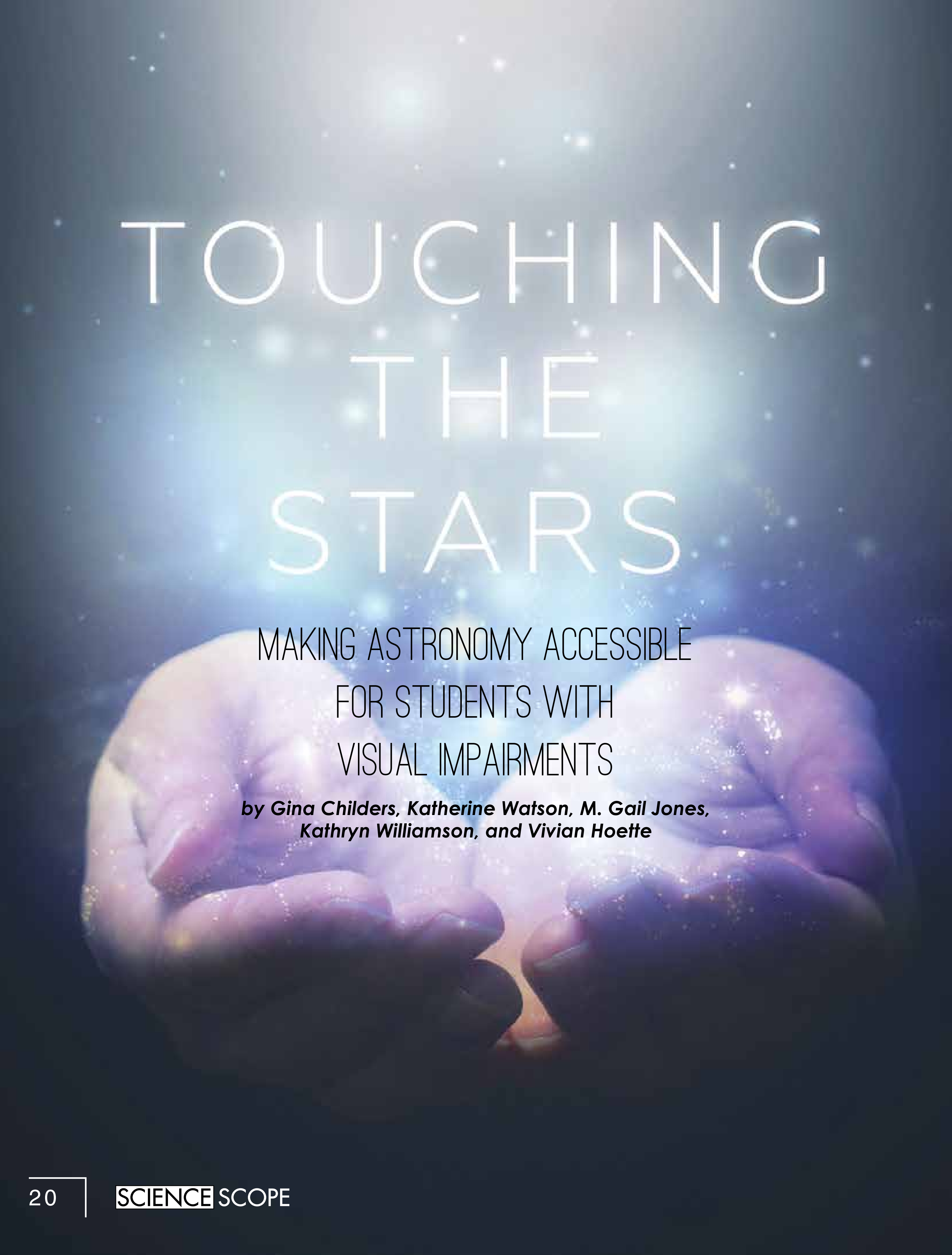


TOUCHING THE STARS

MAKING ASTRONOMY ACCESSIBLE FOR STUDENTS WITH VISUAL IMPAIRMENTS

by Gina Childers, Katherine Watson, M. Gail Jones, Kathryn Williamson, and Vivian Hoette

Gazing into the night sky can be an awe-inspiring experience, and often is what first sparks a student's interest in science. But how would you share the wonder of the night sky with a visually impaired student? How would you explain the different brightness of stars, the shapes of constellations, or the relationship between the various objects in our solar system without the use of a visual aid?

Traditional astronomy instruction is dependent on visual modes of learning, such as textbooks, pictures, and movies. Because of this reliance on visualizations, students with visual impairments are at a disadvantage when it comes to learning astronomy (Beck-Winchatz and Riccobono 2008; Jones et al. 2006). In addition, accommodations for students with visual impairments are often regarded as taxing and costly to schools because of the low enrollment of students with visual impairments. It is not uncommon for there to be a single student with a visual impairment enrolled in a particular school (Beck-Winchatz and Riccobono 2008). Consequently, students with visual impairments often never fully participate in science instruction because of the lack of appropriate models and instructional tools. In order to level the playing field, teachers need to provide research-based accommodations, strategies, and programs for students with visual impairments (Rule 2011; Wild and Allen 2009; Jones et al. 2014). Advancements in tactile, modeling, and computer technologies are allowing students with visual impairments to discover astronomical concepts with innovative tools. New programs and technologies for teaching astronomy have demonstrated that *universal design* (developing tools and educational environments that are usable and accessible by all individuals, including individuals with disabilities) is often beneficial for students with visual impairments, as well as those with normal vision.

FIGURE 1 A model depicting how light enters a telescope lens and bends to a focal point to produce an image

Program description

Skynet Junior Scholars (SJS; *https://skynetjuniorscholars.org*) is a free online program designed to teach astronomy by developing technological tools through a universal design lens. This new astronomy program for middle and high school students is funded by the National Science Foundation and is being developed by the University of Chicago's Yerkes Observatory in partnership with the National Radio Astronomy Observatory, the University of North Carolina at Chapel Hill, the Astronomical Society of the Pacific, and 4-H. The University of Chicago's Yerkes Observatory had previously designed other astronomy programs that promote "active learning in astronomy and physical science for all students, including those with vision or hearing impairments" (Backman and Hoette 2009). The astronomy content taught to students with visual impairments aligns with *Next Generation Science Standard* (*NGSS*) MS-ESS1: Earth's Place in the Universe (NGSS Lead States 2013).

Now, thanks to technological advancements, SJS participants can request and use images taken by research-grade radio and optical telescopes located all over the world to observe and learn about asteroids, galaxies, star clusters, and planets. SJS facilitates the following experiences:

1. Participants have online access to optical and radio telescopes, data analysis tools, and professional astronomers.
2. The SJS website portal provides an age-appropriate, web-based interface for controlling remote telescopes.
3. The SJS website portal provides inquiry-based, standards-aligned instructional modules.

FIGURE 2 **Located in Green Bank, West Virginia, the National Radio Astronomy Observatory's 20-meter-diameter antenna is the only radio telescope on the Skynet network, giving students a window into the invisible universe**

The SJS program is accessible for participants with visual impairments because of technology that can convert digital images into tactile models. Once an image is requested by a student, a tactile picture is created through the use of a tactile generator graphic machine capable of producing raised, tactile images (two tactile picture generators are listed in Figure 3). This is accomplished by first printing the image onto specialized tactile generator paper and subsequently running the paper through the machine. When heat is applied to the black ink on the specialized tactile generator paper, a tactile image is created. An online Braille translator (a free Braille translator is listed in Figure 4) is used to convert traditional font to Braille, so the student-generated tactile images can be annotated in both print and Braille (see Figures 4 and 5). This allows students to feel the image and label the astronomical object they requested (see Figures 6 and 7). In this article, we describe a program to teach students with visual impairments about astronomy. The goal is to share our experiences so that teachers can adapt these strategies to teach astronomy concepts to all students using universally designed technological tools.

Skynet Junior Scholars program experience for students with visual impairments

Students with a range of visual impairments attended three one-hour sessions hosted by the Wisconsin Lions Camp in Rosholt, Wisconsin, during the annual summer camp experience. These sessions introduced the topics of astronomical objects (planets, stars, and galaxies) and explored different astronomical tools and how those tools were used by scientists to gather data (using telescopes). Students collected astronomical data through the SJS website portal.

The first class introduced the purpose of using telescopes, terminology associated with telescopes, and the parts that comprise a telescope. While partnered with a sighted leader who had normal vision and who could provide an articulate description of what students were touching, students could feel the telescope and manipulate the telescope by changing the settings. After touching the telescopes and becoming familiar with how they work and their parts, students created a model of a telescope lens composed of art foam and straws that demonstrated how light enters the telescope lens and bends to a focal point to produce a magnified image of the object in the sky (see Figure 1). (Note: Students should wear safety glasses while working to construct the model.)

FIGURE 3 Materials that enable accessibility of astronomy and other science concepts for students with visual impairments

Item	Supplier	Description/purpose	Cost
Skynet Junior Scholars	Skynet Junior Scholars *https://skynetjuniorscholars.org*	This site provides online access to optical and radio telescopes, data analysis tools, and professional astronomers.	No cost for online use; however, the site requires users to create an account
STEM Resource iBook: *Reach for the Stars: Touch, Look, Listen, Learn*	iBook provided by the Space Telescope Institute with Braille overlay by the National Braille Press *www.sascurriculumpathways.com/portal/#/astronomy*	The goal of the iBook is to provide information and ideas to make science accessible to all students, including students with visual impairments.	No cost associated; free download
Swell-Form Graphics Machine II	American Thermoform Corporation *http://americanthermoform.com/swell-form-graphics-ii-machine*	This machine can be used to create tactile diagrams and images.	$1,350
Picture in a Flash (PIAF) tactile graphic maker	Humanware *http://store.humanware.com/hus/piaf-picture-in-a-flash-tactile-graphic-maker.html*	This machine can be used to create tactile diagrams and images.	$1,395
Swell-Touch Paper	American Thermoform Corporation *http://americanthermoform.com/swell-form-graphics-ii-machine*	This product is used as the paper for printing diagrams on a laser printer or photo copier. Then the paper is fed through the Swell-Form Graphics Machine to create tactile diagrams. You can also draw on this paper using a special black marker and then feed it through the machine to create tactile images.	100 sheets per package, starting at $105; price increases depending on size
Prismacolor kneaded rubber eraser	*Amazon.com*, local arts-and-crafts stores	This eraser can be kneaded into any shape, making it easy to make 3-D models of planets, Moon phases, and other astronomical objects.	Less than $1 each
Braille translator	*www.mathsisfun.com/braille-translation.html*	This online translator is used to convert traditional font to Braille.	Online use results in no cost
Inflatable solar system	*www.enasco.com*	This realistic-looking, inflatable solar system can be used to demonstrate the sizes and distances between planets.	$43.50
Wikki Stix	Amazon.com, The Braille Store, various local arts-and-crafts stores	Create tactile representations of what you've drawn on the board using these bendable sticks.	$13.95 for a pack of 96 from The Braille Store
Orion TI-36X talking scientific calculator	*www.orbitresearch.com*	This fully-featured, talking scientific calculator is a talking model based on the Texas Instruments Ti-36X Solar Educational Calculator. It is easy to teach students to use independently.	$249
Talking Scientific Calculator app for iPads and iPhones	iTunes app store	This calculator is fully supported by VoiceOver and can be used to perform scientific or basic calculations.	$4.99

FIGURE 4 A student's requested digital image of M27 converted into a tactile image with a Braille description: "M27 Dumbbell, a planetary nebula, imaged with r filter (red-yellow), Yerkes 41 inch telescope. ID 8875535"

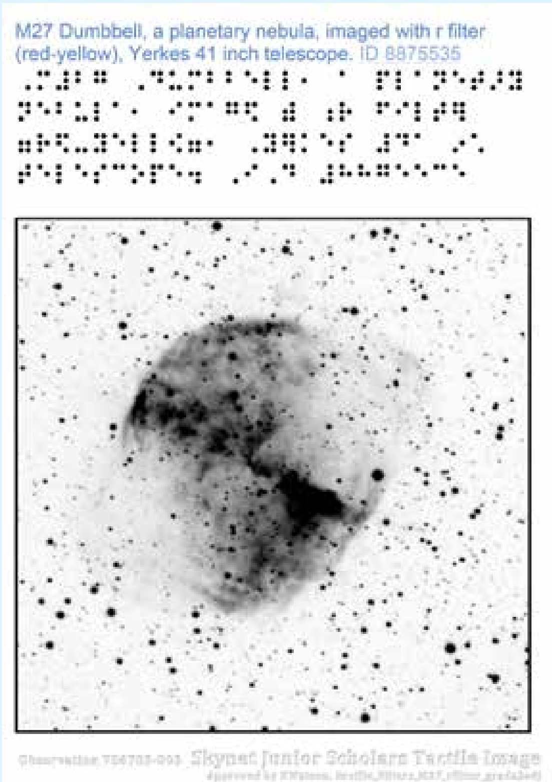
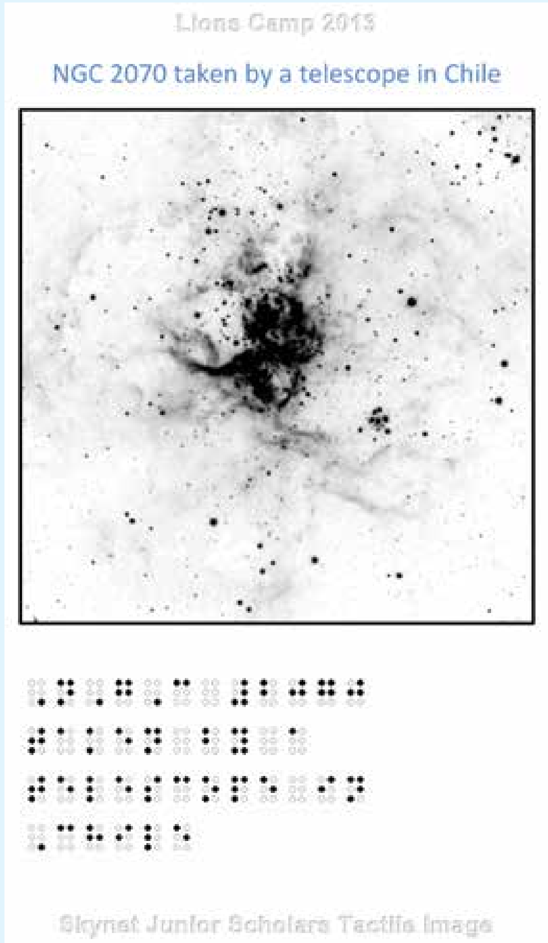


FIGURE 5 A student's requested digital image of NGC 2070 converted into a tactile image taken by a telescope in Chile with a Braille description: "NGC 2070 taken by a telescope in Chile"



Throughout the second one-hour session, tactile images of the objects in the sky were given to students so they could feel and compare and contrast the features of planets, star clusters, and galaxies. A list and description of similar tactile images (e.g., Crab Nebula, M65 Galaxy, and NGC 2158) are available for download (see Resources). A blind eighth-grade student said that feeling the tactile images strengthened her interest in astronomy. "I didn't know that the rings of Saturn looked the way they do," she said. "It was really cool feeling all the pictures and learning that people can actually do this stuff, like look through telescopes and make the pictures."

During the second session, Rebecca Russell, Astro-Tech Program Coordinator and sighted leader, commented about the student experience with the tactile images: "One thing I noticed is that for the students with some vision, it was really helpful to have the tactile images because it provided a way for them to experience astronomy using both sight and touch. It was pretty cool to see that both the blind and partially-sighted students were equally so excited about the tactile materials." Another sighted leader, Kathryn Williamson, Public Education Specialist at the National Radio Astronomy Observatory, stated, "The tactile images are a critical way to connect with Skynet Junior Scholars for students with visual impairments. Hands-on activities are also critical. [It was explained] how important it is to lead up to Skynet Junior Scholars [with tactile images] because when students hear that they will be taking pictures with telescopes, they automatically assume they won't be able to participate and they may write off the experience as not for them." Student experiences during investigations, along with the use of tactile images, are valuable in teaching abstract astronomical concepts. The universal design and hands-on approach of tactical images can also be used in science classrooms facilitated by teachers to enable students to experience astronomy through the sense of touch and sight. By integrating multiple senses during a learning session, tactile images are meaningful learning tools for students. Once students had a grasp of the basic astronomical terminology, the third one-hour session familiarized students with the SJS website portal to explore and collect information about and images of different astronomical objects in the universe.

The SJS website portal introduced students to the different telescopes (optical and radio) they could select throughout the world and learned how to choose astronomical objects, select filters and exposure times, and request an image to be taken by the selected telescope (see Figure 2). Depending on students' degree of visual impairment and ease of manipulation of a computer, students navigated the website in several ways, including increasing the font size on the screen for students with low vision, using software to have the text on the website read out loud to students, or partnering with a sighted leader who guided the student through the SJS website. For teachers who want to incorporate the SJS program into the classroom, the website portal is designed to guide both students and teachers through the process.

FIGURE 6 Students exploring a Hubble tactile image of a spiral galaxy

FIGURE 7 Students exploring a Hubble tactile image of a spiral galaxy

Student reactions to Skynet Junior Scholars

These advances in technology are allowing individuals who once did not have an opportunity to learn astronomy to use scientific tools in order to study astronomy in an innovative fashion. Students who participated in the astronomy classes that used SJS shared the following thoughts about their experiences:

> Reaction #1: "I think that if I didn't join with this project, I would be out of the astronomy world. This has let me realize that I can be an astronomer even though I am blind." – Female Middle School Student, *Anna*

> Reaction #2: "It is a very interesting concept, giving all of that scientific power to people who normally couldn't get their hands on it. It feels like 'the real deal'." – Male Middle School Student, *Dean*

> Reaction #3: "Awesome that science is more accessible." – Male High School Student, *Robert*

Additional materials and teaching strategies

There are materials that can be used to make astronomy and other science concepts accessible to youth with visual impairments. (Note: Teachers should call their central/district office to receive information about funding for students with disabilities.) The following include tried-and-true instructional strategies that are effective for teaching science to students with visual impairments. These include:

- providing large-scale, tactile objects and models of astronomical concepts for students with visual impairments to touch during a lesson;
- creating tactile images in the classroom using a 3-D tactile printer;
- using magnifying or electronic enlargement tools to enable students with low vision to read and view visuals;
- using specialized software to enhance navigation of websites with a speech function;
- providing Braille-enabled models, reading materials, and tools;
- explaining visuals and videos in depth;
- encouraging students with visual impairments to participate in labs;
- granting additional time to explore laboratory components;
- encouraging student interest in science, support student self-efficacy, and empower the student to pursue individual interests; and
- finding creative ways to use everyday materials, such as puffy paint or clay, to create representations and models of astronomical phenomena.

These strategies and tools are also essential to assess student understanding. Asking students to create three-dimensional models in astronomy or other subjects requires a student to demonstrate knowledge that is often not assessed with verbal-based assessments. Advancements in tools and materials have opened new doors for students with visual impairments to fully learn science concepts and phenomena and more educators are closer to realizing science for all. ■

References

Backman, D., and V. Hoette. 2009. Astronomy for students with sensory impairments. *The Science Teacher* 76 (3): 64.

Beck-Winchatz, B., and M. Riccobono. 2008. Advancing participation of blind students in science, technology, engineering, and math. *Advances in Space Research* 42 (11): 1855–58.

Jones, M.G., J. Minogue, T. Oppewal, M. Cook, and B. Broadwell. 2006. Visualizing without vision at the microscale: Students with visual impairments explore cells with touch. *Journal of Science Education and Technology* 15 (5): 345–51.

Jones, M.G., G. Childers, B. Emig, J. Chevrier, H. Tan, V. Stevens, and J. List. 2014. The efficacy of haptic simulations to teach students with visual impairments about temperature and pressure. *Journal of Visual Impairment and Blindness* 108 (1): 55–61.

Rule, A. 2011. Tactile earth and space science materials for students with visual impairments: Contours, craters, asteroids, and features of mars. *Journal of Geoscience Education* 59 (4): 205–18.

Wild, T., and A. Allen. 2009. Policy analysis of science-based best practices for students with visual impairments. *Journal of Visual Impairment & Blindness* 103 (2): 1–7.

Resources

Skynet Junior Scholars—*https://skynetjuniorscholars.org*

Tactile images—*https://sites.google.com/a/starsatyerkes.net/visions-of-the-universe/home/wpcp*

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Engineering Progressions in the *NGSS* Diversity and Equity Case Studies

by Emily C. Miller, Rita Januszyk, and Okhee Lee

The seven online case studies that supplement Appendix D of the *Next Generation Science Standards* (*NGSS*) feature the four federally defined accountability groups—students of low socioeconomic status (SES), students from major racial and ethnic groups, students with disabilities, and English language learners (ELLs)—and three additional groups—girls, students in alternative education, and gifted and talented students. The case studies illustrate *NGSS* implementation in classrooms with each of these identified diverse student groups. While the teaching strategies outlined in the case studies will work well with all students, they were specifically developed to address "what classroom teachers can do to ensure that the *NGSS* is accessible to all students," particularly nondominant student groups.

Four of the seven case studies (1, 2, 4, and 5) in the *NGSS* prominently feature engineering, and they demonstrate how engineering practices and core ideas leverage student sense-making and reasoning with respect to three-dimensional learning. In particular, these case studies illustrate diverse student groups successfully engaged in the *NGSS*. Teachers of diverse student groups seek examples of *NGSS* implementation in authentic contexts to inform teaching. We offer the case studies to show that the *NGSS*, rather than being another obstacle for teachers to hurdle, is an exciting opportunity to transform thinking about what it means to know and do science and engineering and enable all students to succeed in both. This article describes engineering for diverse student groups as illustrated in the *NGSS* case studies. The case studies can be accessed at *www.nextgenscience.org/appendix-d-case-studies*.

FIGURE 1 Progression of engineering practices and core ideas (NGSS Lead States 2013)

Demographic group	Engineering practice	Engineering core idea
ELLs Focus: Earth science	**Designing Solutions** • Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena. • Compare multiple solutions to a problem.	**ETS1.C. Optimizing the Design Solution** Because there is always more than one solution to a problem, it is useful to compare designs, test them, and discuss their strengths and weaknesses.
Girls Focus: Engineering	**Defining Problems** Define a simple design problem that can be solved through the development of an object, tool, or process and includes several criteria for success and constraints on materials, time, or cost.	**ETS1.A. Defining Engineering Problems** The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.
Race and ethnicity Focus: Life science	**Engaging in Argument from Evidence** Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	**ETS1.B. Developing Possible Solutions** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
Students from low SES Focus: Engineering	**Designing Solutions** Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ETS1.B. Developing Possible Solutions** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

Engineering in the classroom

Integrating engineering solutions into instruction allows the teacher to accomplish a number of learning objectives. The vignettes below represent real classrooms with diverse students and revolve around a phenomenon in everyday life, which gives students the opportunity to apply science core ideas and engineering practices to solve a real-world problem (see Figure 1 for a list of some of the ideas and practices involved in these activities). These vignettes focus on the integration of engineering practices and core ideas within the four disciplines (Earth science, engineering, life science, and physical science) and represent instruction for grade bands K–2, 3–5, middle school, and high school. In each example, engineering provides real-world relevance to students.

Engineering makes the science contextual and place-based.

In the Case Study 1 vignette, ELL students became interested in everything soil. They met the challenge of constructing claims about where unnamed soils came from and used evidence (e.g., pine needles and colors) and their soil-profile models to make predictions. Many students in the vignette had observed trash being blown into the urban marsh near their apartments. When they dug a pit in the soil and discovered layers and layers of trash, they were aghast (and thrilled at their discovery). With teacher and peer support, they were able to piece together how the trash had gotten into the soil. With the engineering problem "How can we stop wind and water from changing the soil in the urban marsh?" students were motivated to take language risks and explain their thinking to their peers. They used their science knowledge to develop plans to help solve the problem. Although students were already heavily invested in the Earth-science unit, the application of engineering became another entry point for students to express their thinking and participate in meaningful discourse with their peers.

Engineering involves students in collaborative problem-solving.

In the Case Study 5 vignette, female students began with an engineering problem that set the stage for science learning. Ms. G took students into their woods to help them think about ways to provide for the animals that weren't getting enough food during certain times of the year. The engineering problem provided an avenue for student-directed research on characteristics of plants that would not only provide for birds in the early spring, but also meet the criteria students had agreed upon (e.g., are native species, thrive in the low-sunlight woods, provide food for a diversity of animals). The students used the data they collected to ask questions, identify patterns, and define a problem. They asked, "How can we…?" The problem-solving took into account many pieces of data and included a growing understanding of ecosystem dynamics necessary to solve the problem and come to a workable, optimal solution.

Engineering applies science core ideas to the engineering problem.

