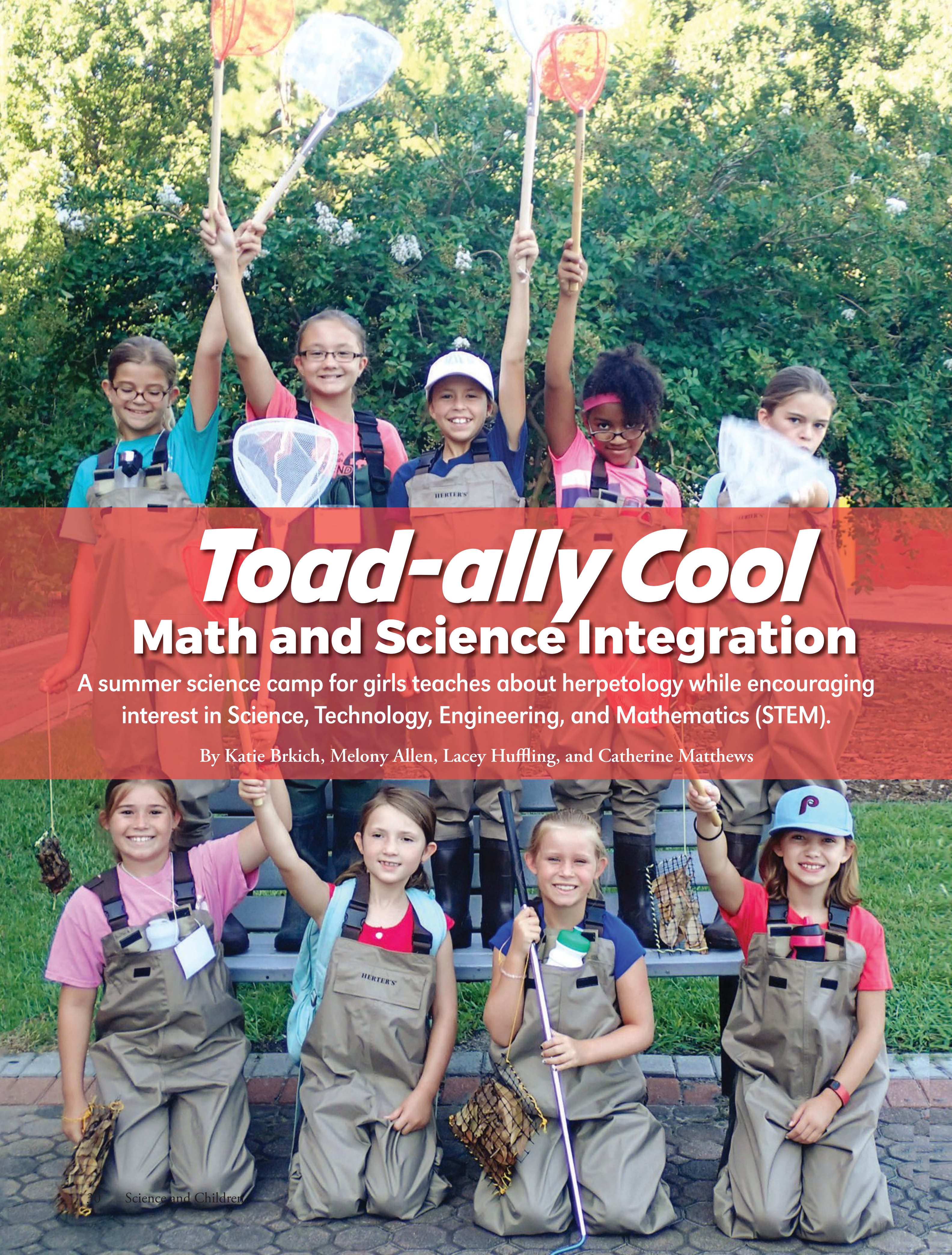


Toad-ally Cool

Math and Science Integration

A summer science camp for girls teaches about herpetology while encouraging interest in Science, Technology, Engineering, and Mathematics (STEM).