In the Case Study 2 vignette, eighth-grade students from various racial and ethnic groups sought to apply their definition of energy efficiency to the process of refining and using switchgrass as fuel. To accomplish this task, students needed to use a model they had developed to explain the cycle of matter and the flow of energy, first as gasoline fuel and then as ethanol fuel, to a new fuel source, switchgrass. Students applied their new learning to a problem that was related to, but not the same as, their earlier understanding. In this way, students showed integrated understanding and versatility and generalization of their science learning.

Engineering presents opportunity for formative assessment.

In the Case Study 1 vignette, a teacher with students of low SES used an engineering problem as a means of informally assessing their understanding of core ideas in physical science—in this case, the behavior of gas. Students had developed models that described pressure change when a gas condenses. Students' conceptual models illustrated their understanding of molecular movement when thermal energy is removed from the system. Students needed to design a solution to solve the problem of a tanker imploding due to decreased internal pressure. One group of students applied the science ideas and solved the problem by making a hole in the tanker that would allow additional air to rush in as the air and water vapor inside the tanker cooled. Students described their solution and how it worked and demonstrated understanding through application.

Progression across grades

Engineering practices and core ideas become more sophisticated throughout grades K–12. The progression is exemplified in the vignettes, as teachers identify entry points for students to solve problems at appropriate developmental levels. The vignettes show students meeting the required expectations according to their grade bands.

The progression for engineering core ideas is featured in the *NGSS* Appendix I: Engineering Design. Appendix I describes core ideas ranging from simple, concrete applications of the design cycle for problem-solving in grade band K–2 to an increasingly complex, formalized, and focused understanding in grade band 9–12. *NGSS* Appendix F: Science and Engineering Practices demonstrates the increasing sophistication of the engineering practices across grade bands.

The four *NGSS* case studies involving engineering in the classroom reflect the increasing sophistication of learning expected of all students across all grades. The grade 2 students in the ELLs' vignette develop simple solutions to the problem of sand flowing into the urban marsh and changing the soil. They use materials to generate and compare multiple solutions to the problem. Appendix F states that K–2 students should be able to "Use … materials to design and/or build a device that solves a specific problem or solution to a specific problem" and "Generate and/or compare multiple solutions to a problem" (NGSS Lead States, p. 75).

By the time students are in third grade, as in the girls' vignette, the doing of engineering has become more formalized. Students define and evaluate criteria to arrive at the optimal solution to the native-species problem in the woods. They address the expectations that relate to grade band 3–5 in Appendix F for the practice of defining problems: "Define a design problem that can be solved through the development of a … process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions" (NGSS Lead States, p. 68).

In middle school, students in the race and ethnicity vignette engage in a more complex and abstract problem. After collaboratively coming to agreement for a definition of energy efficiency, students engage in argument using their definition to compare various fuels. The progression for engineering practices in Appendix F describes what students can do to demonstrate proficiency in argumentation: "Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts" (NGSS Lead States, p. 76).

Finally, in high school, students construct explanations about design solutions by breaking their task into manageable parts, keeping in mind the relationship between dependent and independent variables, prioritizing criteria, and using the scientific principles under study. In the vignette, students of low SES design solutions to keep a tanker from collapsing when the pressure changes due to change in state of gas. They use science core ideas to construct their design solutions. Appendix F describes the progression of the practice of designing solutions in high school: "Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations" (NGSS Lead States, p. 75).

Across all grades, students are depicted as capable of meeting the increased science and engineering expectations. Teachers provide scaffolding by using real-world contexts, problem-based learning, peer collaboration, and other strategies for diverse learners. The conceptual leap from comparison of concrete solutions to application of abstract science core ideas is pronounced. By engaging in many engineering experiences per grade band, students develop scientific knowledge over time and are ready for increased challenges each year.

Conclusion

The case studies in Appendix D offer guidance for teachers on how to approach teaching engineering and the level of complexity appropriate for their grade level. The four vignettes illustrate that all students can participate in engineering practices and core ideas to build on learning developed across years. When students engage with engineering, they are equipped with the capacity to analyze solutions to design problems in their everyday life. They are able to successfully participate in decisions that are necessary for citizenship in a democracy. In addition, all students will view themselves as engineers and may be empowered to consider engineering as a possible path for college and career. ■

Acknowledgment

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References

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

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Supporting Science Access for All Students

by Gillian Puttick and Karen Mutch-Jones

Using Content Enhancements to Create Pathways to the Big Ideas

Ms. Hanson is frustrated. Many of her seventh-grade students enjoy doing investigations, but they find it difficult to make sense of the science ideas they are exploring. Some of these students have learning disabilities, but others struggle as well. All are capable, and Ms. Hanson is sure their performance is not indicative of their ability or interest. She notices that her struggling students often miss critical steps in collecting data, have difficulty understanding how an activity relates to the learning goal, and do not build their understanding incrementally across related activities. She knows that middle school students benefit from scaffolding, so she provides lesson goals, key words, and focus questions on the board. She also carefully structures her lectures and class discussions to fill in gaps. While these seem to help, they don't engage students in the kind of science sense-making she'd like to see. As she begins her new unit on ecosystems, Ms. Hanson is determined to develop curricular supports that better move her students toward deeper understanding.

Student challenges in the science classroom

Students with learning disabilities (LD) achieve at lower levels than their nondisabled peers (U.S. Department of Education 2011). One intention of the *Next Generation Science Standards* (*NGSS*) is to address these achievement gaps. The *NGSS* affirm that all students, including those with disabilities, "are capable of engaging in scientific practices and meaning-making in both science classrooms and informal settings" (NGSS Lead States 2013, Appendix D, p. 1). At the same time, the *NGSS* note that the standards are "cognitively demanding" and require teachers to "make instructional shifts."

The transition to middle school is an especially important time for addressing learning gaps and improving science instruction so that the curriculum is accessible to all students. Making science accessible to all students can be difficult because, unlike other middle school subjects, it requires students to make sense of phenomena that are "invisible" (e.g., cells, plate tectonics) and concepts that are abstract (e.g., structure and function, deep time). Vocabulary can be challenging, and expectations are higher for scientific reasoning. Also, complex science practices, such as controlled experimentation, systematic data collection, and analysis of results, need to be mastered. Such challenges are correspondingly greater for middle school students with LD. Moreover, even with rich curricula, high levels of engagement do not ensure that students are "making meaning" from their daily classroom learning experiences. Students with LD have difficulty seeing where individual lessons fit into the larger narrative of the science unit.

In this article, we share lessons learned from our Accessing Science Ideas (ASI) project (see Resources) that may help science teachers make "instructional shifts" as they teach a wide range of learners in their inclusive science classrooms. We describe an approach for creating a connected set of supports to make science curricula more accessible to students with LD, as well as others who struggle in middle school classrooms.

Understanding and responding to students' struggles in science

Learning disabilities affect students in different ways in the science classroom. Research shows that many students with LD find it difficult to effectively classify and systematize or find relationships (e.g., similarities and differences, cause and effect) between/among facts, data, and concepts (Stefanich 2007; Mastropieri et al. 2006; Gore 2004; Ivie 1998). Students with LD also experience difficulties with inductive and deductive thinking (Mastropieri et al. 2006), making inferences, and linking ideas to chains of reasoning (Lynch et al. 2007).

The groundwork must be laid for these types of complex thinking. Often, special educators are the ones who provide valuable, but general, learning and study strategies for students and teachers. For ex-

ample, they may create vocabulary lists, study guides, and investigation checklists. In addition, digital supports such as glossaries and writing prompts can be helpful. However, in many schools, special educators do not have sufficient time to work specifically in science classrooms, and digital supports in science are frequently not available or well integrated with lessons.

Moreover, studies have shown that teachers with knowledge of how the discipline is structured and how students build knowledge within it can craft better lessons and be more responsive to diverse student needs (Brownell et al. 2010; Ball et al. 2009; Hill et al. 2008). To do this, we believe that science teachers might benefit from a process for translating general learning strategies into science-specific content enhancements (CEs), much like the one we designed for the ASI project, where CEs help students focus on the work of individual science activities and reason across investigations to make sense of the concepts they are studying. This scaffolded progression of learning is shown in Figure 1.

Creating content enhancements

Content enhancements are instructional strategies and materials that do not change but rather "enhance" the curriculum, making the goals and processes of science activities more connected and explicit. Our CEs were designed for and integrated into two curriculum units on biodiversity and populations and ecosystems (see Resources). Based on the work of Hughes and colleagues (Dexter, Park, and Hughes 2011; Hughes 2007), we made sure the CEs we developed are appropriate for a range of students in inclusive science classrooms. You can find digital copies of these CEs online at *www.nsta.org/middleschool/connections.aspx*.

Our process for creating CEs included three key steps: First, we identified the challenges that might prevent students with LD from accessing science content; next, we identified the "big ideas," that is, the essential science concepts represented in the investigations of the unit, and documented the unit's narrative "story line"; and lastly, we created concept maps to identify the unit activities that built toward the big ideas, noting the types of demands they placed on students (Figure 2; see "Building CEs into your instructional repertoire," below, for more information about these steps). These steps helped us choose critical places in the unit to integrate CEs.

Example: Developing CEs to support student understanding of energy flow in ecosystems

Within the populations and ecosystems unit, we identified energy flow in ecosystems as a big idea that would be challenging for all students, not just students with LD. Students begin by identifying the organisms in an ecosystem and organizing them into a food web that shows feeding relationships. Then, after a short presentation by the teacher about the functional roles of organisms (e.g., primary producers, primary and secondary consumers), students reorganize the organisms into trophic levels according to these roles. Next, students burn Cheetos to measure their energy content. They read about photosynthesis as the mechanism that captures the sun's energy within sugar molecules in producers and learn that this energy is transferred

FIGURE 1 Scaffolding deeper understanding

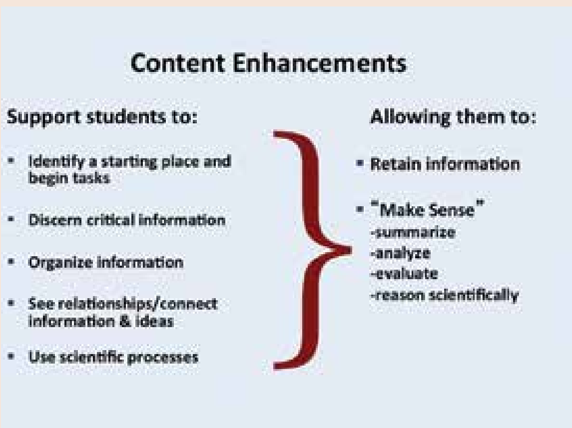
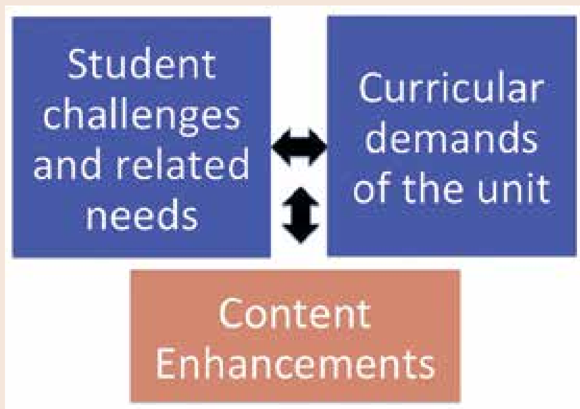


FIGURE 2 General process for analyzing the curriculum to design content enhancements



to consumers for growth, movement, maintenance, and reproduction. Students finish by constructing a physical model of an energy pyramid, showing that approximately 10% of the energy from each trophic level is transferred to the next level. Your curriculum may not include this specific sequence; you can record the sequence of the unit you use (see the next section of this article).

Based on our analysis of these activities, we determined that students with LD would not understand energy flow or be able to generalize energy flow across different ecosystems if they: (1) could not remember what trophic levels are; (2) became confused about what a food web represents versus what an energy pyramid represents; and (3) did not understand relationships among food, energy, and heat. Therefore, it is critical to support each of these content-learning challenges with CEs (Figure 3).

We developed a set of four CEs carefully tied to the energy-flow activities. The CEs built toward this concept sequentially, as shown in Figure 4. First, students completed *cloze sheets* (top left of Figure 4), which scaffold reading and comprehension by asking students to fill in key information, using a provided word bank (Dexter et al. 2011). The top section of the sheet helped students identify and remember critical vocabulary and facts about trophic levels. Two "making sense" questions at the bottom of the page required understanding of this information. Next, a graphic organizer (bottom left of Figure 4) helped students organize information so they could see relationships—that trophic levels represent the flow of energy and that only 10% is available for transfer because the other 90% is used for the activities of life. Because the proportions of the levels in the graphic organizer are not represented in the correct ratio, students extended the bottom trophic level by attaching correct lengths of colored ribbon to the diagram. This CE also helps working memory by reinforcing the fact that trophic levels represented food-web relationships from the previous lesson. The CE on telling the "energy story" (bottom right of Figure 4) helps students work in small groups with assigned roles to re-represent the information from the graphic organizer to build understanding further. Each student tells the story of one trophic level verbally to the group, with assistance from a helper who checks the story against the graphic organizer, as the group scribe writes it down. Finally, the ecosystem discussion and guiding questions (top right of Figure 4) help students apply and transfer understanding to a new situation—that functional groups are present in all ecosystems and that the abstract concept of energy flow can be generalized to all ecosystems.

Building CEs into your instructional repertoire

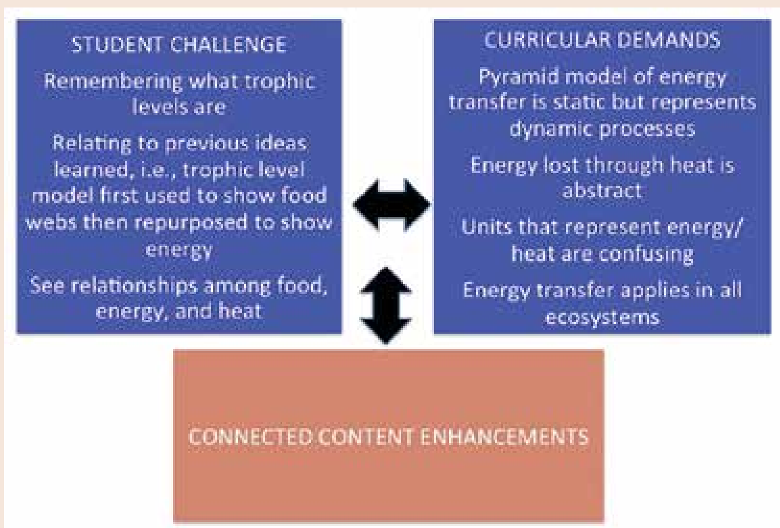
If you are interested in developing CEs for your own science units, the following steps can help.

Step 1: Analyze your unit and take stock of the science challenges

Set aside some time to analyze the unit you are going to teach. Pay particular attention to the overarching "narrative."

- How was the story line of the unit developed so that activities, readings, and classroom discussion work coherently toward the learning goals?
- How are the learning goals connected to the big ideas?
- What are the connections from lesson to lesson?

FIGURE 3 **Interaction between LD student challenges and content demands related to energy flow, which require content enhancements to support understanding**



Step 2: Identify all the places where your students with LD will struggle

Reflect on the tasks students must accomplish as they work through the unit. Taking into account what you know about your students, think about what is likely to be challenging.

- Are there readings where students need to
  - ✧ identify the critical main points?
  - ✧ summarize the main points?
  - ✧ find critical information to answer questions?
- Are there places where students are expected to
  - ✧ remember and make sense of topics or concepts that have been discussed in groups?
  - ✧ remember something (e.g., concept, idea) and apply it to a present task?
  - ✧ keep several ideas in mind as they reason about a phenomenon?
  - ✧ connect ideas (e.g., draw from readings to interpret data from investigations)?

Once you have done this, choose which "big idea" you want to address and focus on three to four specific challenges related to it across the unit. These are the places you will want to enhance first.

Step 3: Create linked CEs that build toward the concept

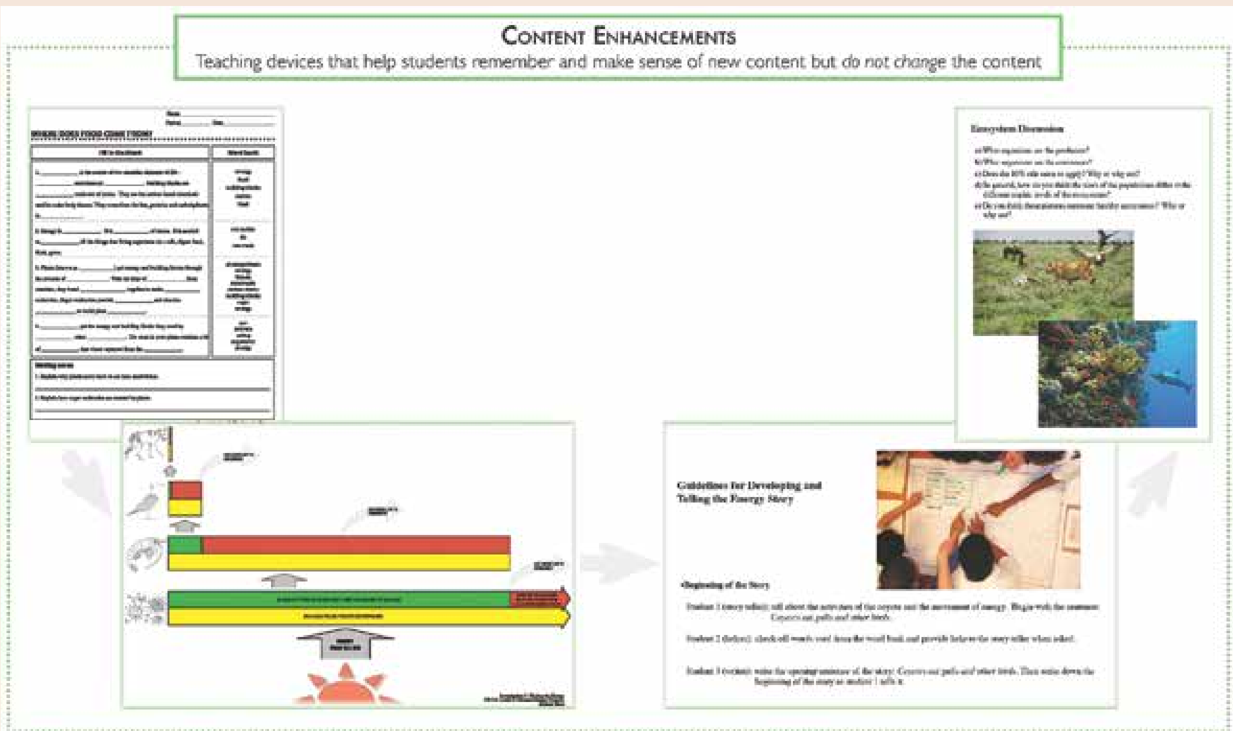
Now you are ready to think about CEs. Figure 5 will help you match the specific function with a type of CE that supports the function. Note that the list is not exhaustive, but a place to start. Ask yourself:

- What functions are required for each place you will insert a CE?
- What types of supports best address that function?
- This is critical: Is the progression from one CE to the next logical?

Once you have created your CEs, review the sequence to make sure they link together toward student understanding of the big idea.

We suggest you begin with just one of the big ideas

FIGURE 4 Connected set of content enhancements related to energy flow in ecosystems



in the unit. You can build up your repertoire over time whenever you teach the unit and either develop different kinds of CEs to expand the possibilities or apply the same kinds of CEs more frequently in the same or other units.

Instructional benefits of CEs

After piloting our CEs in 17 classrooms and extensively revising them, we measured the impact of CEs on 60 intervention teachers and their students, comparing their outcomes to 59 control classrooms. Teachers were randomly assigned. They came from nine states representing 32 districts and a total of 2,696 students. Twenty-five percent of students either had an individualized education program (IEP) or were experiencing LD challenges similar to IEP students.

Overall our results were positive, showing some statistically significant differences between groups. Intervention teachers learned new ways to support students with LD. Their students, both with and without LD, demonstrated greater understanding of unit concepts (Mutch-Jones, Puttick, and Demers, 2014). Even so, we knew that CEs also had to be easy to use, appropriate for all students in inclusive science classrooms, and help teachers identify how well their students were building their understanding of the big ideas. Teachers reported that the CEs were easy to incorporate, not overly time-consuming to use, and kept students engaged in activities and focused on the big ideas in both units. We were particularly pleased that teachers noted that the CEs supported students with and without LD equally well.

In addition, teachers perceived CEs as making a difference in student performance. A large majority of intervention teachers indicated that CEs supported students in improving reasoning skills, understanding the big ideas of the unit, and working on investigations with greater confidence. Again, teachers' perceptions were that the CEs supported students with and without LD equally well in these areas.

Teacher comments underscore these positive ratings and provide a fuller sense of their experience using the CEs. The most frequent comments focused on the benefits to students. Consistent with our primary goal, they noted increased accessibility for struggling students. In most cases, teachers also emphasized the benefit of CEs for all:

"We realized that the accommodations developed specifically for students with special needs could also be used to increase accessibility for all students, especially those nondisabled students who tend to struggle."

Teachers also commented that the CEs helped students build connections to the lessons' big ideas and truly engage in science thinking. Some noted the contribution of CEs to their teaching as well:

"[The CEs] were a great help to get the kids thinking about the 'point' of what was being done."

"I think the CEs helped all of the students. The CEs especially allowed students to create a story line of all the material, which allowed them to use the information and apply it to other situations."

"I feel this group of students understood the science concepts significantly better than any other kit/unit/class I have ever taught. The process [using the CEs] has made me a better science teacher."

As a result of positive experiences with CEs during the study, some teachers were eager to integrate them within other units:

FIGURE 5 Function that each student task requires and types of CEs that match that function

Identify and remember critical information

- Discern critical information from text, lecture, and class work
- Understand and follow steps of a process
- Identify a starting place for an open-ended task

Examples of CEs to support functions: cloze sheets, focusing questions, checklists

Organize information to see relationships

- Organize data or factual information
- Understand information
- Identify relationships
- Connect information to bigger ideas

Examples of CEs to support functions: graphic organizer with symbols to indicate various connections, physical and visual models

Work with information to deepen understanding

- Retain information
- Summarize/analyze information
- Describe the type and nature of relationships among data/ideas

Examples of CE to support functions: Telling-the-story activities, making-sense questions tied to an organizer or cloze sheet

Apply and transfer understanding

- Evaluate information and initial understanding
- Reason scientifically
- Apply scientific understanding to new situations

Examples of CEs to support function: Photographs/diagrams to interpret, concept map with new data

"The CEs that were provided enhanced the learning and understanding of difficult content. Please quickly develop more for [other] modules."

Others felt ready to make CEs of their own:

"The content enhancements inspired me to create similar enhancements for the other … units that I teach."

Additional study findings are available with the online at *www.nsta.org/middleschool/connections.aspx*.

Conclusion

ASI findings suggest that employing a process such as the one described here may help teachers make instructional shifts that support students with LD. In fact, teachers in the ASI project were able to generate their own CEs for another science topic after they had implemented the CEs described here. Furthermore, connected sets of CEs designed to move students from simple to more complex ways of thinking about science ideas can be helpful for a wide range of learners in an inclusive classroom. For students with LD in particular, understanding and organizing factual information and being supported when discerning relationships and making connections across ideas may be particularly important for the kind of "meaning-making" advocated by the *NGSS*. ■

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References

Ball, D.L., M.H. Thames, and G. Phelps. 2009. Content knowledge for teaching: What makes it special? *Journal of Teacher Education* 59 (5): 389–407.

Brownell, M.T., P.T. Sindelar, M.T. Kiely, and L.C. Danielson. 2010. Special education teacher quality and preparation: Exposing foundations, constructing a new model. *Exceptional Children* 76 (3): 357–77.

Dexter, D.D., Y.J. Park, and C.A. Hughes. 2011. A meta-analytic review of graphic organizers and science instruction for adolescents with learning disabilities: Implications for the intermediate and secondary science classroom. *Learning Disabilities Research and Practice* 26 (4): 204–13.

Hill, H.C., M.L. Blunk, C.Y. Charalambos, J.M. Lewis, G.C. Phelps, L. Sleep, and D.L. Ball. 2008. Mathematical knowledge for teaching and the mathematical quality of instruction: An exploratory study. *Cognition and Instruction* 26 (4): 1–81.

Hughes, C.A. 2011. Effective instructional design and delivery for teaching task-specific learning strategies to students with learning disabilities. *Focus on Exceptional Children* 44 (2): 1–16.

Ivie, S.D. 1998. Ausubel's learning theory: An approach to teaching higher order thinking skills. *High School Journal* 82 (1): 35–43.

Lynch, S., J. Taymans, W.A. Watson, R.J. Ochsendorf, C. Pyke, and M. Szesze. 2007. Effectiveness of a highly rated curriculum unit for students with disabilities in general education classrooms. *Exceptional Children* 73 (2): 202–23.

Mastropieri, M.A., T.E. Scruggs, J. Norland, S. Berkeley, K. McDuffie, E.H. Tornquist, and N. Connors. 2006. Differentiated curriculum enhancement in inclusive middle school science: Effects on classroom and high-stakes tests. *The Journal of Special Education* 40 (3): 130–37.

Mutch-Jones, K., G. Puttick,and L. Demers. 2014. Differentiating science instruction: Teacher and student findings from the Accessing Science Ideas project. Paper presented at the American Education Research Association Conference, Philadelphia, PA.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Stefanich, G. 2007. *Inclusive science instruction. www.uni.edu/stefanic/Inclusive_Science_Strategies.pdf.*

U.S. Department of Education. 2011. The Nation's Report Card: Science 2011. *www.nationsreportcard.gov/science_2011.*

Resources

Diversity of Life, Populations and Ecosystems units: *www.fossweb.com*

Information about the Accessing Science Ideas project: *www.terc.edu/display/Projects/Accessing+Science+Ideas*

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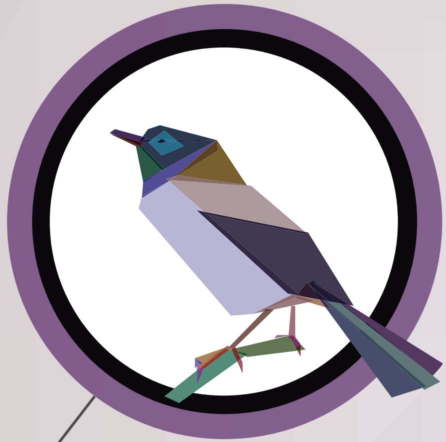
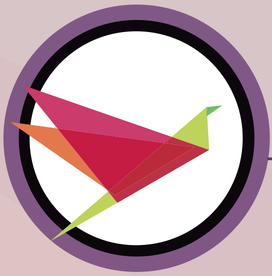
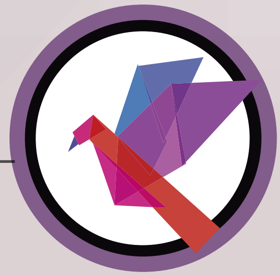
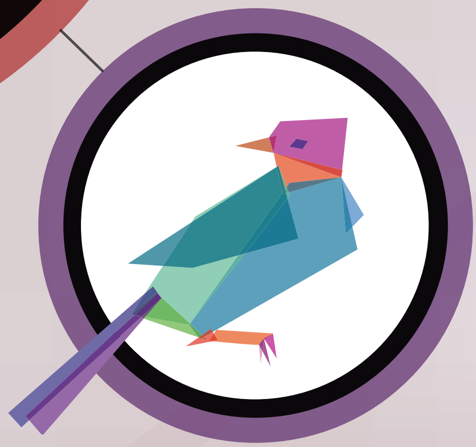


COLLABORATIVE CONCEPT MAPS





A Voice for All Science Learners



by Kim Cleary Sadler, Samantha Stevens, and James C. Willingham

One of the greatest challenges teachers face is ensuring that all students receive equitable learning opportunities. Students have differing academic abilities, needs, and achievement levels, and may come from a variety of ethnic and socioeconomic backgrounds. The increasing diversity in the classroom has led to new questions:

- What is your pedagogical stance and how effective is your middle school science curriculum in addressing the academic needs and interests of all students?
- Do you have instructional tools appropriate for all students that will allow them to construct their new knowledge and defend their solutions?

This article proposes the use of collaborative concept maps as a valuable instructional tool to prompt learners to make connections and establish relationships between new concepts and prior schema. This tool provides the teacher with an instrument to help differentiate instruction for all students using a single activity that is time efficient and allows assessment of small-group understanding.

The process of creating a collaborative concept map can vary based on students' academic level. Students can brainstorm concepts in a small- or whole-group setting or the teacher can provide key terms. The map is generated through communication and debate as students select the most inclusive concepts to represent nodes (key terms, or the topic from which the connections are made). Students then use lines with arrows to indicate the direction of thoughts and write valid statements on the connecting lines to explain the meanings of the connections. Groups no larger than four, large paper, and established norms such as using appropriate social skills, listening to the ideas of others, and exercising negotiation skills promote group interaction. Color can provide additional meaning and connections among concepts. If you are not familiar with concept maps and how to use them, previous Science Scope articles have excellent information about constructing concept maps in the science classroom (Llewellyn 2007; Vanides et al. 2005). Differing from the individual construction of concept maps, collaborative concept mapping exercises Vygotsky's zone of proximal development through peer exchange of information, tutoring, and argumentation. Group members assume individual responsibilities and monitor the progress of the group (Forman and Cazden 1985).

A Framework for K–12 Science Education states, "concerns about equity should be at the forefront of any effort to improve the goals, structures, and practices that support learning and educational attainment of all students" (NRC 2012, p. 277). Collaborative concept mapping in the science classroom is a constructivist approach that actively engages all students in the building of individual understanding through connections of new and prior knowledge acquired from discussion and argumentation with other students (Sandoval 1995). Such instruction allows for varied learning opportunities when groups are diverse in ability (Kinchin, Hay, and Adams 2000). Students with disabilities, through a reciprocal exchange of ideas in a group problem-solving process, experience the benefits of small-group learning, including higher achievement, broader peer acceptance, and increased self-efficacy and "overcome obstacles they might not overcome working alone" (Jenkins et al. 2003, p. 280). Additionally, collaborative learning approaches have been found to promote academic achievement and improved student attitudes for both male and female students in STEM courses (Prince 2004).

The "Bird Beaks" activity and classroom context

This article describes an expansion on collaborative concept mapping, with an example of student outcomes from a middle school life-science lesson focused on adaptation and change over time. Students had previously completed a unit on heredity and diversity and were preparing to move into a unit considering the dynamic properties of the Earth. Therefore, we designed a unit review based on a modified version of the Bird Beaks activity (AAAS 2015; Piltz 2004), which incorporates concepts of heredity, environmental influence, and the

fossil record. We explain the activity here to clarify the context for our use of collaborative concept mapping.

The Bird Beaks activity engages students as they model the behaviors of competition among individuals of different bird populations attempting to feed on assorted items that are assigned different caloric values. Common materials, such as dried beans and rubber bands, represent the food sources available to the birds, and multiple beak types are represented by tweezers, toothpicks, chopsticks, or spoons. At the beginning of the activity, beak types are randomly distributed and each member of each group uses one of the four beak types to pick up the "food." After each round of feeding, survivorship is tallied and individuals that did not meet their caloric needs "die." The class calculates the ratio of the surviving beak types to represent the remaining population and records the deaths in a "fossil record" that tracks the changes in the population's composition over time. Extinct beak types are removed from the activity, while surviving beak types are redistributed randomly throughout the class in proportion to the ratios found above for the next round of feeding. Based on the environment being modeled, new bags of food are distributed that represent the food sources available. Students repeat the activity through multiple rounds, collecting data and observing iterative, generational changes in bird-species populations.

The activity specifically addresses three guiding questions:

- How and why do offspring differ from their parents?
- How do environmental factors influence the change of species and populations over time?
- How does the fossil record reflect these changes?

These questions focus on disciplinary core ideas ESS2.A: Earth Materials and Systems, LS1.C: Organization for Matter and Energy Flow in Organisms, and LS2.A: Interdependent Relationships in Ecosystems from the *Next Generation Science Standards* (*NGSS*) (NGSS Lead States 2013) and lend themselves well to the system-modeling approach of the Bird Beaks lesson design.

Creating a collaborative concept map

Our prelesson concept-mapping activities occupied a single class session. As our students had not worked with concept maps before, we explained that concept maps allowed us to see how they organized their thoughts. We then completed a whole-group concept-mapping activity, focusing on the similarities and differences between reptiles and amphibians, as a warm-up exercise. This exercise helped establish our expectations for students' future work and modeled the type of negotiations required by all group members to create a collaborative product. Although group norms had been established throughout the year, student teams were closely monitored to ensure the inclusion of all group members.

After this preliminary activity, teams were given poster paper, colored markers, and a vocabulary list with terms such as *adaptation*, *gene*, *heredity*, and *variation* to serve as potential nodes for their concept maps. They were instructed to use these materials to create a concept map similar to the one we had created together, focusing on the theme of adaptation and variation. Students had autonomy to develop their map as they determined, with team members having equal voice in the negotiated product. Each group member was actively involved in constructing the map by either drawing nodes and lines or discussing the constructs of the map. Much of the value of this exercise occurred through allowing students to engage in conversation, defend their claims, and explain their understanding. By monitoring these conversations and observing the products generated, the prelesson concept map provided insight into students' prior knowledge and misconceptions related to these ideas.

Collaborative concept mapping as an instructional tool

When we first began thinking about using concept mapping for this lesson, our intent was to use the concept maps generated by student groups as a formative assessment to help direct questioning in the Bird Beaks activity. It then occurred to us that a more meaningful

Tips for implementing collaborative concept maps

- Set classroom norms for collaborative work and maintain high expectations and accountability.
- Provide terms and perhaps set a minimum number of these to use, but allow student teams to make their own selections. Do not give students too much instruction—the maps will be unique for each team.
- Keep groups small (no larger than four) and use large sheets of chart paper with different types of writing utensils for pre- and postwork.

assessment would permit students to demonstrate these connections before and after the Bird Beaks lesson to examine the effects of our instruction. As described above, students were asked to create a collaborative concept map connecting ideas related to adaptation and variation. Although related terms were provided, students were informed that the list was not exhaustive, that they might not use all of the terms, and that they should include ideas in their map that made sense to them even if they were not on the list. Student teams used markers to generate the prelesson concept map and switched to different-colored markers or pencils to make additions or corrections on the postlesson concept map.

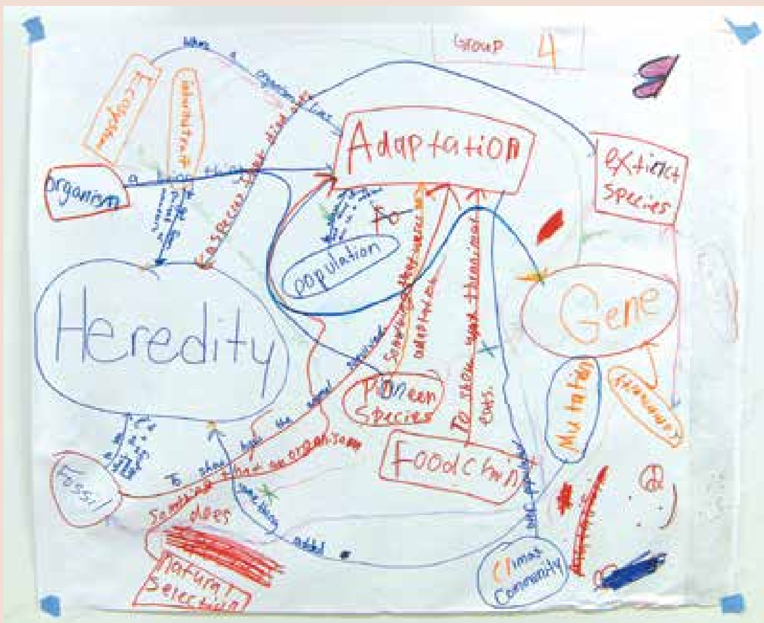
This lesson design proved effective, and we were surprised at the extent to which the concept-mapping exercises served as tools for student learning, as well as assessment. Although assessment and learning are always coupled to some degree, we explicitly noticed the value of concept mapping for the learning process in two main areas: the depth and connectedness of the content review it provided and the extent to which it encouraged all students to have a voice in the exercise. These ideas are briefly developed in the section that follows, with examples of student conversations or samples from their concept maps.

Depth and connection of review

One of the immediately apparent benefits of collaborative concept mapping was the extent to which it moved students to review both the depth and connectedness of their prior knowledge. In both the pre- and postmapping exercises, students reviewed material in multiple ways, including recalling and discussing the meaning of important terms, debating the ways in which ideas

FIGURE 1 A premapping representation of the relationship between adaptation, genes, and inherited traits

FIGURE 2 A concept map demonstrating multiple connections of significance to students



were connected, and suggesting connections to their group, which required some form of defense. In the premapping exercise, the textbook was a popular source for this arbitration, while in the postmapping exercise, more reference was made to the Bird Beaks activity. Throughout both exercises, the groups actively negotiated concepts and connections, engaged in rich discussions of the content, and explained their ideas to both small and large groups.

As an example of this activity, consider the central pathway of Figure 1, seen to the bottom left in green (pre-) and repeated on the right (post-). This map was generated by a group of three students who appeared to be disengaged and rowdy during the initial mapping exercise. However, with a prompt from the teacher to their small group to explain the green pathway, the group began to debate the role of genes in inheritance. Once the debate began in earnest, students were left to sort through their ideas with a reminder that they should be able to explain their thinking to their classmates. For the remainder of the exercise, students discussed this central idea, referring to their textbooks to support their arguments to one another.

At the end of the first class period, after the initial prelesson maps had been generated, small groups were asked to briefly justify the organization of specific branches of their maps. During this whole-group reporting, students in the group referred to above were asked to explain their mapping along the "gene" branch, and the depth of this group's review became obvious. Peter (a pseudonym) began the group's report by stating, "A gene is passed down from your parents, and that [causes] a physical adaptation." When the teacher asked him to give an example supporting his description, he traced the path from adaptation through gene to inherited trait, stating that the gene was passed down and caused inherited traits "like pointed ears." His classmates were mixed in their acceptance of his explanation, with one student citing that an adaptation had to help an animal in a specific environment, such as a tundra. The teacher then prompted Peter to explain how his mechanism might align with this description and he described the layers of skin and fat of a polar bear as a physical trait that helped the polar bear in its environment. When another student asked the group how the layers of skin and fat were passed on, another member of Peter's group, Jose (pseudonym), opened his book and read, "a gene contains the chemical instructions for inherited traits." With minimal prompting from the teacher, the class resolved their understanding of this central idea, preparing them for engagement with the Bird Beaks activity.

While Jose and Peter's group review illustrates the depth of some discussions, the group that produced Figure 2 focused more heavily on the connectedness of their ideas. Although this structure may appear disorganized, remember that it is a sense-making exercise for the students involved. Asking students to describe the connections within their small groups quickly reveals their understandings and misconceptions and allows targeted review by the teacher. This group's initial work contained five well-connected ideas that the teacher judged useful for the upcoming lesson. Although these representations are not perfect in their initial form, they serve as discussion-starters and question prompts for the instruction to follow. The flexibility in the construction of the collaborative maps permits differentiated learning by allowing students to make individually significant contributions and to construct the maps in their own way. Furthermore, information collected from the maps allows teachers to differentiate instruction as needed based on the results. An example of follow-up assignments includes the construction of a pedigree for a certain trait exhibited by the individual to address the misconceptions surrounding individuals that have a different phenotype than his siblings or parents. Another example of a follow-up assignment is having students list five traits and whether each trait helped the species survive to address the misconception that all traits are adaptations (Whitsett 2014). The teacher can promote the pedagogy of think-pair-share to allow peers to determine whether the traits helped the species survive.

As demonstrated previously, collaborative concept mapping allows all students to express their ideas. Through debate and negotiation, all students have op-

FIGURE 3 A pre-/postconcept map illustrating group consensus through negotiation

portunities to voice and justify their reasoning as a means for reaching group consensus. Teachers should use acute listening and observation skills to identify students who are reluctant to participate. To encourage participation, teachers may choose to ask students questions about content or to present their ideas to the group. However, teachers must maintain and relate high expectations for all group members; this relay should occur throughout the year as group norms and individual accountability are exercised.

Collaboration promoted a communal understanding of ideas—vetted through sources, reasoning, and peers—rather than rote acceptance from a teacher or a textbook. A further example of debate and negotiation is displayed in Figure 3. This map displays greater conceptual understanding after the Bird Beaks lesson, as multiple connections are displayed and others have been crossed out, indicating that students agreed that they failed to see a connection between concepts. Upon completion of the mapping activity, maps were displayed on the board in front of the classroom. Prior to presenting their map, students negotiated which part of the map that they would explain to the class. All students in each group took turns explaining concepts and connections; this exercise promoted individual and group accountability. To help students transfer their thoughts to written form, the teacher can conduct a whole-class discussion about the development of a rubric. Students can produce a written reflection summarizing their verbal presentation of the collaborative concept map.

Accessibility and differentiation through collaborative learning

Students who participated in the collaborative concept-mapping exercises differed markedly in ethnic and socioeconomic backgrounds and school structures. As we promote equity among diverse learners in our classrooms, a potential explanation for the success of collaborative concept mapping includes the elements of positive interdependence, personal and group accountability, and useful interaction (Johnson and Johnson 2009). Common goals and a sense of community ensure that students find the work beneficial and that all group members contribute to its product in a meaningful way. Repeated use of activities such as this one establish this sense of community and provide students an opportunity to monitor their teamwork skills. Expectations that all members of the classroom will be able to describe the concepts mapped and defend the decisions made in its creation are supported by the groups' negotiations to improve the quality of their product. To ensure positive interdependence and group accountability, members of each group could rate all members on their contribution to the activity. Teachers should monitor group dynamics and make changes based on dispositions as well as academic need. Since students need to learn to work together, groups should be repopulated with members of mixed ability every month.

Conclusion

While the greatest value to the learner occurs in engaging in a collaborative process of constructing knowledge, the greatest value to the teacher is found in the rich representations and descriptions of student thinking produced. In combination, collaborative concept mapping allows the classroom teacher to consider individual students' understanding and needs through graphic representations of student misconceptions and targeted interactions that force students to defend their thinking and elaborate on the way in which their understanding is organized. Additionally, this process allows teachers to shape their questioning and future instruction to target specific student misconceptions. The two aspects of equity—accessibility of learning opportunities for students and insight into student thinking for differentiation of instruction—are highlighted with collaborative concept mapping activities. ■

References

American Association for the Advancement of Science (AAAS). 2015. *Bird beaks. http://sciencenetlinks.com/lessons/bird-beaks.*

Forman, E.A., and C.B. Cazden. 1985. Exploring Vygotskian perspectives in education: The cognitive value of peer interaction. In *Culture, communication, and cognition: Vygotskian perspectives*, ed. J.V. Wertsch, 323–47. Cambridge, United Kingdom: Cambridge University Press.

Jenkins, J.R., L.R. Antil, S.K. Wayne, and P.F. Vadasy. 2003. How cooperative learning works for special education and remedial students. *Exceptional Children* 69 (3): 279–92.

Johnson, D.W., and R.T. Johnson. 2009. An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher* 38 (5): 365–79.

Kinchin, I.M., D.B. Hay, and A. Adams. 2000. How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. *Educational Research* 42 (1): 43–57.

Llewellyn, D. 2007. Making the most of concept maps. *Science Scope* 28 (8): 27–31.

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Piltz, H. 2004. Bird beak lab. *The Science Teacher* 71 (1): 62.

Prince, M. 2004. Does active learning work? A review of the research. *Journal of Engineering Education* 93 (3): 223–31.

Sandoval, J. 1995. Teaching in subject matter areas: Science. *Annual Review Psychology* 46 (1): 355–74.

Vanides, J., Y. Yin, M. Tomita, and M. Ruiz-Primo. 2005. Using concept maps in the science classroom. *Science Scope* 30 (5): 74–7.

Whitsett, S. 2014. The role of adaptation in biological evolution. In *Hard-to-teach biology concepts: Designing instruction aligned to the* NGSS, eds. S. Koba and A. Tweed. Arlington, VA: NSTA Press.

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The Fish Weir

A Culturally Relevant STEM Activity

by Anne Kern, Melinda A. Howard, Aimee Navickis Brasch, Fritz Fiedler, and Jillian Cadwell

Curriculum and instructional strategies that are personally meaningful are key to engaging students from diverse ethnic and cultural backgrounds. A "one size fits all" approach to curriculum development does not always translate to accessible education for many students, particularly in science, technology, engineering, and mathematics (STEM) education (Lynch 2001). Meaningful and relevant activities that demonstrate a direct application of STEM to the lives of students or their communities can increase engagement in STEM (Jarosz 2003). Specifically, students are more likely to relate to instructional activities that draw on historical references, descriptions, examples, and analogies related to their communities. For example, Native American students have been traditionally marginalized in STEM education, yet tribes throughout North America have STEM-rich histories that provide many examples upon which engaging lessons can be developed.

The Fish Weir Engineering Challenge described in this article provides one example of how cultural and historical STEM practices can be integrated into science and engineering lessons for Native American students. Although we discuss this lesson in specific context to Native American students, it can be adapted to meet other cultures or curricular goals. *Fish weirs* are an ancient technology used around the globe for centuries in places including Asia, Europe, and the Middle East. These traps were built from rocks, pilings, or wooden posts that are designed to direct the movement of fish in streams or tidal waters. While all fish weirs maintain the goal of directing and trapping fish, they are specifically designed to meet the unique conditions of their landscape and water bodies and the biology of the fish they catch. Furthermore, fish weirs are still being used today for scientific monitoring or, in some cases, for illegal fish harvests (Jha 2013). The Fish Weir Challenge activity allows students to explore how tribal communities (as well as other communities) have used engineering practices to adapt fish weirs to various environmental conditions and community needs over time.

In this lesson, students will gain a hands-on experience with engineering by designing, building, and testing a model fish weir. They also explore the rich historical and cultural traditions of this ancient method of gathering an important—and in some cases, the only—food source. This activity and its associated lessons are designed to engage students in the skills and practices aligned with the science and engineering practices (SEPs) of the *Next Generation Science Standards* (*NGSS*). An *NGSS* crosscutting concept (CC) associated with this lesson is the Influence of Science, Engineering, and Technology on Society and the Natural World. In addition, while the central focus is on learning about and using engineering skills, there are a number of *NGSS* disciplinary core ideas (DCIs) that can be integrated and extended in this lesson (see standards sidebar on p. 50; find additional standards connections with the online version of this article at *www.nsta.org/middleschool/connections.aspx*).

For Native Americans dependent on inland water bodies for food, fish weirs were used to catch large quantities of migratory fish such as salmon. By drawing on students' curiosity about their community's history, culture, and ancestors, STEM practices become evident as accessible and necessary contributors to the growth and heritage of their community. In this sense, the fish-weir activity enables students to identify with STEM by providing a culturally relevant STEM context (Cajete 1999).

The Fish Weir Engineering Challenge (Figure 1) was developed to address the strategies suggested in the *NGSS* for teaching science to students from diverse racial and ethnic backgrounds. The *NGSS* advocate that science and engineering lessons for traditionally marginalized students be "relevant to their lives and future," which can be accomplished by including "community involvement and social activism" and providing "multiple representations and multimodal experiences" (NGSS Lead States 2013, Appendix 7, case study 2). The Fish Weir Engineering Challenge aims to make science

FIGURE 1 Unit overview

Lesson	Objectives	Approximate time*
Lesson 1: Identify the Challenge	Identify the engineering challenge and define the design constraints that limit a successful design.	One class session
Lesson 2: Develop Background Knowledge	Students develop background knowledge relevant to the challenge including: introduction to fish weirs; the history, application, evolution, and size of fish captured. *Recommend tribal community speaker to provide this lesson.*	One to two class sessions
Lesson 3: Plan	Students work collaboratively in teams to brainstorm multiple fish weir designs, evaluate the pros and cons of possible designs, and develop a conceptual plan (drawing) of their design.	Two to three class sessions
Lesson 4: Implement	Student teams build a model size fish weir model.	Two to three class sessions
Lesson 5: Test and Evaluate	Test, Evaluate, and Rebuild/Improve fish weir model including; test model to determine if design constraints are met, evaluate the strengths and weaknesses of the solution, improve the design as needed, and retest. The process is repeated until the model is successful. Students draw their "as built" design and provide an explanation of how and why their design works.	Two to three class sessions

*One class session = 30 minutes; 4 to 6 hours to complete unit and engineering relevant for Native American students by acknowledging the science and engineering practices of their ancestors, providing a relatable, hands-on engineering experience and inviting the community to participate in sharing knowledge and teaching lessons.

Lesson 1: Determine the challenge

Imagine a stream so crowded with fish that you could use their backs as steppingstones to cross! Imagine it being like this only a few weeks out of the year when the fish return from their ocean habitat to lay their eggs in the stream and die. What if you and your community ate so much fish that it made up at least half of your diet throughout the year? Imagine having no grocery stores, only the land around you to provide your food. How could you gather enough fish during this short window of time to feed everyone in the community, young and old?

The scenario presented above introduces students to the Fish Weir Engineering Challenge. Students are first asked to think of the kinds of foods their ancestors may have eaten. They should note that in the "old times," there were no grocery stores or restaurants where they could grab a quick meal. They are then asked to consider ways they could gather enough food to feed not just their family, but also their entire community. They should brainstorm answers to the question, "How could you capture the most fish in a limited timeframe?" It is not uncommon for students to propose a "hook-n'-reel" method; however, they quickly determine that this is not a very efficient method. This conclusion provides the opportunity to introduce students to the technology their ancestors used: fish weirs, which were engineered to efficiently capture a vitally important food staple. In North American river systems, fish weirs were used to capture migratory fish during their seasonal spawning periods. Of particular importance were anadromous fish, such as Pacific salmon, which annually swim upstream from their ocean habitats to their natal tributaries, where they spawn and die. The only opportunity to capture these (adult) fish in a river is during this migration period, generally spanning a period of only a few weeks.