By Katie Brkich, Melony Allen, Lacey Huffling, and Catherine Matthews

Male toads are typically much smaller than female toads. This statement—and others similar to it—on various "about toads" websites and in some field guides served as the springboard for our phenomenon-based exploration integrating science and mathematics. The setting was a weeklong herpetology-focused summer STEM camp for rising fourth-, fifth-, and sixth-grade girls. Our camp, *Hop to It*, provided young females with authentic, hands-on science experiences, allowing them to develop the habits of thought and processes of action used by STEM field experts while also engaging and sustaining their interest in the STEM fields. In this way, *Hop to It* also served as an excellent opportunity to redress a longstanding and persisting educational inequity of women being underrepresented in STEM (Sassler, Glass, Levitte, and Michelmore 2016). Scholarships for students from low socioeconomic homes were funded by *The Herpetology Education in Rural Places and Spaces (HERP) Project*, a collaborative, statewide informal science education NSF grant–funded project created to provide opportunities for the general public, high school students, and secondary school teachers to learn about and collect scientific data on common native species of reptiles and amphibians in local habitats (see Internet Resources). The HERP Project Cyberhub is designed for people of all ages who are interested in herpetology, particularly the herpetology of North Carolina. Under Resources teachers can find a variety of resources including apps, videos, puppet plays, and costume ideas to help teach this content, including six sets of free curricula on the following topics: box turtles, ephemeral pools, stream amphibians, aquatic turtles, lizards, and snakes.

Inquiry and fieldwork were central features of *Hop to It*. Additionally, we incorporated a strong component in mathematics, including measurement, which ultimately supported participants' use of evidence-based reasoning and scientific argumentation. In this article, we explain the activities, describe the elementary-age girls' engagement in the various activities, and offer suggestions for providing similar learning experiences.

The activities described in this article are certainly appropriate for mixed gender classrooms, as we have found in our prior instructional experiences that both boys and girls enjoy fieldwork and classwork with living organisms. We also recommend considering the cultural differences among students—being outdoors and handling animals can elicit different responses based on students' backgrounds. It is important for teachers to be aware of students' comfort levels in the outdoors. While our girls elected to participate in *Hop to It* and knew that a lot of our time would be spent outside, a class of elementary school students will likely include some students who are comfortable outdoors and have caught common animals along with other students who are not comfortable outdoors and have never had opportunities to catch common animals. It is also likely that some students and their parents may insist that toads cause warts *even though we know that is not the case*. Knowing students' backgrounds can help in grouping students by comfort level with being outdoors and handling animals. Having jobs such as recorder, finder, catcher, and watcher provides opportunities for initial task differentiation as students can determine what job aligns with their comfort level and start their experiences there.

Let's Head to the Field!

We began with fieldwork, visiting nearby wetlands including lakes, streams, and mud puddles. In the true spirit of inquiry, beginning with fieldwork allowed the girls to explore and discover the abundance of life that exists in these habitats. It should also be noted that beginning our day with fieldwork increased our chances to see active animals, rather than waiting until later in the day when temperatures increase and herps seek shelter.

PHOTOS COURTESY OF THE AUTHORS

Students search for amphibians among leaf litter (left) and learn how to catch specimens with nets (right).

Students prepare a leaf trap (left) and examine a water sample (right).

Follow your school or district guidelines for outdoor exploration and field trips. We provided chest waders for the girls to wear and nets to catch any specimens we saw. Girls were encouraged to catch tadpoles, dragonfly larvae, scuds, worms, and frogs, and they even chased a snake but couldn't catch it (we did explain that they should catch only nonvenomous snakes that they could identify). NSTA also recommends the use of safety goggles during fieldwork to keep twigs or branches from scratching students' eyes (Roy 2015). Gloves were available for use in the field and in the classroom, and we made sure students practiced proper hand washing.

Students observed how to safely obtain specimens.

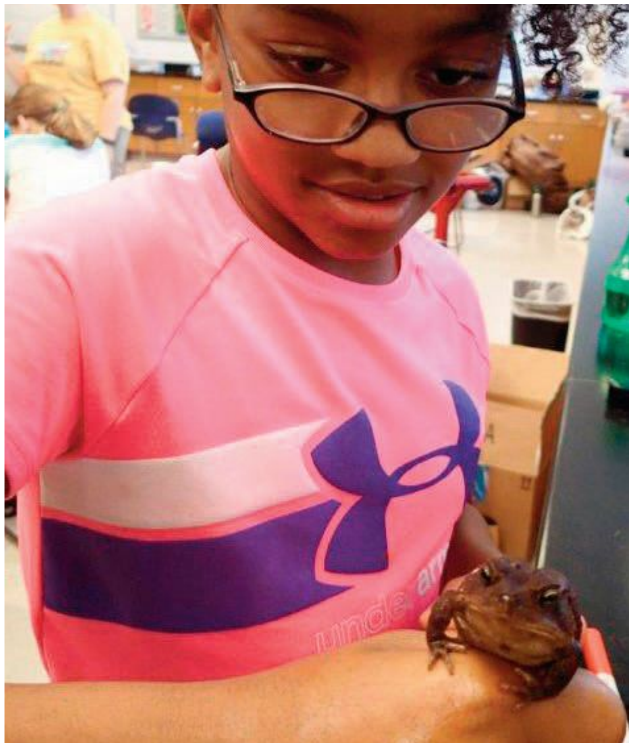
Participants immediately noticed an abundance of toads in these locations. They became distracted from setting leaf packs (passive traps for aquatic vertebrates and invertebrates consisting of handfuls of leaves packed inside mesh containers) and more interested in toad catching! Based on the girls' reactions to these creatures, it was clear we needed to bring toads into the classroom.