After defining the challenge (i.e., design and build a model fish weir that will span a model stream and capture model fish), students are guided through the engineering-design process.

Lesson 2: Develop background knowledge

In this lesson, students develop background knowledge by familiarizing themselves with the history, construction, and use of fish weirs. Teachers are encouraged to compile resources for students to research the various construction elements of fish-weir design and uses over time (see Resources for suggested books, websites, and videos). Photos and diagrams of historical and modern fish weirs provide students visual interpretations of weirs' various designs and uses. These images offer inspiration and ideas to students as they enter the planning phase of the activity. Students should note which materials are used, how the materials are used in construction, and how the weir is placed in the water.

Fish-weir design is diverse in that they are adaptable to different landscapes, waterways, and targeted fish species. According to the type, size, and hydrological patterns of the water body, as well as the behavior and size of the fish species to be caught, weirs were engineered to guide and trap fish to meet a community's need for food (see Figure 2 for a fish weir, circa 1866). A key feature of fish weirs is that they direct movement of fish into a trap based on the directional movement of the species's seasonal migration. For example, as migratory salmon are returning to their spawning grounds, they swim upstream. Therefore, the weirs are placed in a manner that blocks their upstream passage. At this point, possible content-teaching extensions could be to discuss the lifecycles of salmon, as well as the movement of fish as a function of the body type and form (e.g., fish are able to swim with little resistance due to a fusiform body shape) (*NGSS* disciplinary core idea LS1.A; NGSS Lead States 2013).

Depending on the customs and protocol for harvesting salmon set by each community, fish weirs were erected and left in place until it was determined that enough fish had been harvested to feed everyone. Weirs were also constructed with gaps to allow some fish to escape and were often taken down at night until fishing resumed the next day. These practices are important to note because they allowed for sustainable harvests of salmon populations by ensuring at least half of the fish reach the spawning beds. In general, commercial fishing practices are not concerned about the sustainability and maintenance of fish life cycles; therefore, fish populations were decimated (Montgomery 2004). That, combined with migration-route obstruction by dams and various environmental impairments, resulted in the loss of migrating salmon in many inland streams. Therefore, the traditional use of fish weirs has largely been eradicated. If possible, we recommend inviting a knowledgeable tribal member to speak to the class about the customs and ceremonies surrounding these protocols, as this person can provide a rich background in the traditional ecological knowledge and sustainable management of salmon practiced by the tribe.

Today, fish weirs are used to manage and monitor fish populations (Figure 3). Although they may be constructed out of modern materials such as steel, their basic design mimics those of ancient fish weirs. Scientists and engineers working for tribal entities draw on the knowledge and experiences of elders and community members to understand native fish in their local streams and gain new understandings using data from modern weirs. This integrated knowledge is used to aid in the regulation, maintenance, and restoration of local water bodies and fish populations. If possible, these scientists and engineers may be invited to the classroom to give presentations to students on how the rich histories and culture of Native Americans are still used in today's science and engineering practices.

FIGURE 2 Salmon weir at Quamichan Village on the Cowichan River, Vancouver Island, ca. 1866

WIKIMEDIA COMMONS

FIGURE 3 Example of a modern fish weir

BACK TO THE EARTH ARCHIVES

Lesson 3: Plan

In this lesson, students are directed to work in groups to draw a diagram of the fish weir they intend to build and eventually test in a model stream. The student groups may be formed in any way (e.g., random selection, formal groupings, existing cooperative groups) so there are no more than four students to a group. Students are shown examples of the various building materials and supplies they will be able to use (Figure 4). Students collaborate to draw one diagram of their conceptual design on a plan sheet (Figure 5) or plain graph paper. They are asked to consider various constraints that should be included in the specific designs of their models (*NGSS* disciplinary core idea ETS1.B; NGSS Lead States 2013), including the depth and width of the model stream, as well as the width of the model fish they aim to capture. Students might need assistance to understand which dimension of the fish should be measured. Water should be able to flow through the fish-weir structure, but not allow fish to pass.

Before proceeding to the next lesson, students should be given opportunities to discuss their plan with the teacher or other review partner (e.g., another student group, visiting engineer, or community member) for completeness. This mimics the process of "peer review" common in engineering practice. Students' plans should include a list of materials they intend to use and notation of the design criteria (i.e., length and height of weir, width between the slats of their fish-weir model). Students can also use this opportunity to ask questions or vet concerns.

Lesson 4: Implement

Student groups next use their plan as a guide to build a model fish weir. They can use various materials to build their models such as craft sticks (smooth or notched), dowels, toothpicks, twine, pipe cleaners, and string (Figure 5). We found that pipe cleaners worked particularly well as a binder, as they are easy to manipulate and handle. Students should frequently be reminded to follow their plan sheets, as this is an important practice in the engineering-design process.

Students generally find the building aspect of the lesson to be both rewarding and frustrating. For example, if students want to build a tripod structure as part of their weir design, they may find it difficult to bind the dowels near the peak and maintain an upright position.

Teachers may want to help students brainstorm ways of overcoming the challenges faced and encourage teamwork. Engineering requires perseverance, creativity, and collaboration to turn a plan into a working model (Figure 6).

Some precautions and warnings should be considered before implementing the Fish Weir Engineering challenge. Due to the collaborative and hands-on nature of the activity, students should review and follow safety procedures for use of scissors, sharp objects, and other materials. Students should wear safety glasses during the construction and testing lessons. Due to the "wet" nature of this challenge, assuring that plenty of towels and waterproof traps are on hand will make clean-up and accidents more manageable.

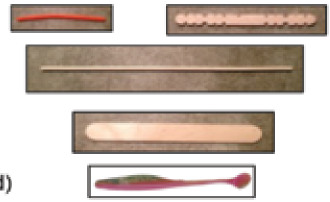
Lesson 5: Test and evaluate

Next, students test how well their model works and consider if modifications might improve it. In our example, students test their fish weir in a flowing model stream (Figure 7). A model stream can be constructed from a commercially available, plastic stream table (see Resources) or large tray. A household aquarium water pump and five-gallon bucket are used to recirculate water through the model. The output water flow should be adjusted so that there is a steady but light flow of water in the stream to allow the model fish to "swim." For the "swimming" fish, we use common fishing lures, with the hook removed (Figure 7).

Although we describe salmon as swimming upstream, the model fish in this activity are passive and thus must "swim" with the current. Students place their models in the stream and first analyze the overall fit, stability, and durability of their weir, and then determine how effective the weir is at capturing the model fish. Students are provided opportunities to assess needed improvements and redesign their models for further testing. A success-

FIGURE 4 Equipment and supplies for fish weir engineering activity

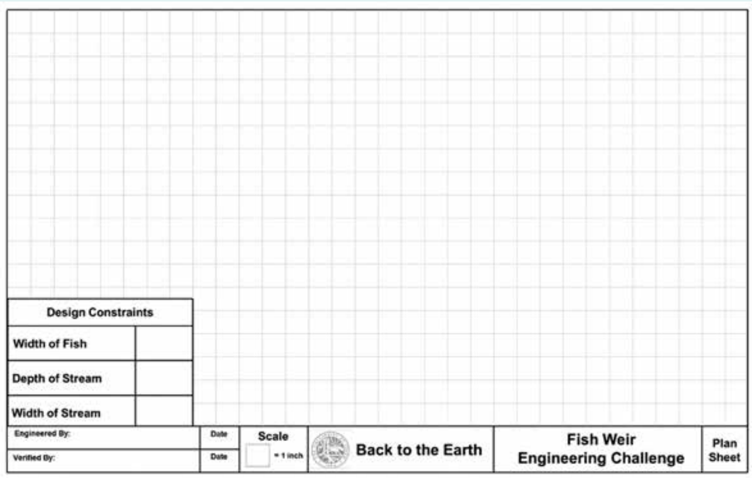
- Pipe cleaners
- Craft sticks
  - Notched
  - Wide
  - Long (12 in.)
- 12 in. dowel
- 4 in. rubber fishing lure (e.g., sea shad)



- Table for simulated stream (48 in. ×12 in. × 2 in.)
- Small garden pond pump
- Plastic spring clamps (to attach the tubing to the table)
- Plastic barb fittings (same size as tubing, used for connecting tubing together)
- Corrugated tubing (same diameter as pump in flow connections)
- Valve (same diameter as tubing)
- Window-cleaning bucket (as wide as the stream discharge, but preferably as wide as the stream)
- Tarp
- Towels

SOURCE: BACK TO THE EARTH ARCHIVES

FIGURE 5 Fish weir engineering plan sheet

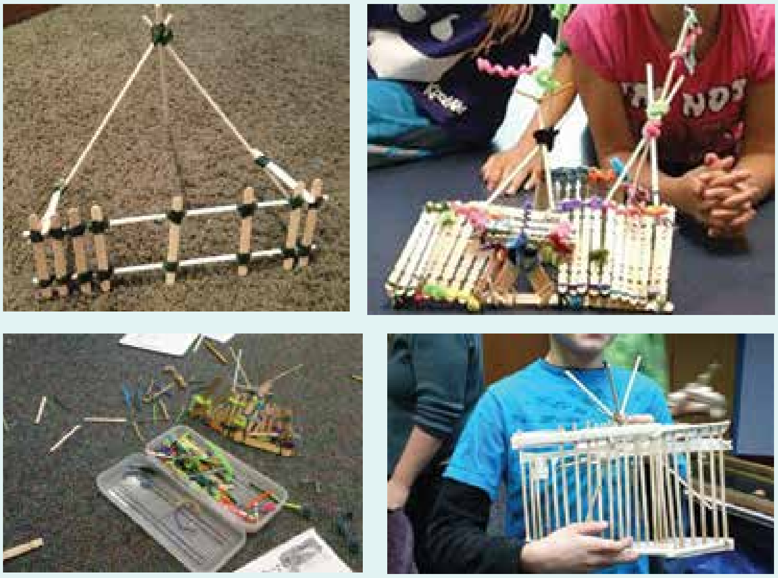


BACK TO THE EARTH ARCHIVES

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

Standard MS-ETS1: Engineering Design *www.nextgenscience.org/msets1-engineering-design*		
Performance Expectation The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectation listed below. MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.		
Dimension	**Name or *NGSS* code/citation**	**Matching student task or question taken from the activity**
Science and Engineering Practices	Constructing Explanations and Designing Solutions	Students design a device to capture the most fish to feed the community.
Disciplinary Core Ideas	ETS1.B: Developing Possible Solutions • A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. ETS1.C: Optimizing the Design Solution • The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. *Note:* Other science *NGSS* disciplinary core ideas, such as MS-LS1.A: Form and Function, MS-ESS3.A: Natural Resources, and MS-ESS3.C: Human Impacts one Earth Systems (NGSS Lead States 2013), can be addressed throughout the activity.	Students work collaboratively in teams to brainstorm multiple fish-weir designs, evaluate the pros and cons of possible designs, and develop a conceptual plan (drawing) of their design. Students test, evaluate, and rebuild/improve fish-weir models, following steps including: test the model to determine if design constraints are met, evaluate the strengths and weaknesses of the solution, improve the design as needed, and retest.
Crosscutting Concept	Influence of Science, Engineering, and Technology on Society and the Natural World	Tribal elders can be invited to speak to students about the traditional ecological knowledge and sustainable management of fish practiced by Native Americans. Scientists and engineers working for tribal entities can discuss how history and native culture are still used in the regulation, maintenance, and restoration of local water bodies and fish populations.

FIGURE 6 Sample of fish weir models



PHOTOS COURTESY OF THE AUTHORS

ful fish weir model would stand upright in the model stream for an extended length of time and capture most of the "swimming" fish. As noted above, tribal communities highly value the sustainability of resources; thus, by allowing some fish to swim though the fish weir, tribal members are ensuring that the fish population will be sustained. Therefore, after students master the initial successful design, they may refine their model to accommodate more sustainable practices.

Students gain insight and learn from their peers by sharing and comparing their fish-weir designs at the end of this activity. In this whole-class discussion, teachers ask students to discuss why and how their models work and how they might improve their models to accommodate a changing environment or situation (i.e., faster stream, to catch different aquatic fauna and animals). This discussion reinforces the iterative process of engineering to modify designs according to changing needs or conditions.

Once students have completed the challenge and reflective discussion, they should draw an "as built" diagram of their final model, labeling significant features and providing a list of materials used. They should use a blank "Engineering Plan Sheet" (Figure 6) to draw these final designs. Engineers use "as built" drawings as an initial template for a blueprint design and scale-up of the models that will become structures. Students can also provide a written narrative describing the construction and materials of their models, as well as provide an explanation and justification for how their fish weir works. These activities provide useful assessment opportunities for the Fish Weir Challenge activity the enable links to the *Common Core State Standards* for writing as well as mathematics (see additional standards information with the online version of this article).

While the Fish Weir Engineering Challenge addresses the NGSS engineering and technology standards, specifically MS-ETS1: Engineering Design (NGSS Lead States 2013), numerous connections exist that extend this activity to other science disciplines, as well as other content areas. Other science NGSS DCIs, such as MS-LS1.A: Form and Function, MS-ESS3.A: Natural Resources, and MS-ESS3.C: Human Impacts one Earth Systems (NGSS Lead States 2013), can be addressed throughout the activity. Extension can also be made to basic physical science concepts, such as velocity, acceleration, and force and motion, as related to water flow and current. Other extensions exist linking the Fish Weir activity to content areas such as social studies, history, and language.

FIGURE 7 Students testing model fish weir in a flowing model stream

PHOTOS COURTESY OF THE AUTHORS

Conclusion

Although the Fish Weir Engineering Challenge was designed to specifically address engineering, science, and mathematics disciplines, we found this activity also provides fruitful ways to involve community members in cultivating student knowledge through their rich and honored history. For example, the Fish Weir Engineering Challenge led our students to build a full-scale fish weir with members of the community using natural materials (Figure 8). This weir was placed in a community stream and monitored for its effectiveness in capturing fish. In this respect, the activity was more than a valuable school lesson: It became a shared community experience. Several elders commented that it was the first time in over 100 years that the community worked together to build and place a traditional fish weir in their waters.

The Fish Weir Engineering Challenge provides students a culturally relevant experience for learning basic science content and crosscutting concepts (see standards sidebar). By designing and building models, students engage in science and engineering in ways that are steeped in their own history and culture. This activity allows students to experience STEM concepts that are relevant to their ancestors' lives and also to the lives of modern-day people. ■

FIGURE 8 Fish weir designed and built by students and community

PHOTOS COURTESY OF THE AUTHORS

Acknowledgments

Thank you to our partners for their ideas, direction, and guidance on the Fish Weir Engineering Challenge, especially the Spokane Tribe of Indians and the Coeur d'Alene Tribe. The material is based on work supported by the National Science Foundation under Grant No. 1139657. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF.

References

Cajete, G.A. 1999. *Igniting the sparkle: An Indigenous science education model.* Skyland, NC: Kivaki Press.

Jarosz, J. 2003. Engineering for Native Americans. *Winds of Change* 18 (3): 52–57.

Jha, A. *International Science Times.* 2013. Google Earth Images Help Researchers Identify Severe Persian Gulf Overfishing; Iran and Bahrain Violate U.N. Fishing Law. Nov. 27. *www.isciencetimes.com/articles/6414/20131127/google-earth-overfishing-persian-gulf-iran-bahrain-united-nations-law.htm.*

Lynch, S. 2001. "Science for All" is not equal to "One Size Fits All": Linguistic and cultural diversity and science education reform. *Journal of Research in Science Teaching* 38 (5): 622–27.

Montgomery, D.R. 2004. *King of fish: The thousand-year run of salmon.* Boulder, CO: Basic Books.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Resources

Ancient Fishweir Project—*www.fishweir.org*

Connaway, J.M. 2007. *Fishweirs: A world perspective with emphasis on the fishweirs of Mississippi.* Jackson, MS: Mississippi Department of Archives and History.

European archaeology abroad: Global settings, comparative perspectives—*www.sidestone.com/library/european-archaeology-abroad*

Fish weir: Ancient fishing tool of hunter-gatherers—*http://archaeology.about.com/od/fterms/g/fishweir.htm*

Fish weirs in Canada—*www.cbc.ca/news/technology/earliest-sign-of-human-habitation-in-canada-may-have-been-found-1.2775151*

Plastic stream tables—*www.sensoryedge.com*

Ross, J.A. 2011. *The Spokan Indians.* Spokane, WA: Michael J. Ross.

Royal fishing weir (fish trap)—*www.coflein.gov.uk/en/site/303159/details/RHOS+FYNACH+WEIR,+RHOS+ON+SEA*

TEDx Talk: In the place we now call Boston—*www.youtube.com/watch?v=ESlvZDOCUeU*

Pristine Native American fish weir (trap)—*www.youtube.com/watch?v=U5-dAfFv048*

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Science Meets Engineering

Applying the Design Process to Monitor Leatherback Turtle Hatchlings

by Megan Lancaster and Gail Jones

The distinction of being the largest living marine reptile goes to the leatherback turtle. These endangered turtles spend the majority of their lives at sea, although the females will come to land to lay their eggs. Scientists have discovered several unique characteristics about the hatching of these eggs, one of which is the environmental influence on sex determination at egg hatching. If the temperature during the incubation time (roughly 60 days) is above 29.4°C and the humidity is relatively low, then more developing turtles become females. Alternatively, if the temperature is below 29.4°C with a relatively high humidity during the incubation period, more male turtles are born. Ideally, a ratio of half male and half female hatchlings would maintain a stable population.

Global warming has the potential to dramatically alter the reproductive success of the leatherback turtle. These amazing turtles lay their eggs on beaches, and the eggs are susceptible to climate change that results in increases in temperature and extended periods of drought. At extreme temperatures, the hatchlings either do not hatch or the sex ratio of hatchlings is disproportionate. In order to monitor the population growth of leatherback turtles, biologists need an integrated sensor that can monitor temperature and humidity and predict hatchling sex. A monitor that predicts the hatchlings' sex can alert biologists to potential problems (such as a nest having all male turtles). The ability to predict the hatchling success rates allows biologists to intervene if needed to save a nest and to ensure the long-term health of the species.

To address this problem of predicting turtle-hatchling sex ratios, students apply the engineering-design process (Figure 1) to create a circuit design that can be used with sensors to analyze environmental data and predict the sex of hatchling leatherback turtles based on temperature and humidity parameters. The activity takes students step-by-step through the engineering-design process to generate possible solutions to this real-world problem (Figure 1).

This activity was done in a middle school science classroom with students in seventh and eighth grade. Within our life-science curriculum, we studied how temperature and humidity can affect different aspects of ecology and biology, particularly with the leatherback sea turtle. We saw a unique opportunity to share the fascinating nature of sea turtle gender determination while introducing students to basic mathematical and engineering principles used in everyday life.

The engineering-design process

The engineering-design process guides students through five cyclical steps: (1) Contextualize the nature of leatherback sea turtles, (2) Identify the problem, (3) Brainstorm possible solutions, (4) Build, test, and evaluate a possible design, and (5) Share possible solutions. Steps 1 and 2 can be tackled in four 60-minute class periods. Steps 4 to 6 may span four to seven 60-minute class periods depending on whether students construct the circuits or just brainstorm possibilities. Our students had varying experience and knowledge regarding leatherback sea turtles, the effect of temperature and humidity on the gender of hatchlings, and what engineering can contribute to the field of life science. Students were not expected to know anything additional before the start of this activity.

Materials (per partner group)

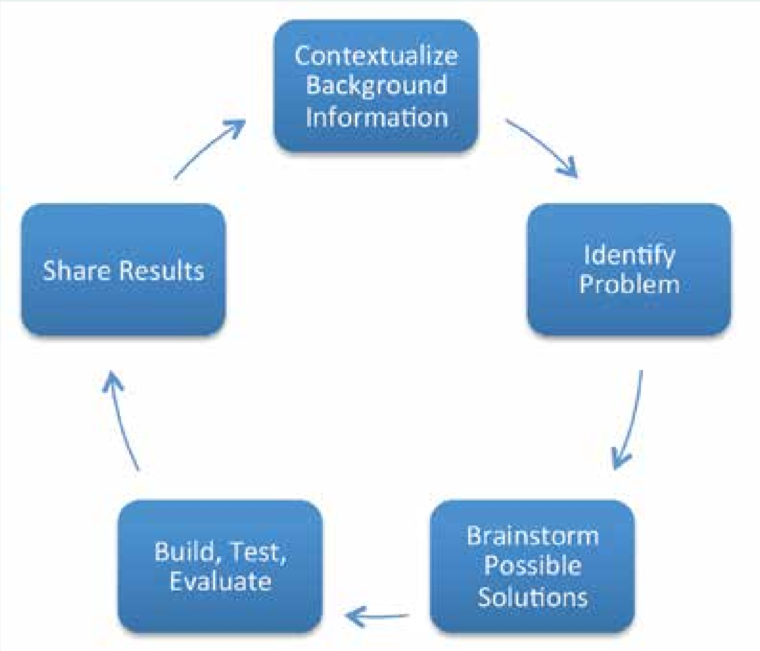
- 1 solderless breadboard (400 contacts)
- 1 74HC08 AND Gate
- 1 74HC32 OR Gate
- 1 74LS04 NOT Gate
- 1 red LED
- 1 blue LED
- 2 330 ohm resistors
- 1 9V battery
- 1 9V battery holder
- Plenty of jumper wires

Step 1: Contextualize the nature of leatherback sea turtles

This activity begins with a video clip showing a sea turtle heading toward the sea after hatching (see Resources). Using one class period, students are asked, "What was the gender of these sea turtles?" Answers may vary, but overwhelmingly students cannot say for certain. A follow-up question is asked: "What factors at hatching determine or influence the sex of a sea turtle?" Students then divide into partners for a "think, pair, share" formative-assessment exercise. In this exercise, students are asked to think about the factors involved in determining the sex of a sea turtle. Students are asked to share their insight with a partner and reflect on their partner's contributions. Answers are generally suggestive of a sea turtle's niche or habitat being the primary influence of gender determination. At the end of the discussion, humidity and temperature are introduced as the primary factors of determining sex at hatching.

Working in the same partnership, students are asked to read an article found on the National Geo-

FIGURE 1 The engineering-design-process cycle

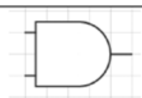
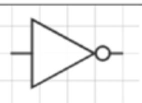
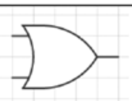


graphic website titled, "Leatherback Sea Turtle" (see Resources). After reading the article, students work with their teams to identify the important characteristics of the leatherback turtle's biology. Each group documents key findings on a whiteboard and shares these findings with the class. This preactivity can be completed in one or two class periods.

Step 2: Identify the problem

After building a better understanding of the leatherback sea turtle, students are encouraged to ask critical questions to identify the problem of determining sex at hatching during the next class. The second day, we revisit the discussion questions from the previous class and review the hypothesized factors involved in determining the sex of a leatherback sea turtle at hatching. At this point, I reintroduce the concept of temperature and humidity as primary factors that influence sex determination. As a class (and with some guidance from the teacher), students determine that a sensor model is needed that can predict sex at hatching for the leatherback sea turtle. The task is for students to develop a model to address these temperature and humidity parameters using logic gates. One or two class periods should be allotted for introducing circuitry components and a discussion of the role that truth tables (see step 3) can play in predicting the output when given certain inputs for the logic gate. Additional details can be found in the student activity handout and are described later in the article.

FIGURE 2 Circuit symbols for AND, NOT, and OR logic gates

Logic gate	Circuit symbol
AND gate	
NOT gate	
OR gate	

Step 3: Brainstorm possible solutions

In the development process of this model, students begin by creating a truth table. A *truth table* is a chart of sequential combinations of binary inputs and their corresponding output. The inputs for the table will be either a 1 or 0. A 1 input indicates that temperature is above 29.4°C or that humidity is high (above 55%). A 0 input indicates that the temperature is below 29.4°C or that the humidity is low (below 55%). In constructing the truth table, students become familiar with counting in a base 2 system. Students first explore AND and OR logic with the help of the truth table. Students may not have had any prior experience with working in a base 2 system or with truth tables. We did not dive heavily into the math involved in converting to a base 2 system, although this would be a great extension to this activity. We focused primarily on getting students familiar with using 1s and 0s to represent a construct.

The third class period was spent getting students familiar with logic gate truth tables and their corresponding schematic. The teacher should draw all of the schematics and label them AND, OR, and NOT on the board. The schematics for all of the logic gates are in Figure 2. Underneath each schematic, draw a truth table to be filled in to model this new information. We introduced the AND gate using a concept that is familiar to everyone, a car alarm. We explained that the car alarm would only go off if two things were present: (1) the door is open and (2) the alarm system is on. If the door is closed, but the alarm system is on, then the car alarm would not sound. If the car door is open, but the alarm system is not engaged, then the car alarm would not sound. We can represent the car door being open or closed using 1 or 0. If the car door is open, it would have an input of 1. If the car door is closed, it would have an input of 0. Similarly, if the car alarm is engaged, it would have an input of 1. If the car alarm is disengaged, it would have an input of 0. Therefore, the only way that the car alarm will go off (output of 1) is when two inputs of 1 are given to the circuit. This can be seen through an AND gate truth table (Figure 3). Students should fill out the corresponding truth table for the AND gate and draw the schematic in their activity handout.

In groups, students are asked to use what they know about an OR situation (based on what they've learned about an AND situation) to fill out the OR truth table and draw the schematic on their handout. The OR truth table can be seen in Figure 4. The NOT gate is a little tricky and not very intuitive. We walk students through this truth table and draw the schematic in their student handout. There are only two inputs for this gate. The output is always the opposite of the input. So if the input is 1, the output is 0. If the input is 0, the output is 1.The NOT truth table can be seen in Figure 5. Many students find it difficult to think about 0s and 1s out of their typical mathematical context. It is important to remind students that these 0s and 1s are indicative of "on" or "off," meaning that the constraint is either present or it is not. Engineers use truth tables as they design a range of things, from sensors to systems. Helping students understand and see the value of truth tables helps them develop metacognitive skills necessary for problem solving and critical thinking.

The fourth and fifth class periods are spent investigating each logic gate in a circuit. The concept of a circuit was a new one for all of my students. While they had explored series and parallel circuitry, they had no experience building a circuit on a breadboard. Working with partners, students construct three different circuits based on the diagram shown in Figure 6. This is a simple circuit powered by a 9V battery. Students were instructed to mimic this design on their breadboards using both the image and the corresponding schematics for AND, OR, and NOT gates (Figures 7, 8, and 9, respectively). There are three things to keep in mind as students are constructing these circuits: (1) Always have a resistor in front of the LED, (2) Be careful not

FIGURE 3 Student example of AND logic gate truth table for receiving text messages on a cell phone

Input A: Door (0 is closed; 1 is open)	Input B: Alarm active (0 is disengaged; 1 is engaged)	Outcome (0 is alarm will not sound; 1 is alarm will sound)
0	0	0
0	1	0
1	0	0
1	1	1

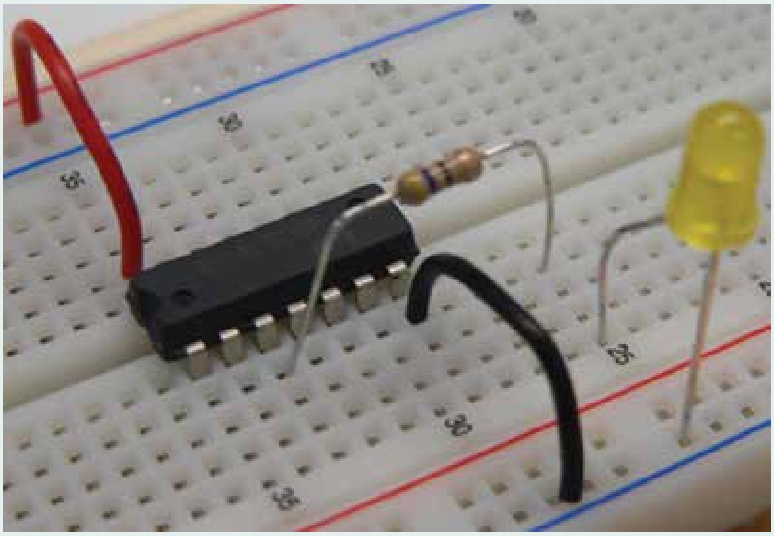
FIGURE 4 OR truth table

Input A	Input B	Outcome
0	0	0
0	1	1
1	0	1
1	1	1

FIGURE 5 NOT truth table

Input	Outcome
0	1
1	0

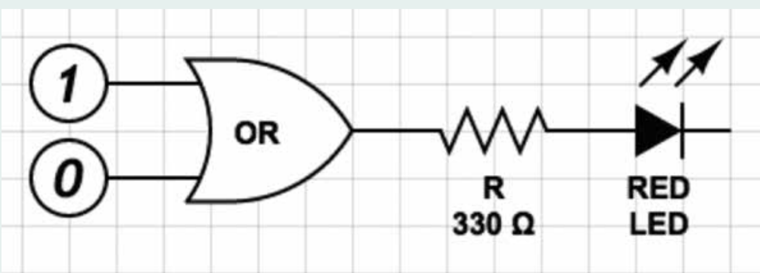
FIGURE 6 Breadboard construction of AND, OR, and NOT gates



(IMAGE OBTAINED FROM: *HTTP://D4WEB.NET/STHS/TEJ/U03LOGICELECTRONICS/A03LOGIC/IMAGES/P1140132.JPG*)

FIGURE 7 Schematic of AND logic gates

FIGURE 8 Schematic of OR logic gates



to break a pin when putting the logic gates in the breadboard , and (3) Be mindful of the orientation of the logic gate and the pin numbers. The diagrams that show what each pin does for the logic gates are shown in Figures 10, 11, and 12. The pin-outs show that you should connect pin 14 to power (red) and pin 7 to ground (black). Each chip has multiple AND, OR, and NOT gates. For example, if you want to use an AND gate on the 74HC08 chip, you would connect an input (either 0 or 1) to pins 1 and 2. To view the output, you would connect a resistor and an LED to pin 3. If the LED lights, the output is 1. If the LED does not light, the output is 0. Students, while working in pairs, should test each gate for all of the inputs found in their truth tables and document their outputs in the student activity handout. The output would be whether the LED turned on or off.

The sixth class period is spent taking students' newly learned knowledge of circuits and logic gates and applying this to the previously defined problem: How can we use a sensor to model sex determination of the leatherback sea turtle? After becoming comfortable with AND, NOT, and OR logic, students work in pairs to construct a truth table to represent the leatherback sea turtle hatchling problem based on the information gathered in Steps 1, 2, and 3 of the engineering-design process. For our sensor-model truth table, there are two binary inputs and one output. With the leatherback sea turtle hatchling problem of developing a sensor to predict sex determination at hatching, a temperature below 29.4°C is considered to be 0, and above 29.4°C is 1, since a male is more likely to hatch. Similarly, low humidity below 55% is represented by a 0 while high humidity above 55% will be represented by a 1, since a female is likely to hatch. Any other combinations of input will not promote egg hatching, so the outcome is 0. As a class, we worked through each possible input scenario for both temper-

FIGURE 9 Schematic of NOT logic gate

ature and humidity to decipher whether or not the hatchling will be male or female.

Step 4: Build/test/evaluate/design

In this investigation, students use a truth table to construct their own explanations and design a model solution. Based on the truth table constructed in the previous class period, students brainstorm with their partners to predict which logic gates should be used for our sensor model (Figure 13).

In the eighth class, we show students one possible solution for our model-circuit schematic for both male and female turtle hatchling sex outcomes (Figure 14). When given an input of 1-0, a red LED on the sensor will light up to indicate that a female hatchling is likely. If the input is reversed to 0-1, a blue LED will light up to indicate that a male hatchling is likely. Any other input combination will not light up the LED. These alternate conditions do not predict the sex of a hatchling, making the probability of a female hatchling equal to the probability of a male hatchling.

In this circuit activity, most of our students arrived at the same outcome through entirely different means. One of the key things emphasized in engineering is creativity, and this activity allows students to tap into their creative potential. With a basic understand of AND, OR, and NOT gates, students and teachers can create this circuit to predict the sex determination outcome of leatherback turtle egg hatchlings. We emphasized that there are several ways to model this sensor and that no way is better than any other way. In our activity, we modeled one possible circuit for our sensor, but there are many other ways that this could be modeled. Using students' newfound knowledge with logic gates and truth tables, we challenged

FIGURE 10 Pin-out of AND logic gate

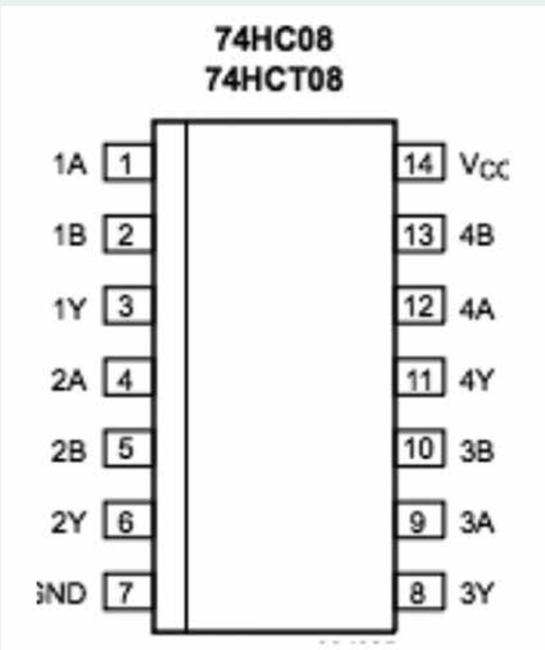


FIGURE 11 Pin-out of OR logic gate

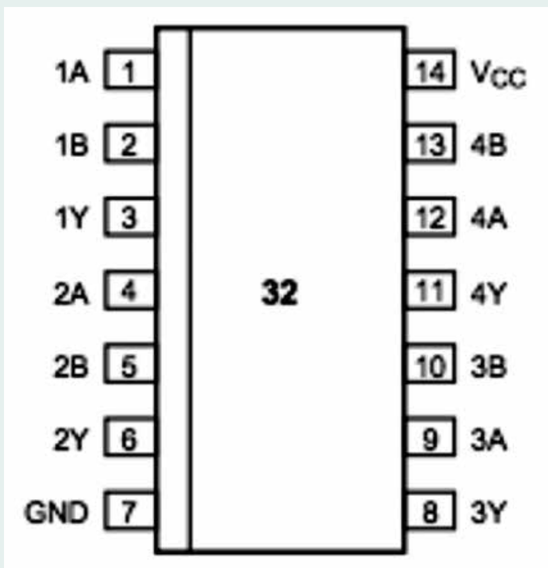


FIGURE 12 Pin-out of NOT logic gate

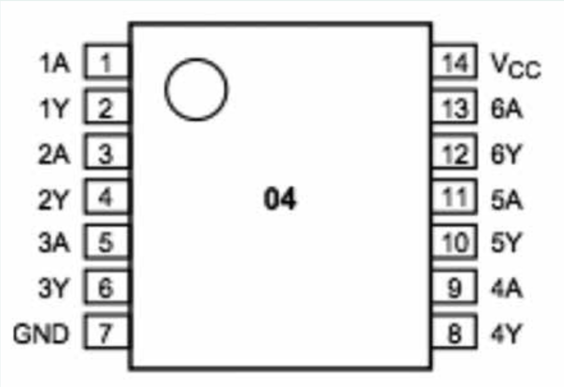


FIGURE 13 Students' construction of the leatherback sea turtle hatchling sex problem

Temperature	Humidity	Outcome (hatchling sex)
0	0	0
0	1	1 (male)
1	0	1 (female)
1	1	0

our students to design another solution for this sensor as an extension activity.

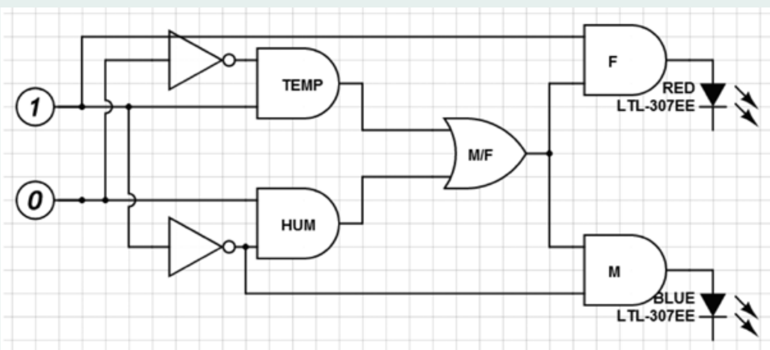
Step 5: Share solutions

After all of the groups generate a possible solution to address the design challenge of modeling a sensor to predict turtle hatchling sex ratios, they present their results to the class. Students are encouraged to ask other groups how they navigated the engineering-design process to arrive at their final solution. Each group is also asked how it would change its design if given the opportunity to progress through the design process again. This discussion serves as an informal, postactivity assessment to gauge how much students learned about engineering and its value to science. We concluded this lesson by showing a short clip on how scientists are using sensors to predict when sea turtles hatch so they can safely guide them to sea (see "Nerds Without Borders" video in Resources).

Assessment

There are numerous opportunities for assessment with this circuit-design activity. Our main objective was to teach the engineering-design process with the help of a real-life science application. After completing the activity, students had a growing understanding of how the engineering design process works. This was shown through the successful progression of each of the steps of engineering as well as through our postassessment discussion of the activity. Before the activity, many students did not realize that engineering takes place through systematic steps. One of our students commented, "See, I can't even get this to work. How am I supposed to be an engineer?" This comment opened up a class discussion about how in engineering, failure is not only OK, it is expected. By the end of the first progression through the engineering-design process, students were able to formulate additional ideas and potential prototypes to test if they were to do another cycle progression. The grading rubric used to assess the work of each partner group is shown in Figure 15, which can be found with the online version of this article at *www.nsta.org/middleschool/connections.aspx*.

FIGURE 14 Teacher-created example of a circuit design addressing the leatherback sea turtle hatchling problem



Conclusion

This activity is flexible and could be adjusted based on a teacher's goals

STUDENT ACTIVITY WORKSHEET

Introduction
Scientists and engineers use sensors to determine temperature and humidity in a variety of contexts, particularly atmospheric conditions. These sensors currently exist, but are not integrated in a model to allow scientists to predict the sex of turtle hatchlings.

Research problem:

What two factors influence sex determination at sea turtle hatching?
(1)
(2)

Logic gates
A car alarm would only go off if two things were present: The door is open and the alarm system is on. Fill in the table with the appropriate outputs as given by your teacher.

AND truth table

Input A	*Input B*	*Output*
0	*0*	
0	*1*	
1	*0*	
1	*1*	

AND schematic

Now it's your turn. Think about this: You can rake the leaves OR clean up your room to get an allowance. Try to fill out the OR truth table based on this example.

OR truth table

Input A	*Input B*	*Output*
0	*0*	
0	*1*	
1	*0*	
1	*1*	

OR schematic

A NOT gate changes the input from either a 1 to a 0 or a 0 to a 1. You can think of this as "It's NOT a 1, it's a 0!)

NOT truth table

Input	*Output*
0	
1	

NOT schematic

What two numbers serve as inputs for a logic gate?
________ and __________

Building logic gate circuits
These images show exactly how you should set up your logic gate on your breadboard. Take a close look at where each of the wires go. Also, take a look at each of the logic gate pin-outs to ensure that you place the wires in the right place. You should put a wire from pin 14 to your red (power) row on your breadboard. You should put a wire from pin 7 to your black (ground) row on your breadboard. The other pins may vary. Remember that you're looking for two inputs and an output (1A, 1B, 1Y) for the AND and OR gate and one input and an output (1A, 1Y) for the NOT gate (see Figures 6, 7, 8, 9, 10, 11, and 12).

For each input, place your input wire on the (red) power row for a 1 and input wire on the (black) ground row for 0. You should always have both inputs either on 1 or 0. Please do not leave one disconnected when you're viewing your output LED. You will get an error result (i.e., your LED may falsely light or falsely turn off). Once both of your input wires are connected to either 0 or 1, look at your LED. If the LED is lit, your output is 1. If your LED is not lit, your output is 0. Go through each of the combinations outlined in your truth table (four

STUDENT ACTIVITY WORKSHEET *(continued)*

combinations each for AND and OR, two combinations for NOT). Mark a check or an "x" by each of the outputs as you check your circuit.

If it is an "x," why do you think you got that result?

Designing a sensor to model sex determination

For our sensor-model truth table, there are two binary inputs and one output. With the leatherback sea turtle–hatchling problem, a temperature below 29.4°C is considered to be 0, and above 29.4°C is 1, since a male is more likely to hatch. Similarly, low humidity is represented by a 0 while high humidity is represented by a 1, since a female is likely to hatch. Any other combinations of input will not promote egg hatching, so the outcome is 0.

Now it's time to take our knowledge of circuit design and logic gates and really put it to the test. Let's start by constructing a truth table of what we want to model for our sex-determination sensor.

Sensor-model truth table

Input A (temperature)	Input B (humidity)	Outcome (male or female)
0	0	
0	1	
1	0	
1	1	

Let's design our sensor using the schematic below. Remember to take your time.

What component is always placed in front of an LED?

Revising the design

With your partner, try and come up with another design using an AND, OR, and NOT gate that will fulfill our sensor-model truth table.

How could you test this model?

Discussion

1. What did you like about the engineering-design process? What did you not like?
2. What would you do differently for the next iteration of the cyclical steps of the design process?
3 List three things that you learned from this activity and one question that you still have.
   a.
   b.
   c.
   d.

and objectives for a particular unit. The problem context is interdisciplinary and allows students to apply their knowledge of turtles, circuit design, and environmental conditions. Students could extend the leatherback sea turtle hatchling problem by adding another parameter, such as oxygen levels, clutch size, or hatchling survival rates. Another extension could be to encourage students in applying this engineering-design process to another science application altogether. In an Earth-science lesson, for example, teachers could use the same temperature and humidity parameters to predict weather patterns. The possibilities are plentiful based on the teacher's unit goals and objectives. ■

References

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts and core ideas*. Washington, DC: National Academies Press.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states*. Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

Standard
MS-LS1: From Molecules to Organisms: Structures and Processes *http://nextgenscience.org/msls1-molecules-organisms-structures-processes*
MS-ETS1: Engineering Design *www.nextgenscience.org/msets1-engineering-design*

Performance Expectations
The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectations listed below.
MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
MS-ETS1-4. Develop a model to generate data for iterative testing of a proposed object, tool or process such that an optimal design can be achieved.

Dimension	**Name or *NGSS* code/citation**	**Matching student task or question taken directly from the activity**
Science and Engineering Practices	Asking Questions and Defining Problems Analyzing and Interpreting Data Using Mathematics and Computational Thinking	Students ask questions about the leatherback sea turtle and identify the problem of predicting hatchling sex using sensors. Students then use a proposed model to carry out the sensor investigation. Based on the output received from trying various inputs, students interpret whether the hatchling will be male or female.
Disciplinary Core Ideas	LS1.B. Growth and Development of Organisms • Animals engage in characteristic behaviors that increase the odds of reproduction. ETS1.B Developing Possible Solutions • A solution needs to be tested, and then modified on the basis of test results, in order to improve it.	Students explore how the ambient temperature and relative humidity at the time of hatching determine the sex of a leatherback sea turtle. Students design and test a sensor, present their solution, and discuss how they could revise the design.
Crosscutting Concept	Systems and System Models	Students identify a system (leatherback sea turtles and sex determination), specify its boundaries (temperature and humidity values) and model a possible solution for predicting the sex of a turtle hatchling.

Resource

Baby sea turtles hatching—*www.youtube.com/watch?v=TGoayx3Hvo4*

National Geographic: Leatherback sea turtle—*http://animals.nationalgeographic.com/animals/reptiles/leatherback-sea-turtle*

Nerds Without Borders Create a Turtle Hatch Warning System—*www.youtube.com/watch?v=SP9G6WJyLeo*

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Artificial Floating Islands

An Integrated STEM Unit

by Devarati Bhattacharya, Selcen Guzey, Christina Miller, and Tamara Moore

The integrated science, technology, engineering, and math (STEM) unit described in this article focuses on Artificial Floating Islands (AFIs), human-made structures capable of supporting aquatic vegetation on a floating platform. In the last decade, many European countries and the United States have recognized AFIs as a successful tool for long-term habitat restoration (Somodi and Botta-Dukát 2004; Winston et al., 2013). AFIs create near-shore mini ecosystems on a water surface without occupying any shoreline space (see Figure 1). The AFIs consist of floating platforms to support vegetation. The roots of the vegetation growing on the AFI extend into the polluted water body underneath and clean water through the absorption of pollutants. AFIs can move up and down with fluctuating water levels and can be mobile (unanchored) or stationary (anchored) depending on the type of water bodies they serve (see Resources for more information on how AFIs are used).

FIGURE 1 An artificial floating island

PHOTO COURTESY OF THE AUTHORS

In this STEM-integration unit based on AFIs, middle school students learn about remediating polluted aquatic ecosystems through measurement and data analysis and then use this knowledge to design prototype AFIs for cleaning up a polluted lake. The unit consists of five lessons (see Figure 2 for an overview) and is designed to take a week; however, a teacher can take up to two weeks if more time is spent on a certain lesson within the unit. These lessons do not have to be conducted successively. The unit is designed to address ecosystem dynamics and water pollution along with science and engineering practices such as defining problems, designing solutions, and understanding stability and change in ecosystems (see Figure 3). Before starting the unit, students need to have some basic knowledge about the relationships between living things, their environment, water resources, and causes and effects of water pollution.

FIGURE 2 Unit overview

Lesson	Objective
Lesson 1 (1 day): Setting the context	Introduce what constitutes water pollution and what could be the potential sources of water pollution within the context provided.
Lesson 2 (2 days): Exploring water quality and performing habitat analysis	• Explain the importance of water quality, illustrate measurement of water quality by using various physio-chemical and biological parameters, and explain how population diversity provides insight into the health of an ecosystem. • Investigate the biodiversity of the habitat where AFIs will be located by determining the habitat characteristics of the lake for which they will design the floating island.
Lesson 3 (1 day): Exploring point and nonpoint pollution in water bodies	Differentiate between point and nonpoint source pollution, provide student ownership for water quality, and ask students to identify best management practices to reduce water pollution. (When students learn about nonpoint source pollution, they realize that practices such as not picking up their pets' waste and over-fertilizing their yard cause a significant amount of run-off pollution. These are the practices they can change; thus, this process allows students to take ownership for water pollution. Otherwise, most students tend to think that big factories are responsible for most pollution.)
Lesson 4 (1 day): Introducing AFIs	Develop student understanding of the concept of AFIs; students then formulate a plan of action to create their own island.
Lesson 5 (2 days): Completing the engineering design challenge	Students determine the design of their AFI, choose materials, select plants, and estimate plant positioning for the construction of the floating island prototype.

Lesson 1: Setting the context

In the first lesson, students read a fictional newspaper article about a polluted lake (the article we used can be found with the online version of this article at *www.nsta.org/middleschool/connections.aspx*). Although our lesson is based on a real lake in Minnesota, teachers can focus the entire discussion around a polluted water body that is in close proximity to their school. If the water body accessible to the school is not polluted, it can still be used as a context for the lesson. In that case the AFIs will be framed as a measure to maintain the health of the water body.

The teacher then invites students to share their

FIGURE 4 Materials price list

- 1 piece of plastic—$4
- 1 piece of cardboard—$3
- 1 piece of foam—$3.50
- 1 cup of moss—$3
- 1 cup of plastic grass—$2
- 1 cup of soil—$2
- 1 empty soda bottle (500mL or smaller)—$2
- 1 ping pong ball—$1
- 1 seed—$0.33

FIGURE 3 Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

Standard **MS-LS2: Ecosystems: Interactions, Energy, and Dynamics *http://www.nextgenscience.org/msls2-ecosystems-interactions-energy-dynamics***		
Performance Expectation The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectation listed below. MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services		
Dimension	**Name and *NGSS* code**	**Matching student task or question taken directly from the activity**
Science and Engineering Practice	Constructing Explanations and Designing Solutions	Students design several AFI prototypes and evaluate them to choose the best prototype to build, test, evaluate, and improve.
Disciplinary Core Idea	• LS2.C. Ecosystem Dynamics, Functioning, and Resilience Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.	Students investigate the biodiversity and water quality of the habitat where AFIs will be placed and discuss the features of healthy and polluted lakes.
Crosscutting Concept	Stability and Change	Students model point and nonpoint source pollution. Students are asked, "How does pollution in a specific area cause changes in another area?"

Connecting to the Common Core State Standards (NGAC and CCSSO 2010)

CCSS.Math.Content.6. Solve real-world and mathematical problems involving area, surface area, and volume.
CCSS.Math.Content.7. Draw construct, and describe geometrical figures and describe the relationships between them.
CCSS.Math.Content.7. Solve real-life and mathematical problems involving angle measure, area, surface area, and volume.

National Governors Association Center for Best Practices and Council of Chief State School Officers (NGAC and CCSSO). 2010. Common core state standards. Washington, DC: NGAC and CCSSO.