As *Hop to It* facilitators, we humanely caught and temporarily added eight toads (they were released within a 48-hour period) to our assortment of live reptiles and amphibians, which served as the centerpieces for teaching and learning. It should be noted that live amphibians were caught by hand by trained adults and always handled with wet hands for the animals' safety and comfort. We believe toads are easier to work with than frogs. We have noted how hardy toads seem to be and are readily abundant in many places. Frogs generally have smooth, slippery skin, making them difficult to handle. They also have the ability to jump long distances, which may intimidate the new handler. Toads, however, generally have rough skins, which are easier to hold. A toad's hop may be less intimidating to students, since it's easier to predict where a hop will land.

Given our students' reactions in the field, we dedicated the first two days specifically to toads. During this time, the girls would be exploring, observing, and analyzing toads, and then drawing conclusions based on their analysis.

Aren't Boys Usually Larger Than Girls?

While some of the girls approached the captive amphibians reluctantly, their interests quickly overrode what hesitations they had, as the allure of doing "real science" enthralled them. We set up five aquaria with one or two toads per aquaria and demonstrated how to carefully measure, weigh, and record data about toads. In addition to observations and data collection, we presented the girls with a question. While doing background research, one of the camp facilitators read a Wikipedia post that said male frogs are usually smaller than female frogs and wondered if this was true. We posed this claim as a question and asked the girls to make a claim supported with evidence: Are male frogs really smaller than female frogs? As our investigation focused on the question of whether male toads are indeed smaller than their female counterparts, participants were first faced with the following question: *How do we tell them apart?* Herpetologists use a variety of techniques to distinguish between a female and male specimen when its reproductive organs are not obvious to the untrained eye, so we taught the girls how to distinguish between the toad sexes. While there are several characteristics that distinguish the female southern toad (*Bufo anaxyrus terrestris*) from its male counterpart, we used their throat coloring to classify them (during the breeding season, males tend to have darker patches of skin around their throats, which is their deflated vocal sacs when they are not calling; whereas females tend to have lighter ones since they do not call). Once the girls could distinguish the males from the females, we asked them: *What differences do you notice between the males and the females?* Answers ranged from the throat patches (we had previously discussed) to comments about the males looking slightly smaller than the females and having slightly more skin under their chin than the females (from the presence of vocal



sacs, which the females do not have). Once these initial observations were made, we were able to ask additional questions: *Why do you think these differences exist* and *Why do you think the male is able to call and the female is not?* During this portion of the activity, we prompted participants (through discussion and questioning and use of their field guides to determine how to correctly sex toads) to reason why size, coloring, and ability to "call" might provide an advantage in finding mates and/or reproducing.

The girls' interest in toads led to investigations back in the classroom.

The students had the opportunity to see toads eat crickets in their enclosures. After they completed their introductory observations, which took about 30 minutes, we modeled how to safely handle the toads. Teaching children how to catch and handle toads in the natural environment can be difficult. We placed the specimens that we caught into an empty plastic baby pool, which provided an orderly approach for teaching students how to catch and handle the toads in responsible and humane ways. The girls were taught how to properly hold a toad by its hind legs with clean, wet hands. Each girl practiced this with an instructor, making sure the toad was no more than a few inches from the floor in case the toad fell from the student's hand. It is important to take time to teach students proper handling techniques to ensure the safety of the organisms. For more information on toad handling, see the Animal Handling Guide on the HERP Project Cyberhub (see Internet Resources). Students washed their hands with soap and water after handling toads. CAUTION