FIGURE 5 Scoring rubric for testing the efficiency of an AFI

Criteria				Score
Buoyancy (Does the prototype float?)	0 The island does not float.	1 The island floats.		
Durability	0 The structure breaks after a short time, within 5 minutes of floating in the tub.	1 The structure does not break but shows damage after 1–2 hours of being in water.*	2 The structure is resistant to water. No water damage is seen.	
Whether the AFI is protected from damage and stays horizontal	0 The AFI is damaged, tips over.	1 The AFI is somewhat protected, partially tips over.	2 The AFI is entirely protected, does not tip over.	
Ability of plants to grow on the AFI	0 There is no space for roots to reach the water.	1 There is very little space for roots to reach the water.	2 The roots have ample space to reach the water.	
Cost of materials	1 The materials cost $20 or more.	2 The materials cost $7.01–$19.99	3 The materials cost $7 or less.	
Maintenance	1 The materials need to be replaced quite often(1-2 hour period)	2 The materials need to be fixed (glued, taped) quite often.	3 The materials need not be replaced or fixed for a long time.	

* Testing may be done after school if class periods are shorter than 1 hour.

prior knowledge about point and nonpoint water pollution. *Point water pollution* comes from a single source (e.g., outlet from a factory) while *nonpoint water pollution comes* from many diffused sources that do not have a single source of emission (e.g., fertilizers and pesticides used in lawns and gardens and storm water contamination). Students usually share their knowledge of this issue and what they understand to be best practices for lake-pollution prevention, control, and management (e.g., modifying usage of fertilizers and pesticides in yards, taking care of septic systems and not disposing of trash in lakes). After students have shared their ideas, the teacher discusses scientific terms such as *turbidity*, *nitrogen*, *oxygen*, *phosphate*, and *data* so that students are able to conceptually understand pollution in water bodies and correlate the scientific terms as well. The teacher also shares ideas about the restoration of water bodies and discusses AFIs as a method for restoration of water bodies (use websites provided in the Resources). In this way, a context is established for the forthcoming engineering challenge.

The teacher then provides students with a newsletter that explains why the polluted lake described in the article needs to be restored (see the newsletter with the online version of this article). After students review the newsletter, the teacher assesses if students were able to understand the problem that the newsletter is presenting (pollution in a particular lake). This can also be another opportunity to review the scientific concepts associated with pollution of water bodies (point and nonpoint water pollution, turbidity, nitrogen, oxygen, phosphate) and biological indicators of the health of a water body(macroinvertebrates).

Lesson 2: Exploring water quality and performing habitat analysis

During this lesson, students visit a lake accessible to them to collect water samples. This is the same lake

FIGURE 6 Sample student AFI prototypes

that the newsletter was based on. *Safety note:* The water must be free from dangerous microbes and toxins, and students must wear indirectly vented chemical splash goggles and gloves when working with the water and wash their hands afterward. Dispose of the water after use. Be sure to follow all instructions for the storage, use, and disposal of water-testing chemicals and follow all manufacturer instructions.

Students work in groups to collect water samples and run tests to measure water quality by focusing on biotic and abiotic factors. They conduct these tests to understand various water quality parameters. When considering a field trip, it is is important that school-board policies and procedures are followed, administrative approval is obtained, bus arrangements (if necessary) are made, and parental consent and student assent are obtained. Students should also be aware of the objective for the field trip and their responsibilitiies. If it is not possible to bring students to a pond or lake, the teacher can collect water samples for students to run water-quality tests in the classroom itself. In the first part of the lesson, students examine the water samples to determine the natural range of factors that indicate the health of water. Water quality is determined by three major parameters:

- Physical measurements of color, clarity, and conductivity of the water
- Chemical analysis (temperature, pH, dissolved oxygen, carbon dioxide, nitrates, phosphates)
- Biological indicators (macroinvertebrates)

Students can use lab probes to complete the chemical analysis and physical measurements of color, clarity, and conductivity. Care should be taken that students follow appropriate safety procedures while using the lab probes and conducting water quality tests in the classroom. Calibrating the conductivity, nitrate, and phosphate probes may be challenging for middle school students, so the teacher should calibrate the probes ahead of time. It is easier to calibrate pH, dissolved oxygen, and carbon dioxide probes (than the nitrate and phosphate probes); most manufacturers provide instructions. Finally, it is critical to collect the water sample as indicated in the instructions for the dissolved-oxygen test you are using. Extreme care should be taken to ensure that the sample is not aerated during collection and air bubbles are not trapped in the container during sampling. If the teacher does not have access to probes, students can collect data on water color, turbidity, temperature, and pH using color charts, a secchi disk, a thermometer, and some pH strips, respectively. If teachers do not have access to a polluted lake, teachers can collect water from any water body accessible to them and students can run the water-quality tests on those water samples.

Furthermore, this lesson is a great opportunity to integrate mathematics, as it is infused with math concepts, mainly in the form of data analysis. While students are analyzing water samples, they can use arithmetic skills to calculate averages, identify trends, and create graphs using their own data collected from their analyses. After students analyze their data, the teacher can ask questions such as "How does the pollution identified through the water-quality indicators affect the lake organisms and humans?" and "Is water quality important to humans and organisms that live at least part of their lives in the water? Why or why not?"

In the second part of this lesson, students perform habitat analysis. *Habitat analysis* is a process during which students work in groups of three or four to collect data about the habitat surrounding the polluted lake they were focusing on in part one of this lesson. As noted earlier, this is the same lake that the newsletter was based on. (This is the same target lake students are planning to clean up using an AFI, eventually). They establish relationships among animals, plants, and decomposers within the lake ecosystem. The main objectives are to explore the habitat around the lake for which the floating island needs to be designed. An in-depth understanding of the various components of the ecosystem, as well as the interactions among them, helps students envision the floating island as a habitat that supports the same flora and fauna as the lake ecosystem where it is situated. This is essential for the efficient and effective designing of the AFI prototype. If the teacher cannot go on a field trip to the lake, pictures or videos of the chosen water body can be used. The teacher can ask students to identify the communities of organisms shown in the pictures or videos.

Lesson 3: Exploring point and nonpoint pollution

This lesson is helpful in establishing student ownership of point and nonpoint pollution. As noted earlier, point and nonpoint water pollution indicate the source of the pollution of a lake within a watershed. Here we want to emphasize that through changing behavior and practices, individuals can make a difference in water quality. We recommend the use of an EnviroScape model (see Resources). This model is a three-dimensional, self-contained mini-watershed unit that shows nonpoint source pollution and how everyone can contribute in the prevention of environmental contamination. Students can work in groups of three or four to set up their own watershed. They can use readily available products such as cocoa (soil), colored drink mixes (chemicals), and oil to represent point and nonpoint source pollution. Using a water sprinkler to represent rain, storm-water pollution, and runoff become visually apparent. Additionally, students can use materials provided within the model to understand best management practices. The materials, such as felt buffer strips (vegetation) and clay can be used to show conservation and water-pollution prevention measures. This model comes equipped with a user guide, as well as all the materials required for set-up. While this model is easily available to teachers through the local natural resource department, teachers can build their own models by carving a watershed model from Styrofoam (*www.iwla.org/index.php?ht=a/GetDocumentAction/i/2194*). Topological features can be added by cutting the Styrofoam and using water glue to attach features that represent factories, farms, and forests. As a final step, the model is sealed with polyurethane or other coatings to make it waterproof.

Lesson 4: Introducing AFIs

In this lesson, students are introduced to AFIs and learn about their design and function. The teacher can provide information about AFIs by giving students an article (see the online version of this article). After reading the article, students discuss the design and functionality of AFIs in the context of the lake being investigated. Students in groups of three or four can also do online research on AFIs and present their findings to the class. Students should search for information regarding the design of AFIs (e.g., purpose, shape, size, buoyancy, durability, and what could be grown on the island).

Lesson 5: Completing the engineering-design challenge

This lesson introduces students to the engineering-design challenge and offers a second opportunity to integrate math concepts by applying relational thinking through measurement. Working in groups of three or four, students plan, create, evaluate, and revise an

AFI prototype. In our case, we presented a math-based design challenge and asked students to create an AFI with a perimeter of 66 cm because we have found that this size is relatively easy to build and test. Additionally, students estimate the shape (circle, triangle, square) that would provide the maximum amount of area for plant growth. Students also need to consider the number of plants the floating island can hold, given the information that one plant can be planted every square inch. Finally, students choose materials, select plants, and estimate plant positioning for the construction of the AFI prototype.

Students individually brainstorm possible shapes for their floating island and then share their designs with their teammates. As a team, they choose a prototype shape and start discussing which materials they will use to build their AFI prototype. At this point, teams receive a list of materials and a materials price list, along with the rubric that will be used to score their AFI prototype (see Figures 4 and 5). The goal is to meet all the criteria in the rubric and get a high score.

After teams design and build their AFI prototype, they test it by leaving it in a container filled with water (plastic storage containers or aluminum-foil cooking containers work well) for at least 1 hour and then scoring their AFI on their rubric (testing may be done after school if class periods are shorter than 1 hour). Finally, the groups share their prototype and scores from the rubric with the whole class. After seeing other designs and receiving feedback from classmates, students reevaluate their prototype. The final step in the engineering-design process after students have tested and analyzed their product is to make revisions to improve their design. This allows students to understand the iterative process of an engineering design. Figure 6 shows sample AFI prototypes designed and built by students.

Conclusion

Water quality, water purification, and biological components of an ecosystem make up a large part of the LS2: Ecosystems: Interactions, Energy, and Dynamics disciplinary core idea in *A Framework for K–12 Science Education* (NRC 2012). While the recent science-education reform efforts call for integrated STEM education, it is still challenging for many science teachers to create effective engineering activities to use in their life-science classrooms. Integrated STEM units such as this one provide an exciting opportunity for teachers to explore the ways in which students learn and apply math and science concepts while engaged in an engineering-design challenge. This integrated STEM unit not only incorporates these science ideas, but also emphasizes the scientific and engineering practices dimension ETS1: Engineering Design through the context of an engineering challenge. In this unit, students first enhance their understanding about the diversity and dynamics of ecosystems and then learn how pollution can impact an ecosystem. The engineering challenge, which requires students to design and build a prototype AFI, helps students realize that engineering practices and the use of available resources allow us to solve certain crucial environmental issues. While the activities in this unit allow students to understand that engineering is involved in the application of science, we also believe that the engineering challenge to design an AFI motivates "engineering habits of mind" (NAE and NRC 2009). It allows students to understand how and why science is crucial in developing a product to meet specifications of engineering and vice-versa. ■

References

National Academy of Engineering and National Research Council (NAE and NRC). 2009. *Engineering in K–12 education: Understanding the status and improving the prospects.* Washington, DC: National Academies Press.

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Resources

Artificial islands mimic nature's way of cleansing water—*http://ensia.com/articles/artificial-islands-mimic-natures-way-of-cleansing-water*

EnviroScape—*www.enviroscapes.com/nonpoint-source.html*

Floating Island International—*www.floatingislandinternational.com*

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- ❑ 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. addressses)
- ❑ 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

Contact Information (please print)

M

Name ______________________________

Title ______________________________

Institution ______________________________

❑ Home ❑ Work

Address ______________________________

____

City ______________ State ________ Zip ____________

Country ______________________________

Work Phone ______________________________

Home Phone ______________________________

Fax ______________________________

E-mail ______________________________

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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.

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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

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

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

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.

JM15

NSTA

WEBAREG15/JUNE 1

www.nsta.org/renohousing: Suggested Method for Housing Reservations

Deadline: September 24, 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/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.

NSTA Reno Area Conference

Official Housing Request Form

October 22–24, 2015, Reno, Nevada

NSTA National Science Teachers Association
AREA CONFERENCE ON SCIENCE EDUCATION
Reno, NV
OCTOBER 22-24, 2015
SCIENCE AND LITERACY: CREATING CONNECTIONS!

CONTACT INFORMATION

First: ______________________ MI: ______ Last: ______________________

E-mail: ______________________

School/Company: ______________________

Address: ______________________

City: ______________________ State: ________ Postal Code: ______________

Country: ______________________

Phone: ________________ Fax: ______________________

HOTEL SELECTION

Arrival Date: ______________ **Departure Date:** ______________

HOTEL		SINGLE	DOUBLE	TRIPLE	QUAD
1. **Atlantis Casino Resort Spa** *(Headquarters Hotel)*		$149	$149	$149	$149
2. **Grand Sierra Resort and Casino**	standard	$99	$99	$99	$99
	summit luxury	$125	$125	$125	$125

A Reno Hotel Map is available at *www.nsta.org/renohousing.*

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.*

www.nsta.org/phillyhousing: Suggested Method for Housing Reservations

Deadline: October 12, 2015

NSTA Philadelphia Area Conference

Official Housing Request Form

November 12–14, 2015, Philadelphia, Pennsylvania

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.

CONTACT INFORMATION

First: ________________ MI: ______ Last: ________________

E-mail: ________________________________

School/Company: ________________________________

Address: ________________________________

City: ________________ State: ________ Postal Code: ________________

Country: ________________________________

Phone: ________________ Fax: ________________

HOTEL SELECTION

Arrival Date: ________________ **Departure Date:** ________________

HOTEL	SINGLE	DOUBLE	TRIPLE	QUAD
1. **Philadelphia Marriott Downtown** *(Headquarters Hotel)*	$228	$228	$248	$268
2. **Hampton Inn Philadelphia Center City–Convention Center**	$199	$199	$209	$219
3. **Home2 Suites by Hilton Philadelphia–Convention Center**	$214	$214	$224	$234

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

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 October 12, 2015

❒ *One night's check deposit enclosed and made payable to Orchid Event Solutions. Mail housing forms to Orchid Event Solutions–NSTA/Philadelphia, 175 South West Temple, Suite 30, Salt Lake City, UT 84101. Check deposits must be received by October 12 to be accepted.*

www.nsta.org/kchousing: Suggested Method for Housing Reservations

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)
  801-505-4611 (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/Kansas City
  175 South West Temple, Suite 30
  Salt Lake City, UT 84101

DEADLINE
Reservations must be made by **November 4, 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 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.

NSTA Kansas City Area Conference

Official Housing Request Form

December 3–5, 2015, Kansas City, Missouri

NSTA National Science Teachers Association
AREA CONFERENCE ON SCIENCE EDUCATION
KANSAS CITY, MO
DECEMBER 3-5, 2015
RAISING THE STAKES IN SCIENCE

CONTACT INFORMATION

First: ________________ MI: ______ Last: ________________

E-mail: ________________________________

School/Company: ________________________________

Address: ________________________________

City: ________________ State: ________ Postal Code: ________________

Country: ________________________________

Phone: ________________ Fax: ________________

HOTEL SELECTION

Arrival Date: ________________ **Departure Date:** ________________

HOTEL	SINGLE	DOUBLE	TRIPLE	QUAD
1. **Kansas City Marriott Downtown** *(Headquarters Hotel)*	$159	$159	$159	$159
2. **Holiday Inn Kansas City Downtown–Aladdin**	$115	$115	$115	$115

A Kansas City Hotel Map is available at *www.nsta.org/kchousing.*

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 November 4, 2015.

❒ *One night's check deposit enclosed and made payable to Orchid Event Solutions. Mail housing forms to Orchid Event Solutions–NSTA/Kansas City, 175 South West Temple, Suite 30, Salt Lake City, UT 84101. Check deposits must be received by November 4 to be accepted.*


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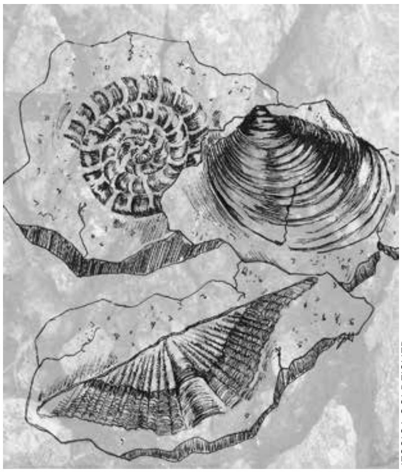
Fossils, inquiry, and the English language learner

by Deborah Goldfisher, Barbara Crawford, Daniel Capps, and Robert Ross


JESSICA GOLDFISHER

Teaching seventh-grade science to culturally and linguistically diverse students in New York City is a challenge. My English language learners (ELLs) come from all over the world, including Tibet, China, India, Indonesia, Eastern Europe, and Central and South America, and range in English language ability from beginning to advanced. To improve the success of these students, I integrate language-acquisition skills into all my lessons, which results in better engagement and success for my ELL students. Further, the authentic context allows my students to engage in important scientific practices as outlined in the *Next Generation Science Standards* (*NGSS*) (NGSS Lead States 2013). One specific lesson I taught incorporated ELL language-acquisition strategies into an inquiry-based fossil investigation.

Recently, I was involved in a National Science Foundation–funded program called Fossil Finders. As part of the program, I participated in a professional-development experience and later taught an inquiry activity in my classroom, which let students engage in scientific behaviors such as asking questions and carrying out investigations. As part of the professional development, I collected rocks from Devonian-age sites in upstate New York and participated in a scientific investigation aimed at determining how fossilized marine organisms found in a currently dry environment indicated the previous presence of a sea. These fossils served as evidence of major environmental change over Earth's history. Some of the unanalyzed samples I collected in the field were later shipped to my classroom, where I engaged my students in the Fossil Finders investigation as part of my Earth science unit covering Earth's history. This investigation followed units on topography, rock formation, weathering and erosion, and finding evidence of Earth's past through stratigraphy and the fossil record. In addition, students need to know how to tally data on a data table and create a graph of their data. Over the course of about two weeks, my students collected data about the identity and frequency of specific Devonian-era marine fossils from actual rock samples. Students used these data as evidence of environmental change in the upstate New York area, which, they noted through current photos, is now dry land. The investigation aligned with the *NGSS*, as aspects of the activity cut across the three dimensions of science described in the new standards document. For example, this investigation allowed students to engage in a number of the *NGSS* science practices (e.g., Asking Questions, Planning and Carrying Out Investigations, Analyzing and Interpreting Data, Constructing Explanations, and Obtaining, Evaluating, and Communicating Information), disciplinary core ideas (e.g., LS4.A and ESS2.B), and crosscutting concepts (e.g., Patterns and Scale, Proportion, and Quantity).

This hands-on fossil investigation helped reiterate an aspect of the nature of science many students struggle with: not all investigations are experiments, and there is no singular scientific method (Schwartz 2007). Because I taught this lesson to my beginning ELL learners near the beginning of the year, I gave students more directions than would be offered in an open-inquiry investigation. Thus, instead of having students formulate their own goal and procedures, I provided these for them and directed them to formulate explanations based on evidence they would independently observe during the investigation. This can be modified as students gain experience in investigational design so that students can perform their own research on an assigned topic and then create and investigate their own questions. (The activity sheet for this activity is available at *www.nsta.org/middleschool/connections.aspx*.)

Fossil-rich rocks can be collected at localities around the country and from local paleontology clubs (see Resources). Museums and colleges could be sources of fossils and information for a similar investigation. Fossil sets can be purchased, and rocks and sand can be added for authenticity. Guides for teachers on regional Earth science, with chapters on fossils, are available for free (see Resources). Those interested in using samples similar to those used in my study can contact the Paleontological Research Institution (see Resources). However, activities that relate natural-history observations to environments are not limited to fossils. The activity described here can be adapted to any type of natural object that can be collected from a local environment (for example, leaves, seeds, soils, or shells). Or one can make observations of birds, flowers, insects, or other organisms. Connecting ELL students to authentic science is not dependent on the discipline.

In order to ensure the success of my ELL students in this investigation, I incorporated six different ELL instructional strategies. These strategies can be adapted to any activity.

1. Paired and cooperative grouping

I selected five students (one for each group that I planned to divide the class into) from various linguistic backgrounds who were strong in English and who had demonstrated their ability to explain science concepts to other students. I trained these "experts" during our mutual lunch periods to identify each type of fossil by showing them reference sheets and actual samples. After I showed students how to identify samples, I gave the experts various unidentified samples and let the students identify the fossils using the reference sheets. We had two meetings to practice, and by the end of the second practice session, these students didn't need the reference sheets. I then divided the class into cooperative learning groups, and assigned one expert to each group as the leader. I paired students who were weaker in English with stronger English speakers from their same linguistic background and placed students with similar linguistic backgrounds into larger groups of six when they engaged in the actual investigation. ELL learners who were without a linguistic partner were placed in groups where the group leader spoke English and was able to demonstrate what the group was doing. In this situation, I spent more time at these groups to ensure that every student was successfully engaged. Though I used this technique in my class composed solely of ELL learners, it can be modified for a setting in which ELLs do not make up the majority of students in the class. For example, ELL students could be paired with a classmate of similar linguistic background or an assigned "buddy" to demonstrate the activities. I would then have resources such as translation dictionaries and picture glossaries available for reference for both the ELL student and the native English speaker to use when explaining any aspect of the investigation.

I then had a whole class "practice" session with sample fossils in order to perfect our skills and identify any weaknesses. I gave each group a rock sample that I had already analyzed. The leaders showed the group how to use the reference material and led them to an identification of their fossil sample. I walked over to each group and asked each to share its identification to confirm the accuracy of the knowledge of the process.

2. Referencing background and prior knowledge

At the beginning of the investigation, I showed PowerPoint slides of me walking along the road at the fossil site, observing the actual rock outcrop in Pompey, New York, and collecting fossils. My PowerPoint was created with photos of representative fossils and can be found in the online version of this article. There are a number of websites that have fossil photos and information that can be used to create a slide or printed visual reference (see Resources). I began the discussion with a series of prompts requiring oral observations: "Describe the area that I am working in. What types of plants do you see? What types of landforms are around me?" After eliciting students' responses as to my obvious location on dry land, near a hill and a highway, student experts carried around sample fossils I had brought back from the Fossil Finders summer institute. The samples included brachiopods, clams, and gastropods. I drew on prior student knowledge by letting students identify and share out loud where we would find animals that resembled my samples. My students explained that animals such as clams live in or near water. To ensure that all students understood this reference, including those who had never visited an ocean, I reinforced my comments with slides of oceans, shells, and clams, as well as a few actual seashells. You may be able to find someone who has been or is going to a beach to provide a bag of seashells, or kits for education can be purchased (see Resources). I then started a discussion about how I was able to find shell fossils on currently dry land. I showed the class a slide with the following questions:

- How could I have found fossil clams on dry land?
- How did they get there?
- Where do we find shelled animals such as clams today?
- Where do you think they lived long ago?
- What can you infer about the dry land where I found the fossils?

Students were instructed to discuss these questions for three minutes with their group members (I stopped the time if I noted the discussion ending). They were told to take notes on their responses if necessary, since using notes assists ELL learners in oral discussions.

Some examples of responses included: "Maybe people brought them there." "They were washed there in a tsunami." "They were dropped there by animals." "Maybe there was once water there." We then had a discussion about how the fossils that I showed them lived in water, both long ago and today. Through discussion, we concluded that since similar shelled animals live near an ocean today, they probably lived in or near one in the distant past. In that case, there must have once been water covering the now-dry area in which students saw me excavating fossils.

3. Supportive visual references

I created visual clues by enlarging scientific drawings of the fossils we were looking for and hung them around the room. I placed laminated sheets of fossil pictures at each table (Online Resource A—this article refers to a number of online resources that are available at *www.nsta.org/middleschool/connections.aspx*). In addition to the previously mentioned fossil-photo source websites, an excellent source of fossil illustrations can be obtained from the book *Fossil Collecting in Pennsylvania* by Donald M. Hoskins, which can be accessed at Pennsylvania's Department of Conservation website (see Resources). I showed PowerPoint slides of each fossil type with its name and pointed out identifying characteristics (see the slides with the online version of this article). For example, I pointed out the symmetry of brachiopods, which I demonstrated by folding a picture in half. I showed some fossils (e.g., trilobites) next to modern equivalents (e.g., horseshoe crabs), which many students recognized, even though they did not know their English name. We then followed up with a quick quiz to practice identifying and saying the names of the different fossils using the reference photos.

4. Demonstrating techniques

As I explained the steps of the investigation, which involved the identification and tallying of fossils, I used an Elmo Visual Presenter Document Magnifier to magnify my demonstrations of the specific traits of each type of fossil. I also went to each group and repeated the demonstration.

5. Words, words, and more words

Each student was given a Fossil Investigation Lab Sheet to complete as part of the lesson (Online Resource B). My word wall became an interactive glossary of index cards, which had our "fossil finder" words on the front and their definitions and pictures on the back. I read the unusual names out loud to the class every day of the investigation and asked students to repeat the names after me. Some of these words included "brachiopods," "trilobites," and "cephalopods" (Online Resource C). I used common "function words and phrases" (Online Resource D) so that students could describe their findings in a scientific manner. These words (and phrases) include "because" and "since" to show cause and effect, "such as" to provide examples, "however" and "as well as" to compare and contrast, and "I can conclude that" and "we found that" to report findings (Carr, Sexton, and Lagunoff 2002). For example, students contrasted brachiopods and bivalves (clams) by saying: Brachiopods *are different from* clams, because brachiopods are symmetrical and clams are not. Beginner ELL students were given "sentence starters," such as "We concluded that the area where the fossils were found used to be covered with a sea because … (clam fossils were found there and clams live in the sea)." We used these phrases to understand the question we were investigating: How can fossils be used to provide evidence of environmental change? Our hypothesis was formed from functional phrases: *If* marine fossils such as clams are found on top of a hill in upstate New York, *then* upstate New York must have once been covered by water because clams are found living in water today. I gave my beginning ELL students the complete hypothesis to demonstrate the structure of this type of statement. In my more advanced ELL classes, I provided a sentence starter: "If marine fossils such as clams are found on top of a hill in upstate New York, then ... " If I were to teach this lesson to native English speakers, I would discuss the question with them and allow them to create a hypothesis using their own format, assessing whether it was relevant to the question. In addition, when writing responses in their lab, students had access to a "Power" word bank of terms from the investigation. The word bank included fossil names as well as words such as "organism," "marine," and "symmetrical" (Online Resource E).

6. Hands-on activities

After our introduction to identifying the fossils and a discussion of the location where they were found and what it implied about how that environment changed over time, we began the actual investigation. The investigation was hands-on, using actual unexamined rock samples I had collected. I have taught all levels of ELL students for almost 10 years and have found the actual observation and handling of realia such as rocks, fossils, and minerals is a necessary strategy for comprehension. Group leaders (the designated "experts") poured a bag of rocks onto newspaper-covered tables. The goal was to examine each sample (without breaking them apart) and locate and identify any fossils that might be present. The groups worked identifying fossils and recording their data. I circulated, answered questions, and ensured that the work was done properly and that each student in the group was involved. Group leaders kept track of their group's progress, as well as any problems. The leaders demonstrated their expertise by pointing out fossils in rocks that at first glance appeared to have none. Students realized that what they thought were parts of the rock were actually small, ancient, preserved creatures. Students engaged in discussions in a number of languages as they identified fossils and recorded their data. The "translators" allowed students of every language level to benefit from this investigation. The use of native language was especially helpful for those students who were just beginning to learn English. I noticed that by encouraging the use of native language, even some of the most tentative English speakers participated fully in the activity. When the last sample was examined, there was obvious disappointment that our "fossil-hunting" activity was over.

My classes took two weeks to complete our investigation, since my participation in this activity required that we complete a number of bags of fossil samples that were then added to the Fossil Finder database. If each group is assigned a collection of around a dozen samples, the identification can be accomplished in one class period. Including an introduction, practice session, and wrap-up, this activity can be completed in a week.

Assessment

After the investigation, students examined their data to determine whether they supported the original hypothesis. Their analysis based on the data was part of their lab report (Online Resource B). Students also wrote a reflection about their experience as "scientists." I used the data collection, graph, analysis, and reflection to assess student learning (Online Resource F).

We collected the class data and created a bar graph illustrating the number and type of marine specimens that were found within our rocks. We had a whole-group discussion, revisiting the type of environment in which these animals would normally be found and compared it to what it looks like now. I then asked students how these results indicated a change in environment in upstate New York. Based on the evidence of fossilized marine organisms, students concluded that at some point in the past, there must have been a sea covering New York, which subsequently receded. Samples of student work from their analyses show how, based on the evidence, students were able to make inferences about ancient environments of New York (see Figures 3 and 4 in the online version).

Students completed this investigation by including a reflection at the end of their lab. For their reflections, I asked students to evaluate their experience in terms of what they learned, how they felt about doing an actual scientific investigation, and what impact such an experience had on them. The experience clearly impacted many of my students, as demonstrated by the following quotes from students:

> "We know that the upstate NY was covered by an ocean because the scientist found lots of sea creatures in there. The fossils we investigated were from upstate NY. It was all clam, brachipod, snail, etc. The fossils were all sea creatures. That is how we know ther was an ocean."
> —*Tenzin, a recent immigrant from Tibet, inferring the previous environment of upstate New York based on her finding*

> "With all the evidence we gathered we knew for sure that NY State was covered by an ocean. Since we looked at water fossils, that explains that NY

State was once covered by a sea/ocean. When I was analyzing the fossils, for a moment I thought I was a real scientist."
—Jose, from Mexico, experiencing what it felt like to be a "real" scientist

"The investigation of the fossils make me feel like a scientist because I had learned how to identify each of the different types of fossil. Also, when I was doing the fossil experiment, I was thinking like a scientist by knowing how to analyze them by their color or size."
—Maria, a recent Columbian immigrant, feeling and thinking like a scientist

Conclusion

Learning science is essential for all students of every cultural and linguistic background and learning ability. Engaging in an authentic investigation allows all students to ask questions and examine phenomena to try and answer those questions by using data as evidence. After completing our fossil investigation, many students thought of themselves as scientists and expressed an interest in entering the field of science in the future. Their language ability did not impede their ability to act or think like scientists. I was not fully aware of the value of this experience until I read my students' reflections, which demonstrated their success with integrating language-acquisition skills, as well as their appreciation of the investigation. By engaging in science activities rather than just listening to teachers talk about it, students think about scientific questions, interpret data, formulate answers, and engage in scientific conversations, just as a scientist would (Meyer and Crawford 2011). With the proper planning, language does not have to be a limitation to learning science. ■

References

Carr, J, U. Sexton, and R. Lagunoff. 2007. *Making science accessible to English learners*. San Francisco: WestEd.

Meyer, X., and B.A. Crawford. 2011. Teaching science as a cultural way of knowing: Merging authentic inquiry, nature of science, and multicultural strategies. *Cultural Studies of Science Education* 6 (3): 525–47.

National Research Council. 2000. *Inquiry and the National Science Education Standards*. Washington, DC: National Academies Press.

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

Resources

A geological trip to Yass—*www.geosci.usyd.edu.au/users/prey/FieldTrips/Yass04/Devonian.html*

Bailey-Matthews National Shell Museum—*www.shellmuseum.org/learn/school-kits-and-school-memberships*

Common squid—*www.squid-world.com/common_squid*

Conchologists of America—*www.conchologistsofamerica.org/clubs*

Coral reefs—*www.noaa.gov/features/economic_0708/coralreefs.html* Deep water crinoid—*www.geol.umd.edu/~tholtz/G331/lectures/331echin2.html*

Falls of the Ohio State Park—*www.fallsoftheohio.org/fossils.html*

Fossil clubs and societies—*www.myfossil.org/paleosocieties*

Fossil identification—*http://fossilidentification.weebly.com*

Fossilicious.com—*www.fossilicious.com*

Horseshoe Crab—*www.tybeemarinescience.org/naturalist/atlantic-horseshoe-crab*

i Love Shelling—*www.iloveshelling.com/blog*

Naturally Curious with Mary Holland—*https://naturallycuriouswithmaryholland.wordpress.com/2010/04/28/land-snails-welcome-to-a-photographic-journey-through-the-fields-woods-and-marshes-of-new-england*

Online Paleontology Museum—*https://sites.google.com/site/sjwamback/fossils:tracesofourpast*

Paleontological Research Institution—*www.priweb.org/index.php*

Penn Dixie Paleontological and Outdoor Education Center—*www.penndixie.org*

Pennsylvania Department of Conservation and Natural Resources—*www.dcnr.state.pa.us/topogeo/collecting/fossilsintro/fossils*

Teacher guides—*http://teacherfriendlyguide.org*

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SCIENCE SCOPE Call for Papers

Here are some of the themes for the upcoming publishing year of Science Scope.
Visit* http://mc.manuscriptcentral.com/nsta *to register as an author and submit your article.

January 2016—Assessment

Submission Deadline: August 1, 2015

Share your methods for developing assessment instruments to provide feedback to you and your students before, during, and after instruction. Tell us how you use assessment results to design or modify lessons, gauge individual student progress, or determine whole-class movement toward a unit objective or an *NGSS* performance expectation. Where do you go to get help crafting assessment tasks, rubrics, and scoring criteria? Have you used the sample classroom assessment tasks from Achieve or any of the NSTA assessment resources to develop your own *NGSS*-aligned, three-dimensional assessment tasks? Share samples of any common grade-level *NGSS* assessments your school or district has devised. Do you have examples of assessments that combine the *NGSS* with other standards? Give us your tips for designing rubrics and teaching students how to use them to improve their performance and learning. Tell us how you teach students to pay attention to and act on the feedback you write on their papers. How do you share assessment results with students and parents?

February 2016—Biology Activities

Submission Deadline: September 1, 2015

The *NGSS* contains four biology standards—From Molecules to Organisms: Structures and Processes; Ecosystems: Interactions, Energy, and Dynamics; Heredity, Inheritance, and Variation of Traits; and Biological Evolution: Unity and Diversity. We invite you to share activities that you have successfully used to help students meet specific performance expectations or bundles of performance expectations for these standards. Provide examples of three-dimensional lessons that combine science and engineering practices and crosscutting concepts with specific biology content. How do you use the performance expectations (and their Clarification Statements and Assessment Boundaries) to guide instruction and assessment? Can you provide examples of engineering-design projects or interdisciplinary lessons that require the application of biology DCIs? Tell us how you use history, medicine, disease, agriculture, food, local sites, and everyday situations to make biological concepts relevant to students' lives.

March 2016—Physical Science Activities

Submission Deadline: October 1, 2015

There are four physical science standards in the *NGSS*—Matter and Its Interactions, Motion and Stability: Forces and Interactions, Energy, and Waves and Their Applications in Technologies for Information Transfer. The disciplinary core ideas and their component ideas in these standards will not only help students build a physical science content foundation but will also be useful to the understanding of other domains of science. We invite you to share activities that you have successfully used to help students meet specific physical science performance expectations or bundles of performances expectations. Provide examples of three-dimensional lessons that combine science and engineering practices and crosscutting concepts with specific physical science content. How do you use the performance expectations (and their Clarification Statements and Assessment Boundaries) to guide instruction and assessment? Can you provide examples of engineering design projects or interdisciplinary lessons that require the application of physical science DCIs? Share lessons you use to teach the involvement of physical science in essential biological processes such as photosynthesis and respiration or in Earth processes such as the water cycle, weather, and climate change. Tell us how you use hobbies, sports, industrial processes, technology/common devices, and everyday situations to make physical science concepts relevant to students' lives.

Upcoming themes

- **Summer—**Engineering Activities
  Submissions due February 1, 2016
- **September—**Planning and Carrying Out Investigations
  Submissions due April 1, 2016
- **October—**Earth Science Activities
  Submissions due May 1, 2016
- **November—**Science for All
  Submissions due June 1, 2016
- **December—**Energy
  Submissions due July 1, 2016

Have an idea that doesn't fit a theme? Send it in. Our issues are a blend of thematic and general material, so we need articles on all topics. Before you sit down to write, check out our manuscript guidelines at *www.nsta.org/middleschool/msguidelines-scope.aspx*.

High quality interactive content for K–12 science teachers

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American Museum of Natural History

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Montana State University–Bozeman

Online graduate credit courses for K–12 science teachers through National Teachers Enhancement Network, as well as online offerings for Masters of Science in Science Education. NSTA member discount.

University of Maryland

The online Master of Life Sciences degree, specially designed for science teachers, is a 30-credit interdisciplinary program offering concentrations in biology and chemistry.

Wildlife Conservation Society

Free Online Webinars allow educators to interact live with WCS scientists and educators - all from the comfort of your own home! Walk away with valuable resources – including classroom lesson ideas. All sessions are also recorded for future reference! Visit – *http://bit.ly/WCSWebinar for more information.*

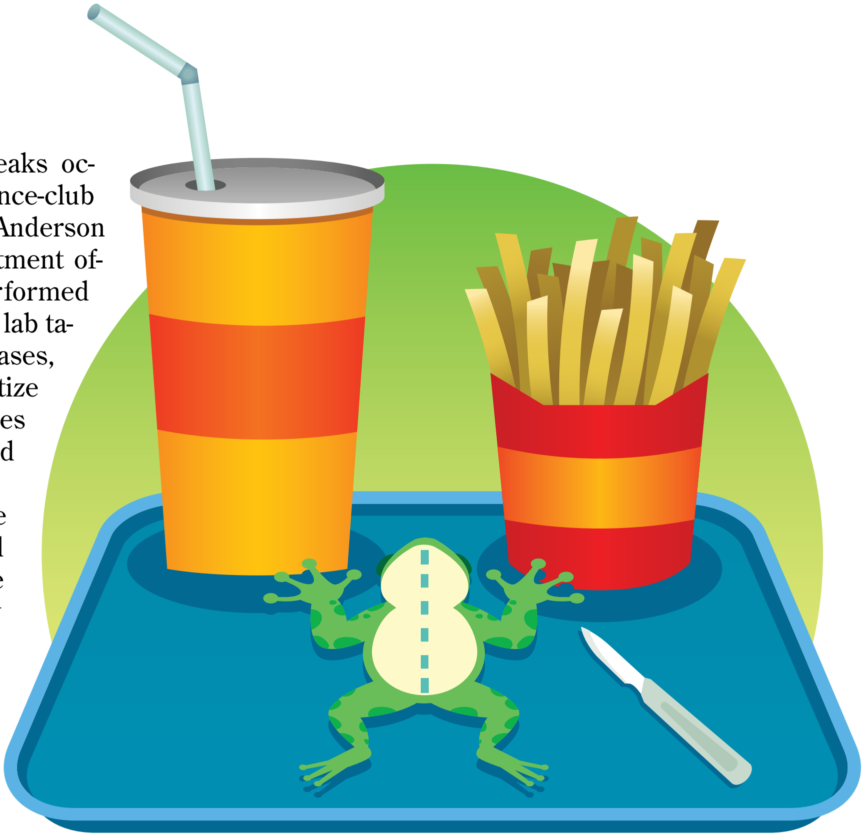
NSTA Virtual Conferences

A day-long series of live web sessions delivered via an interactive distance-learning tool. Each conference features content and/or pedagogy from experts in a particular topic. Participants can log on from anywhere with an internet connection and interact with presenters and educators from across the country.

NSTA National Science Teachers Association

Safety: Food for thought

by Ken Roy



Several years ago, *Salmonella* outbreaks occurred at two schools where science-club students dissected owl pellets (Anderson 2002). In a follow-up review, health department officials found that the dissections were performed on lunchroom dining tables and on science lab tables at both schools, respectively. In both cases, students did not wash their hands or sanitize tables after the activity. The cafeteria tables were then used for after-school snacks and lunch the following day.

Middle school science teachers must be prepared to deal with potential health and safety hazards wherever lab activities are performed. Unless proper health and safety protocols are put into place and enforced, there is risk of cross-contamination and potentially serious health ramifications for students, teachers, and other school employees.

Preventing contamination

Science teachers can reduce the risk of health and safety incidents by planning ahead. Consider the following guidelines to help prevent cross-contamination.

Biological contaminants

The Washington County Department of Health and Environment recommends the following simple but effective strategies for safer school animal-dissection practices:

- Separate areas should be designated for school curricula and functions where contact with animal and animal-derived material is anticipated (i.e., these activities should not occur in food service areas).
- As with all animal-derived materials, handling of owl pellets should be followed by sanitation of contact surfaces [with sanitizing cleaning products] and thorough hand washing.
- Sterilized owl pellets [and all other animal specimens] for use in educational activities should be obtained from [reputable] commercial sources (Anderson 2002).

In addition to these recommendations, the following protocols should also be in place:

- Always use appropriate personal protective equipment (e.g., sanitized indirectly vented chemical splash safety goggles, vinyl gloves and aprons).
- Make sure procedures are in place for the appropropriate disposal of biological waste. Placing remains in labeled and sealed plastic bags

or containers should be done in preparation for commercial-waste disposal through a contractor or other means, as noted by the supplier.

- Remember that microbes should never be cultured at the middle school level. The types of cultures grown can never be known for certain and could be a major health hazard. For additional information, refer to NSTA's Safety Acknowledgment Form for Working with Microorganisms (see Resources).

Sometimes the potential for exposure to contaminants is legislated. For example, Connecticut's Public Act No. 12-198 mandates the following:

> No local or regional board of education may restrict the time and location of blood glucose self-testing by a child with diabetes on school grounds who has written authorization from a parent or guardian and a written order from a physician stating that such child is capable of conducting self-testing on school grounds (2012).

According to this act, if a student wants to self-test blood glucose in the middle of a science lab, the student has the right to do so, regardless of the potential for cross-contamination. However, school nurses and science teachers should try to contact parents in writing that students who do this may harm others. Students should be encouraged to step out of the lab to conduct such a test. They must use appropriate hand-sanitizing procedures after testing blood. Contaminated materials should then be disposed of in regulated waste containers, usually found in the nurse's office.

Chemical contaminants

Unfortunately, it is not always possible to know when a hazardous substance has previously been used in a laboratory. For example, life-science activities using biological stains such as crystal violet (a potential carcinogen, irritant, and toxin) and methyl blue (an acute toxin) can leave chemical residue on desks. This is true even if tables have been cleaned with sanitizers. If students place backpacks, books, and other items on lab tables, these objects can pick up residue and transfer it to other areas, such as the cafeteria, where there is risk of cross-contamination and chemical poisoning. The risk of chemical cross-contamination can be significantly reduced by keeping students materials off tables and stored in a designated area. Students should also wash their hands with soap and water after completing the lab. Also, always check the Safety Data Sheets for any chemical that you know is being used in the science lab to determine whether it poses health hazards and to determine how to protect lab occupants from exposure.

Physical contaminants

Using potentially sharp objects such as glass lenses, metal electrode strips, pins, and compasses can result in cuts or skin punctures. Such injuries allow potentially harmful bacteria on equipment surfaces to be transferred to tissue below the protective epidermal layer and cause infections. Always remind students to check for sharp edges and wear protective gloves and safety glasses or goggles when working with physical contaminants in the lab. It should be standard operating procedure to sanitize work surfaces and equipment such as eyepieces after completing each lab activity.

Eating in the lab

To reduce the risk of food contamination in the lab, never allow students to eat or drink in laboratories.

Sometimes, school administrators don't understand the dangers of contaminants. One middle school

Question of the month

How can I easily let students know the times during which they should be wearing their safety glasses or goggles in the lab?

Answer

Instead of students having to ask you about eye protection, give them the following rule and post it in the lab: "When you see my eye protection on, your eye protection is to be on. When you see my eye protection off, your eye protection can be off." Also, remember that under the Occupational Safety and Health Administration's (OSHA) Personal Protection Standard 1910.132, teachers, as employees, are required to wear appropriate eye protection (see Resources).

Do you have a safety question?

Submit questions regarding safety in the middle school science laboratory to Ken Roy at *Royk@glastonburyus.org*.

administrator decided to adopt an “open lunch time,” allowing students to eat wherever they wanted in the building, including science labs. The school’s science teachers ultimately had to petition the superintendent to note that labs and art studios were exceptions to the new lunch model.

In the end

Just because you can’t see contaminants doesn’t mean they are not there. Remember to drive home safety using AAA—aware, assess, action. Always be aware of potential health and safety issues, assess the level of potential risk, and take action using appropriate protocols. ■

References

Anderson, F. 2002. Salmonellosis at elementary schools associated with dissection of owl pellets. Washington County Department of Public Health and Environment. *ftp://ftp.cdc.gov/pub/infectious_diseases/iceid/2002/pdf/anderson.pdf.*

State of Connecticut. 2012. Public Act No. 12-198. *www.cga.ct.gov/2012/act/pa/pdf/2012PA-00198-R00HB-05348-PA.pdf.*

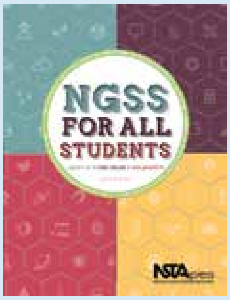
Resource

OSHA Personal Protection Standard—*www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9777*

Safety acknowledgment for for working with microorganisms—*www.nsta.org/docs/MicroorganismSafetyAcknowledgment20120507.pdf*

Ken Roy (*Royk@glastonburyus.org*) is director of environmental health and safety for Glastonbury Public Schools in Glastonbury, Connecticut, and NSTA’s chief science safety compliance adviser. Follow him on Twitter: @drroysafersci.

What Science Teachers Are Reading This Summer

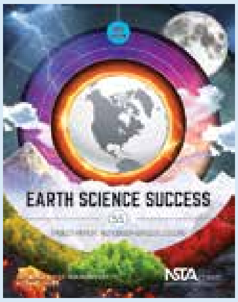


NGSS for All Students

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**
E-book: Member Price: $22.72 | **Nonmember Price: $26.21**
Book/E-book Set: Member Price: $36.35 | **Nonmember Price: $45.44**



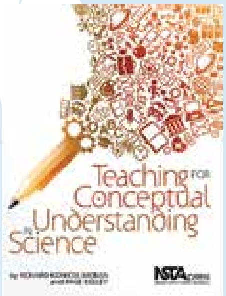
Earth Science Success, 2nd Edition

55 Tablet-Ready, Notebook-Based Lessons

Grades 6–9

Consider these newly revised lessons your survival guide for the tablet age. Written with time-starved teachers in mind, *Earth Science Success* provides a notebook-based, lab-focused, tablet-ready curriculum that has been field-tested and refined for use over an entire school year. All 55 lessons incorporate the disciplinary core ideas from the *Next Generation Science Standards.*

Book: Member Price: $26.36 | **Nonmember Price: $32.95**
E-book: Member Price: $21.42 | **Nonmember Price: $24.71**
Book/E-book Set: Member Price: $34.27 | **Nonmember Price: $42.84**

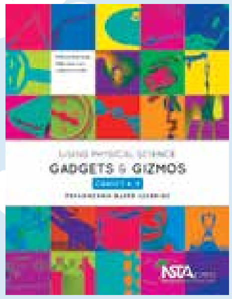


Teaching for Conceptual Understanding in Science

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

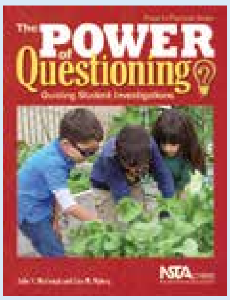


Using Physical Science Gadgets and Gizmos, Grades 6–8

Phenomenon-Based Learning

With 35 experiments, *Using Physical Science Gadgets and Gizmos* lets middle school students explore a variety of phenomena involving pressure and force, energy, light and color, and more. The phenomenon-based learning (PBL) approach introduced by the authors is as educational as the demonstrations are attention-grabbing. Instead of putting the theory before the application, PBL encourages students to first experience *how* the gadgets work and then grow curious enough to find out *why*. The result: Your students learn physical science by doing what real scientists do.

Book: Member Price: $25.58 | 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



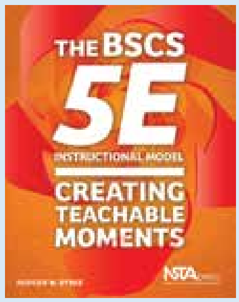
Powerful Practices Series: The Power of Questioning

Guiding Student Investigations

Grades K–6

The authors of *The Power of Questioning* invite you to nurture the potential for learning that grows out of children's irrepressible urge to ask questions. The book's foundation is a three-part instructional model, Powerful Practices, grounded in questioning, investigation, and assessment. To bring the model to life, the authors provide vivid pictures as well as links to special videos and audio recordings. You can actually hear teachers and students engage in questioning and watch two easy-to-adapt examples of the model in action. The book also illustrates how to integrate the *Next Generation Science Standards*, the *Common Core State Standards*, and STEM education practices.

Book: Member Price: $14.36 | Nonmember Price: $17.95
E-book: Member Price: $12.02 | Nonmember Price: $13.71
Book/E-book Set: Member Price: $18.63 | Nonmember Price: $23.04



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.