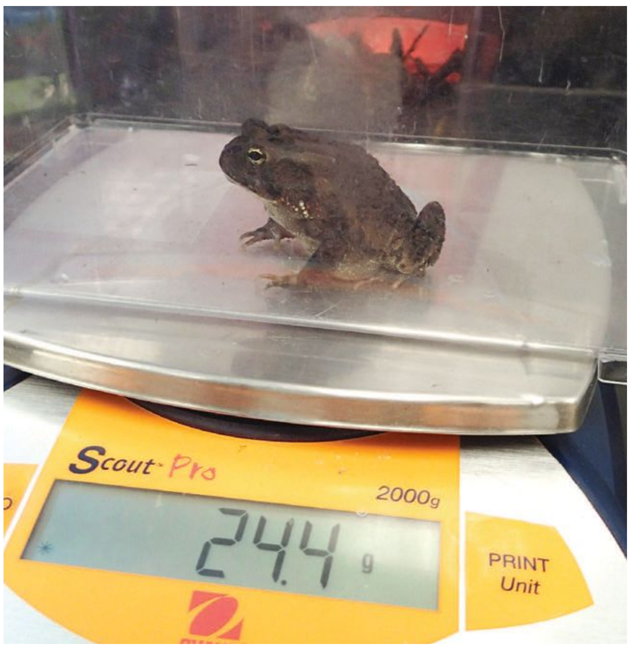
We encouraged the girls to hold and examine the toads more closely and use the criterion of throat coloring, along with their observations and field guides, to identify the type of toad and each toad's sex. They were able to identify the sex of seven southern toads with accuracy—four females and three males. They classified the remaining toad as a juvenile and—because of its small stature—were unable to definitively identify its sex. The girls spent roughly 45 minutes identifying and further observing the toads.

Amphibian Weights and Measures

Once students made their determinations of the specimens' sexes, they were assigned one specimen to measure. Using a digital scale, they took the mass of each specimen in grams and recorded these in a group data table, which we had displayed prominently for all to see. Then, under individual supervision for the specimens' safety and well-being, students were assisted in using a ruler and plastic caliper to measure each specimen's snout-vent length (SVL) in centimeters and likewise recorded these in the group data table. Data collection took approximately 30 minutes to complete. Later that evening, we transferred these data to a digital table for collective use the following day.

By conducting data collection in this fashion, we aimed to provide girls with an experience similar to those of field experts across a variety of STEM disciplines. By their nature, large STEM research projects tend not only to be interdisciplinary endeavors but also require the collaboration of several professionals, each with her own piece of the project to complete. With the understanding that the accuracy of their measurements was essential to the investigation's success, the girls learned that STEM research projects also require elements of interdependence—that if each did not pull her own weight and produce quality work including precise measurements, any subsequent analysis and conclusions would suffer.

Reflecting on this exercise, while a total of eight toads was sufficient to engender our girls' interest in the topic and make them aware of the work STEM professionals



The girls measured the length and weight of the toads.

do in their careers, it might be better to have more. More live specimens will allow for varied measurements and less handling of one particular specimen. However, if only a limited number of specimens are available, then we suggest having students measure each specimen along each criterion three times and report the mean. In this regard, group data will be more precise—and further impart the importance of mathematical precision in STEM.

Mathematics in Action

The next morning—the third day of *Hop to It*—participants began the data analysis phase of the learning experience. Performing some basic descriptive statistics, they identified which specimen weighed the most and least and which specimen had the longest and shortest SVL. Using these data, they were then able to calculate the ranges of the specimens' weights and SVLs. Understanding the data range, we taught the girls what *outliers* are and why being able to identify them is important in science and mathematics (particularly statistics). We explained that an outlier lies outside (i.e., is much smaller or larger than) most of the other values in a set of data. To explain this concept, we used the example of the average age of people in our room. If we included the one teacher's age with all the girls' ages, we got a much different number than if we identified the teacher's age as an outlier and only analyzed the girls' age data.

Using this understanding, they identified both the data on the juvenile southern toad and the tree frog from our collection of live specimens as outliers—statistical anomalies—and gave reasons as to why they should be excluded from further analysis. One pair noted in their analysis that they needed to be excluded "because they were different" in the measurements—providing a mathematical justification for their exclusion. Another noted that the juvenile needed to be excluded "because we couldn't tell the gender." A third stated that they "excluded the juvenile toad and tree frog" but failed to provide a justification for their exclusion from the final analysis. Once excluded, the girls calculated the mean weight and mean SVL of the remaining viable specimens. The data analyses and discussion took roughly 45 minutes to complete.