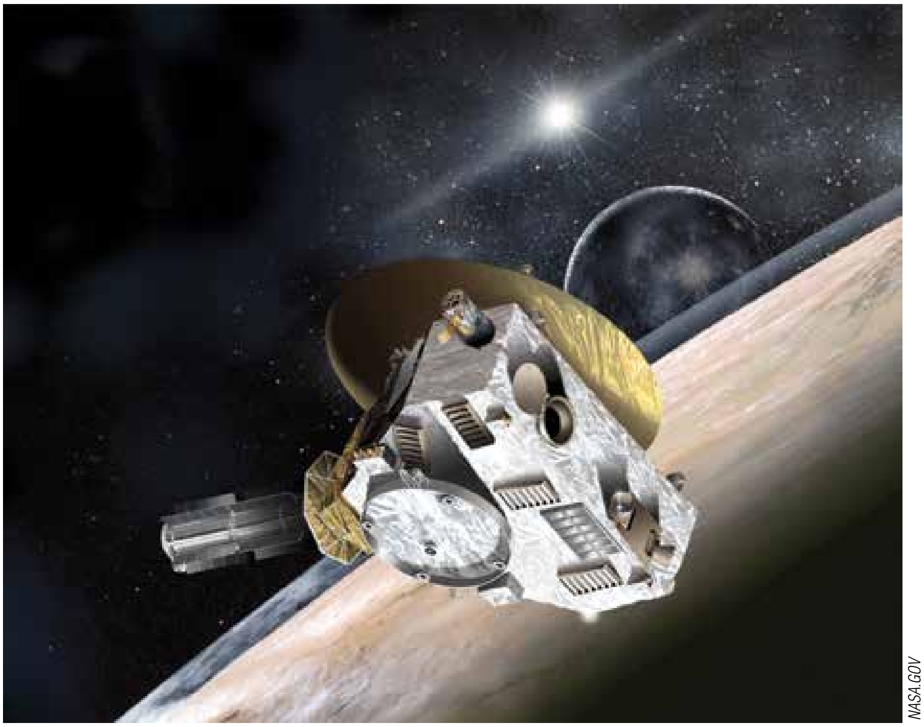
Book: Member Price: $25.56 | Nonmember Price: $31.95
E-book: Member Price: $20.77 | Nonmember Price: $23.96
Book/E-book Set: Member Price: $33.23 | Nonmember Price: $41.54

To place an order or download a free chapter, visit
www.nsta.org/store

NSTA National Science Teachers Association

Far out! Exploring the outer reaches of our solar system

by Bob Riddle



New Horizons Pluto Kuiper Belt Flyby

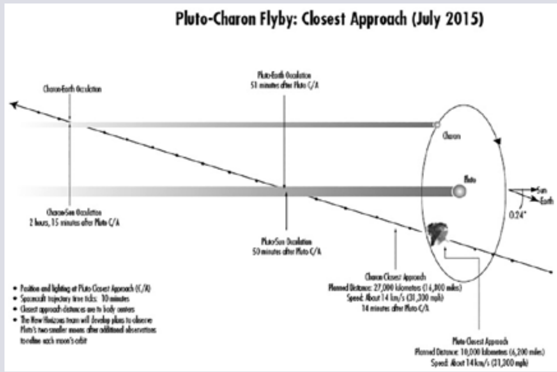
On July 14, 2015, the *New Horizons* spacecraft will pass one of the larger objects in the Kuiper Belt: Pluto, one of the many dwarf planets orbiting the Sun in this region of the solar system.

The *New Horizons* mission began its journey to the outer solar system on January 19, 2006 (see Resources for mission website). Several months after launch, *New Horizons* crossed the orbit of Mars and set aim for Jupiter, which it passed in 2007. As *New Horizons* flew by Jupiter, the spacecraft used the planet's powerful gravitational attraction to increase its speed by about 9,000 mph (14,404 km/h) and continued on toward Pluto. Then, for the following eight years, the spacecraft was in hibernation mode as it completed the interplanetary-cruise phase of the mission, which officially ended in June 2015. In hibernation mode, most systems were turned off; however, the spacecraft communicated weekly with mission control, and each year the spacecraft was brought out of hibernation for a systems check. During the hibernation phase, the *New Horizons* spacecraft crossed the orbit of Saturn in 2008, Uranus in 2011, and Neptune in 2014. In December 2014, the spacecraft was brought out of hibernation mode with all systems working, and it has been "awake" and operational since then.

During July's flyby mission, *New Horizons* will approach Pluto and its five known moons at a speed of about 49,890 km/h (31,000 mph), passing about 9,978 km (6,200 mi.) from Pluto. Because the spacecraft will pass Pluto so quickly, observations and data collection were actually begun in earnest in June 2015, one month before the end of the interplanetary cruise phase. Observations and data collection on Pluto will continue until mid-July. Due to the orientation of Pluto and its largest moon, Charon, at the time of the flyby, the two will be casting a shadow that the spacecraft will pass through, setting up two *occultations* of the Earth, meaning that from the spacecraft's perspective, Pluto and Charon will pass in front of the Earth, blocking the Earth from view momentarily (see Figure 1).

As observations of the other four known moons are made, refinements will be made by mission control scientists in calculations of the moons' respective orbits. Using new data from the spacecraft, the scientists may decide to perform flyby encounters of some of these other moons. Following the Pluto–Charon flybys, the *New Horizons* spacecraft will continue outward through the Kuiper Belt, with the potential for additional flybys of Kuiper Belt objects.

FIGURE 1 Pluto encounter timeline

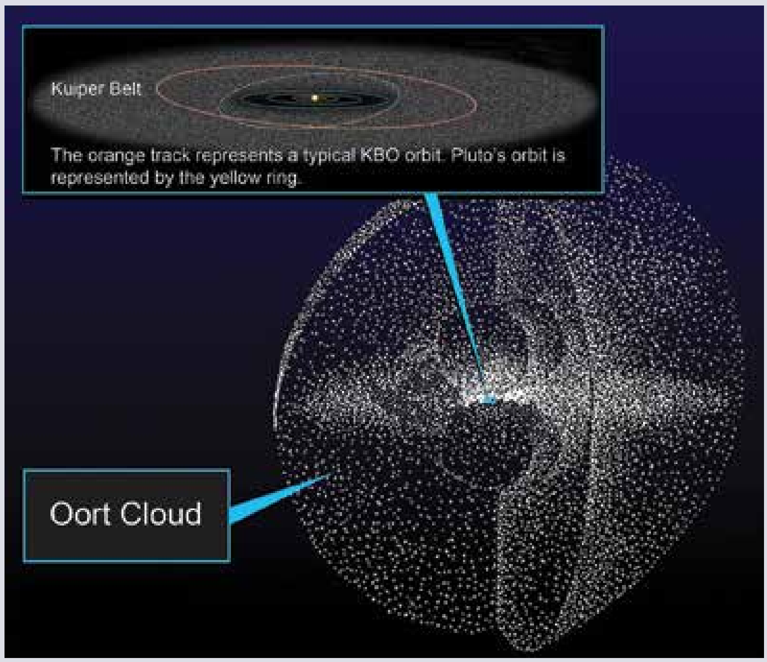


HTTP://PLUTO.JHUAPL.EDU/MISSION

The Kuiper Belt: Home of the comets

The *Kuiper Belt* is a flattened, doughnut-shaped ring of objects orbiting around the Sun that contains leftover planetesimals from the formation of the solar system (see "For Students" question below for more information about planetesimals). It stretches from around Neptune's orbit, 30 AU (4,487,936,121 km or 2,788,674,218 mi.), outward to about 50 AU (7,479,893,535 km or 4,647,790,363 mi.). (One AU, or *astronomical unit*, is the average Earth-to-Sun distance of 149,668,992 km [93,000,000 mi.]). The objects found within the Kuiper Belt all orbit the Sun in the same direction as the planets and follow tilted orbital paths that are more inclined from the plane of the ecliptic than planets and their moons are.

FIGURE 2 Kuiper Belt and Oort Cloud

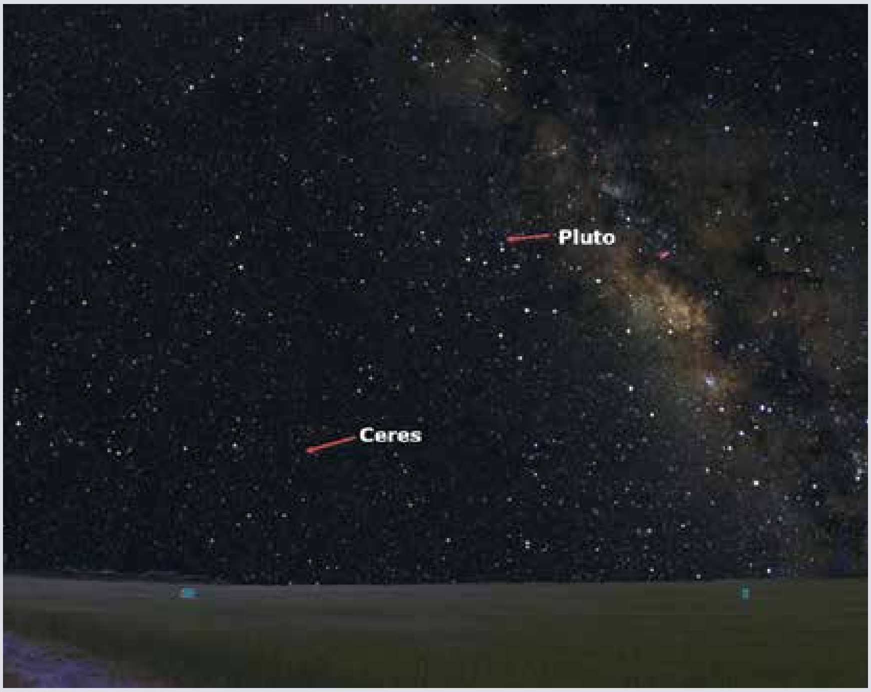


SOLARSYSTEM.NASA.GOV

Some of the objects in the Kuiper Belt are comets, which are classified based on their respective location relative to the rest of the solar system (see Figure 2). Most comets with relatively short *orbital periods* (the time it takes the comet to complete one revolution around the Sun) of less than 200 years come from the Kuiper Belt. However, some of these short-period comets come from distances not much farther than Jupiter's orbit, relative to the Sun. The regular period of Halley's Comet makes it the best known of the short-period comets; it returns to the inner solar system every 76 years.

Farther out from the Sun than the Kuiper Belt, the Oort Cloud, which surrounds the solar system, contains additional planetesimals; however, these objects' respective orbits around the Sun are very random compared to the comets in the Kuiper Belt. Oort Cloud objects have considerably longer periods than Kuiper Belt comets and orbit the Sun from many different angles and directions. It is thought that these comets were "propelled" by gravitational interactions from their original orbits closer to the Sun to where they are now, similar to the way the *New Horizons* spacecraft used a gravity assist from Jupiter to "propel" it toward Pluto. These interactions also cause the randomness in the objects' orbits. One of the recent and more memorable long-period objects from the Oort Cloud was Comet Pan-STARRS (C/2011 L4), which brightened enough at perihelion to become visible with the naked eye (see Resources for more information about comets).

FIGURE 3 Location of two dwarf planets on July 16



Connecting past and future

There are not many generational events in our lifetime that we are able to connect with like we can with Halley's Comet. This comet has a very long history of sightings dating back to Chinese records from around 240 BCE. The last time Halley's Comet passed by the Earth was in 1986 and, with a 76-year period, it will next appear in 2061. It is possible that you or your students know someone born in 1986 and that many will still be around when Halley's Comet returns. Mark Twain was born during the 1835 comet passage and coincidentally passed away with the comet's return in 1910. If possible, show your students a short video of "Halley Came to Jackson" by Mary Chapin Carpenter (see Resources). It tells a story about a girl born in 1910 who is shown Halley's Comet as a baby and again in 1986 at an older age. Follow this up by having students imagine what they and the world will be like in 2061.

Pluto data

- Diameter: 2,274 km (1,413 mi.)
- Average distance from the Sun: 5,913,514,070 km (3,674,487,288 mi.; 39.5294 AU)
- Rotational period: 6.3872 Earth days
- Orbital period: 248.54 Earth years
- Tilt of axis: 122.52°
- Orbital inclination: 17.148°
- Equatorial surface gravity: 0.4 m/s^2 (Earth: 9.8 m/s2)
- Atmospheric composition: Nitrogen, methane

Is it a planet or a comet?

Pluto, which was discovered in 1930 by Claude Tombaugh, is the most well-known and studied member of the Kuiper Belt. For many years, it has been an enigma when considered with the eight planets. Although it is a "hard" planet with rocky terrain, similar to the planets closest to the Sun, it is in a part of the solar system where the planets are mostly liquids and gases. Pluto seems to belong in neither group. With an orbital inclination of nearly 18° relative to the plane of the ecliptic, Pluto orbits the Sun at a steeper angle than the eight planets, making it more similar to the Kuiper Belt comets.

So what is Pluto? It is round like a planet and it orbits the Sun like a planet; however, Pluto fits the current definition of a dwarf planet better because of its distance from the Sun (see Resources for more information about dwarf planets). Pluto is also the first of a group collectively called trans-Neptunian objects, or plutoids. Over the past few years, other objects in the Kuiper Belt have been discovered, some of which have been approximately the same size as Pluto. One of these objects, Eris, which was discovered in 2003, is estimated to be larger than Pluto. The discovery of Eris, as well as many more objects like it, contributed to the impetus to redefine Pluto as a dwarf planet. To get a sense of the number of objects in the Kuiper Belt, visit the Minor Planet website (see Resources). There, under the "Observers" tab, choose "Lists and Plots," then scroll down to the links for plots or graphic displays of the known Kuiper Belt objects. ■

Visible planets

Mercury will be visible over the northeastern horizon at sunrise for the last half of June and first half of July before moving behind the Sun at superior conjunction at the end of July. Watch for Mercury to reappear in the evening skies at sunset during August.

Venus will be visible over the western horizon at sunset during June and July as it heads toward inferior conjunction during mid-August.

Mars will be in conjunction with the Sun and will not be visible during June and July. Mars will reappear in the morning skies during the latter half of August.

Jupiter will be visible but low over the western horizon during June and July, and by August, it will be too close to the Sun to be seen.

Saturn will be visible all night during our summer months and will be in retrograde until mid-August.

For students

1. What are *planetesimals*? *(A* planetesimal *is an object that is theorized to have formed during the early stages of solar system formation. Over time, they collided with other planetesimals and gradually coalesced into planets.)*
2. For about 20 years, Pluto was closer to the Sun then Neptune. At the Minor Planet website (see Resources), there is an animation of the outer solar system showing the movement of Kuiper Belt objects at 200-day intervals over a 100-year period, including Pluto (represented in the animation with a white, crossed circle). During which years was Pluto closer than Neptune? *(Between 1979 and 1999, Pluto was closer to the Sun than Neptune.)*
3. Since Pluto crosses Neptune's orbit, will the two planets ever collide? *(Pluto orbits the Sun twice for every three orbits that Neptune completes. This is called orbital resonance and, as a result, they will not collide because of their respective orbital periods.)*
4. Research the names used for Pluto and its Moons. How is a name determined and what, if any, are the rules or guidelines for naming a planet or moon?

Note: The September issue of *Science Scope* will provide strategies for using the Pluto debate (planet versus dwarf planet) to introduce argumentation and critical-thinking skills into the middle level science classroom.

Resources

Astronomy Day—*www.astroleague.org/al/astroday/astroday.html*

Definition of a planet—*www.iau.org/static/resolutions/Resolution_GA26-5-6.pdf*

"Halley Came to Jackson"—*http://youtu.be/0m3j8VP1oCI*

Halley's Comet—*www.space.com/19878-halleys-comet.html*

International Astronomical Union Minor Planet Center—*www.minorplanetcenter.net*

New Horizons mission—*http://pluto.jhuapl.edu*

Pluto fact sheet—*http://nssdc.gsfc.nasa.gov/planetary/factsheet/plutofact.html*

Information about Pluto—*www.iau.org/public/themes/pluto*

Riddle, B. Scope on the Skies: Comet of the century? *Science Scope* 37 (3): 86–90.

Space Day—*www.spaceday.org*

Bob Riddle (*bob-riddle@currentsky.com*) is a science educator in Lee's Summit, Missouri. Visit his astronomy website at *www.currentsky.com*.

Reviews in this issue:

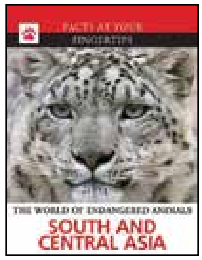
NSTA Recommends: Technology

Looking for reviews of the latest education technology? NSTA Recommends: Technology is now available online at *http://nstacommunities.org/blog/category/recommends-tech.*

Martin Horejsi, an associate professor of instructional technology and science education at the University of Montana in Missoula, and Edwin Christmann, a professor and chairman of the secondary education department and graduate coordinator of the mathematics and science teaching program at Slippery Rock University in Pennsylvania, field test the latest technology for science educators and share their findings in NSTA's newest multimedia blog. Be sure to check out the latest postings, including reviews of the Einstein Tablet, the Weatherhawk myMET Digital Windmeter, and the RSpec-Explorer.

http://nstacommunities.org/blog/category/recommends-tech

The World of Endangered Animals: South and Central Asia



By Tim Harris. $27.95. 64 pp. Black Rabbit Books. Mankato, MN. 2015. ISBN: 9781781210772.

Are your students concerned about endangered animals? Do you personally need an update on the status of Asian endangered animals? This book starts with an overall look at the habitats of, threats to, and conservation efforts for endangered species in South and Central Asia. The author examines animals from several categories, from snow leopards and Asian elephants to spoon-billed sandpipers.

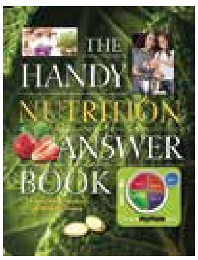
For each animal, the book provides a data panel with information on world populations, habitat, related endangered species, and more. The maps are a great help in understanding the geographic locations of these animals. Appendixes feature wildlife organizations and a list of more endangered animals. A glossary is provided to clarify terms in the book and resources on books and websites to offer more in-depth, specific information on birds, fish, amphibians and reptiles, insects, and general topics related to endangered animals.

The author of the books used a classification system for endangered species with which I was not familiar. 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/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).

This book would allow students and adults to critically evaluate, based on criteria described, the ranking of the species in the books, the potential use of the rankings (automatic legal protection is not provided based on these rankings), 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. The book models a rational, logical way to look at both sides of the question without the drama we are so used to seeing in scientific debates.

Diana Wiig

The Handy Nutrition Answer Book



By Patricia Barnes-Svarney. $21.95. 384 pp. Visible Ink Press. Canton, MI. 2015. ISBN: 9781578594849.

Do you need to find answers to student questions concerning nutrition? Composed as a series of nearly 900 questions and answers, *The Handy Nutrition Answer Book* highlights both explanatory and interesting information related to nutrition. Topics include nutrition basics, food processing and preservation, how to read food labels, food choices, allergies, diets, and food controversies.

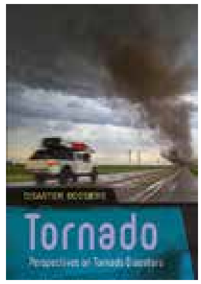
The book's easy-to-use format allows readers to find the answer to a single burning question that is on their mind or to read an entire chapter about a nutrition topic. One section of the book, "Nutrition through the Centuries" addresses how history has influenced our modern eating habits, dating back to the earliest humans. This topic is otherwise difficult to find resources for and is left out of many textbooks. The appendixes are also helpful with a list of nutrition websites, an extensive glossary, and an in-depth comparison of the pros and cons of mainstream diet plans.

This book could be used in a variety of ways in the classroom. It would be a great reference for both teachers and students as a part of any science-classroom library. For classes that focus on the human body or nutrition, this book provides a great jumping-off point for discussion or debate about controversies surrounding food. For example, "What are some major concerns surrounding cow's milk?" "How much arsenic is allowed in drinking water?" and "Is it really necessary to take vitamin and mineral supplements?"

The easy to read Q-and-A style, as well as the high-interest content, makes this a great addition to the middle or high school science classroom. The questions are relevant and the answers are short and to the point. If you have been looking for a helpful and handy nutrition reference, this book may be the answer for you.

Alexandra D. Owens

Disaster Dossiers: Tornado



By Ben Hubbard. $25.13. 56 pp. Heinemann-Raintree. Chicago. 2015. ISBN: 9781484601839.

Have you ever experienced a tornado? In this book, the entire life cycle of a tornado is explored. The authors use charts, maps, time lines, and statistical data to provide extensive information about this phenomenon. The book is designed to help readers understand the nature of tornadoes and how to survive these violent storms.

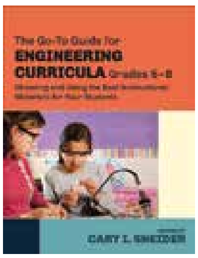
A time line shows the step-by-step development of a tornado. Also, a chart illustrates elements of the Enhanced Fujita Scale (EFS) used to rate tornadoes in the United States and Canada. All of the phases in major tornadoes are described in six dossiers—warning signals, rating, emergency services, the media, scientists, survival stories, rescue, relief, recovery, and reconstruction. Details on each phase are brought to the forefront in dossiers depicting the extraordinary tornadoes in Oklahoma in 2013.

Eyewitness accounts and stories of survivors are intriguing and unimaginable. However, they enable readers to experience the devastation. Further, concise facts about the deadliest tornadoes in modern times are revealed. It is of interest to note that despite the danger, there are still "thrill seekers" who try to outrun tornadoes. In a limited number of pages, a wealth of information is presented that can readily be understood by young readers. At the end of the book, important lessons learned from the Oklahoma tornadoes are listed and the time line is reiterated.

Readers will find a glossary and a Find out More topic listing books, websites, and additional research topics. An index and information about the authors are also included. This would be an excellent resource for government agencies to help the average citizen understand what to anticipate and how to prepare for and survive a tornado, especially for residents in Tornado Alley. Young readers will find this book useful while studying weather phenomena.

Jean Worsley

The Go-To Guide for Engineering Curricula, Grades 6–8



By Cary I. Sneider. $32.95. 223 pp. Corwin Press. Thousand Oaks, CA. 2015. ISBN: 9781483307374.

Need some new ideas for teaching engineering to students in grades 6–8? This impressive book describes 14 design challenges from the experts, ranging from basic to more advanced. The chapters include lessons using Design Squad; using and building models such as a water wheel, which can improved upon; reverse engineering items such as a pen; and solving problems using Lego robotic rovers. There is a good mix of low- and higher-cost materials.

This resource is both practical and useful. The focus of several chapters is on questioning the world, so students can design solutions to real local and global environmental problems. What better way to motivate a group of middle school students? Whether you currently have a Maker's Space or are starting from scratch, this resource provides many divergent ideas that would fill every need, activity, space, and student. Finally, the book has chapters on STEM and girls, robots that travel underwater, news on careers in engineering, and a K–12 course called Engineering by Design. At the beginning of the guide, there is a full page lising 30 reliable K–12 engineering-education websites. To get an overall vision of what is available, there is a two-page table of instructional materials in the *Go–To Guide for the Engineering Curricula* series.

I also highly recommend reading the forward written by Janet L. Kolodner, which validates the reasoning and importance of teaching engineering. She writes that "Good education is not about covering the material." Instead, it is about understanding in depth, spending time thinking, and puzzling out solutions. It takes time, but the gifts are seen in my seventh grade class as students learn about the world and about themselves. One of the questions I ask as they leave my class is, "What did you learn about yourself today?" I am often rewarded with one of my favorite answers: "I learned that I am good at engineering!"

Teri Cosentino

NSTA Recommends is your best source for thoughtful, objective reviews of science-teaching materials. These include books, DVDs, kits, and other materials that are reviewed by your peers. Our volunteer review panel is made up of top-flight teachers and other outstanding science educators who classroom-test these resources and let you know what's really useful. To see more product reviews, please log on to *www.nsta.org/recommends,* where you can search our database of nearly 4,000 teaching resources.

Can you identify our Mystery Photo?

How to submit a guess

In each issue of *Science Scope*, we publish a science-related image for your students to identify. When an image is published, teachers can submit a guess on behalf of their class through our website, by e-mail at *sciencescope@nsta.org* (please include "Mystery Photo" in the subject line), or by mail (*Science Scope*, Mystery Photo, 1840 Wilson Boulevard, Arlington, VA 22201). Those classes that correctly identify the Mystery Photo of the month will be eligible for a drawing to receive an item of their choice from NSTA's Science Store.

Only one entry per class per contest will be accepted. Please be sure to include the instructor's name, subject taught, grade level, and name of your school along with your guess. The names of the contest winners, as well as the solution to the Mystery Photo, will be published in the following issue's column.

This month's Mystery Photo may leave you scratching your head, and your arms, and behind your knees…

Last month's answer: Volcanic Lightning

OLIVER VANDEGINSTE/SCIENCE SOURCE

The winner of the April/May 2015 Mystery Photo Contest is Roberta Brown's sixth grade science classes at the University School in Shaker Heights, Ohio. Roberta and her class will receive one item of their choice from the NSTA Recommends catalog (*http://digital.nsta.org/publication/?i=175447*).

This is a picture of volcanic lightning generated during the 2010 Eyjafjallajökull volcanic eruptions. Volcanic lightning is the release of electric charge that builds up as rising ash mixes with the atmosphere. Scientists theorize that volcanic lightning is generated when particles of ash separate, either after a collision or when a larger particle breaks in two. Differences in the aerodynamics of these particles cause the positively charged particles to be systematically separated from the negatively charged particles. Lightning is the electrical flow that results when this charge separation becomes too great for air to resist the flow of electricity. This flow, in the form of a lightning strike, travels between the positive and negative regions of the cloud. This type of lightning has also been observed during the April 2015 eruption of Chile's Calbuco volcano.

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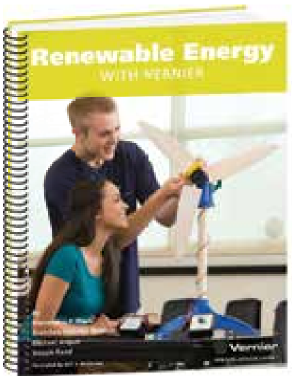

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