By conducting data analysis in this fashion, we aimed to provide the participating girls insights into the steps involved. In the pursuit of STEM research projects, STEM professionals need to be able to sift through large quantities of data in order to come to some meaningful understanding. Furthermore, while statistical outliers provide certain character to a data set, failing to account for or control these sufficiently can lead to inappropriate data interpretation.

Extraordinary Claims Require Extraordinary Evidence

The final task using the toad data was to revisit the statement that prompted this whole exercise: *Male toads are typically much smaller than female toads*. Based on the data they collected and analyzed, we required the girls to develop a Claim-Evidence-Reasoning (CER) argument to either support or refute the phenomenon statement. The CER formative assessment (see NSTA Connection) and discussion took an additional 30 minutes to complete. The students' CERs varied in terms of detail, quality, and focus. Some students presented evidence exclusively on the specimens' weights. One pair stated that "the average female toad weight is 28.5 g and is more than the average male toad weight, 18.5 g"—giving their assertion numerical precision—whereas another noted "the average female toad weighs more than the average male toad." Only one pair included discussion of the toads' lengths in the CER: "Females are bigger than males in length (5.8 cm vs. 5.5 cm)."

In addition to being engaging to the girls, toads are easier to manage in the classroom.

Outdoor explorers demonstrate their readiness to search for amphibians.

Nevertheless, all groups came to the same conclusion—that the phenomenon statement was true. They reasoned: "Our evidence shows our female toads had both more weight and more length than male toads, which supports our claim." Incidentally, they were very excited that their toads "proved Wikipedia was right for a change."

By having participants produce Claim-Evidence-Reasoning arguments, we aimed to cement the notion that STEM professionals do not guess, do not make unsubstantiated claims, and do not use the phrase "I have a theory..." as it is used in common parlance. In the context of their jobs, STEM professionals use evidence and reasoning to either support or refute a claim—and that it is perfectly acceptable to say, "I don't know yet." As the late Carl Sagan once famously said, "I try not to think with my gut. If I'm serious about understanding the world, thinking with anything besides my brain—as tempting as that might be—is likely to get me into trouble. Really, it's okay to reserve judgement until the evidence is in" (1995).

Science and Mathematics—Like Peas and Carrots

The girls' exploration of toads as part of *Hop to It* has shown that science and mathematics go together—as Forrest Gump stated famously—"like peas and carrots." The use of precise measurements, construction of data tables and graphs, and analysis of data to drive evidence-based claims about the world constitutes a large part of what STEM professionals do. In the case of the exploration of the phenomenon statement *Male toads are typically much smaller than female toads*, our students took carefully precise—and when necessary, supervised—measurements, made considerations of which data to include in their final analysis and which to exclude, made mathematical calculations based on these data, and made evidence-based claims with reasoned justifications in support of these claims.

The toad exploration took place over the first three days of *Hop to It*, and our girls developed a significantly deeper understanding of the habits of thought and processes of action used by STEM field experts. Over the next two days, in which we conducted several explorations with lizards, the students took these experiences with them, and—unprompted and unguided—sought out data points they felt were relevant to substantiate the lines of inquiry that enthralled them. Ultimately, we feel that this serves as the measure of success for our endeavor—creating learning conditions that allow girls to sustain an interest and develop a passion for STEM. ■

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Internet Resource

The HERP Project Cyberhub
https://theherpproject.uncg.edu/resources

NSTA Connection

Download the CER rubric at *www.nsta.org/SC1707*.

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

3-LS4 Biological Evolution: Unity and Diversity

www.nextgenscience.org/dci-arrangement/3-ls4-biological-evolution-unity-and-diversity

The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities. The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectation listed below.

Performance Expectation	Connections to Classroom Activity *Students:*
3-LS4-2. Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.	• construct an evidence-based argument to support or refute a phenomenon statement using observation and measurement data of toad specimens.
Science and Engineering Practices	
Planning and Carrying Out Investigations Using Mathematics and Computational Thinking Engaging in Arguments From Evidence	• observe to determine species and gender of toad specimens. • measure weight and snout-vent length of toad specimens. • calculate range and mean for data sets. • construct claim-evidence-reasoning (CER) argument regarding accuracy of the phenomenon based on data.
Disciplinary Core Idea	
LS4.B: Natural Selection Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing.	• examine gender differences in toad specimens and reason why size, coloring, and ability to "call" might provide an advantage in finding mates and reproducing.
Crosscutting Concepts	
Patterns Structure and Function	• look for patterns in data to examine relationship of toad characteristics to gender. • observe toad structures and consider function in reproduction or finding mates.