Real science in the palm of your hand

A framework for designing and facilitating citizen science in the classroom

By Emily Harris and Heidi Ballard

After an eight-week unit exploring ladybugs, third grader Jessica presented findings about the ladybug species found in the school garden to her peers, teachers, district staff, and community members at a schoolwide showcase. Previously, Jessica said she enjoyed science but had not seen herself as a strong science student and was quiet during group discussions. Throughout the unit, students read about and sketched ladybugs in the garden and documented the local ladybug species weekly, photographing those they found. They submitted photographs to the Lost Ladybug Project (LLP), a citizen science (CS) project documenting ladybug species distribution across North America. After her teacher modeled how to take high-quality photographs, Jessica led as her team's photographer, taking, evaluating, and retaking ladybug photographs to submit to LLP. Based on her teacher's suggestion, during the showcase Jessica used the iPad to demonstrate how to take and submit quality photographs. The class also wrote essays about the ladybugs, and Jessica took pride in her writing. In these moments, she was seen—and started to see herself—as an expert. For months afterward, she and her peers continued finding and documenting ladybugs at home and school and helped the garden manager consider new plants to provide a year-round ladybug habitat.

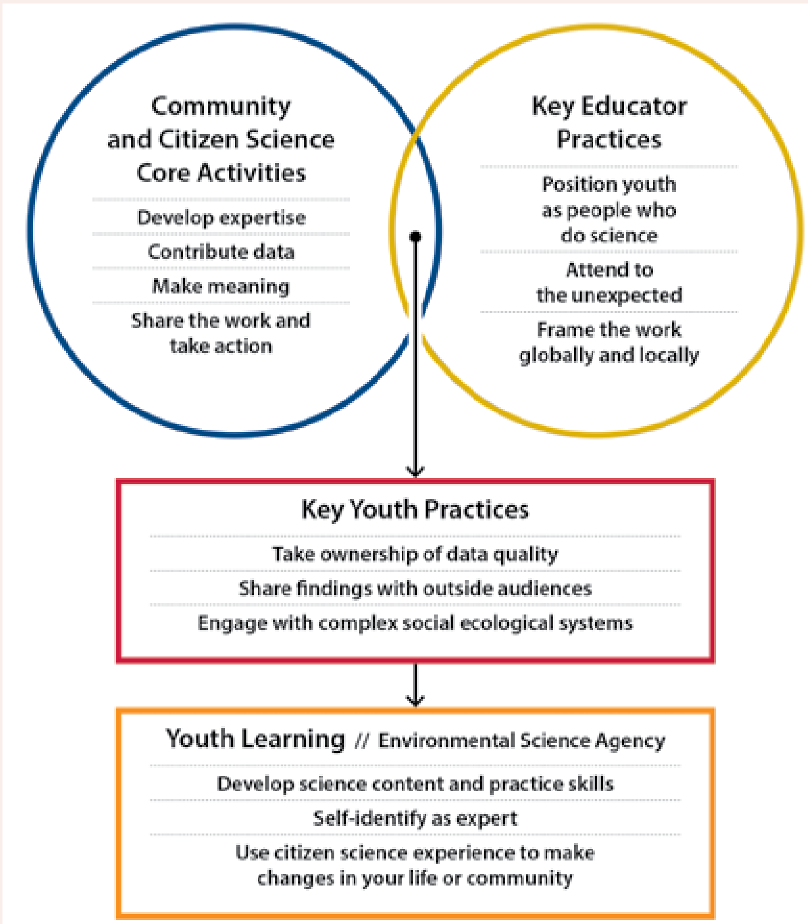
What conditions led to Jessica's experience? Educators and researchers often suggest that participation in "real" science may help students "think like" or "see themselves as" scientists because students participate in and contribute to the broader scientific community. However, bringing CS activities into the classroom does not necessarily lead to these outcomes; Jessica's experience did not happen by default. In this article, we draw on findings from our research (Ballard, Dixon, and Harris 2017) and offer a framework to help educators approach *any* CS project. We share a research-based framework (Figure 1) intended to help educators think beyond *what* CS activities to do and consider *how* to design and facilitate those activities for meaningful student learning.

Environmental Science Agency

Previous research shows that CS can support outcomes such as learning science content or improving student perceptions of scientists (Houseal 2016). Our research focuses on the specific outcome of *environmental science agency* (ESA) (Ballard, Dixon, and Harris 2017), which we examined in 10 case studies of youth participation in CS activities, including groups monitoring bird populations, butterfly life cycles, water quality in urban creeks, or land use. The concept of ESA has three interconnected core elements, which build on work by Basu and Barton (2009). First and foundational is that young people *develop an understanding of environmental science content and inquiry practices*. In our case studies, students developed deeper understandings of the ecosystems and organisms they worked with. Students learned how to collect and analyze data, evaluate data quality, draw conclusions, and communicate findings through writing and presentations. For example, Jessica learned about the stages of ladybug life cycles (including egg, larva, pupa, and adult) and analyzed ladybug data from the garden, presented to school stakeholders, and wrote about her findings. This ESA component aligns directly with the disciplinary core ideas (DCI) and science and engineering practices (SEP) in the *Next Generation Science Standards* (*NGSS*). Second, ESA highlights the ways young people *self-identify as experts* and develop personalized roles within scientific work. Our research identified scientific and social roles students take up, such as teaching peers how to collect data or leading presentations. For example, Jessica became the team photographer, photo quality monitor, and presenter of technological tools. These roles allow students to specialize, develop, and recognize their unique expertise that aligns with who they are or want to be. Finally, ESA involves young people building on their CS experiences to *create change—large or small—in their own lives or communities*. We saw student actions manifest in many ways, from gaining confidence to share ideas, to advocating for chang-

FIGURE 1.

Research-based framework.



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es in land management policy to city council members. Jessica made recommendations for school staff to select plants to promote year-round ladybug habitat. This ESA component is crucial. Emphasizing youth agency moves beyond considering science content as the only important outcome for student learning (Basu and Barton 2009) and is particularly relevant for CS that often targets environmental issues such as habitat restoration, biodiversity, and community health.

Core CS Activities

Our framework outlines four kinds of Core CS activities that, with careful facilitation, can foster ESA (Table 1, adapted from Fee 2005 and Herszenhorn, Johnson, and Young 2015). Though they appear linear, activities could happen anytime during a CS project. First, activities that allow students to *develop expertise* involve opportunities for students to develop interest and learn about the study organism, explore the study site, and/or practice data collection protocols. For example, in one fourth-grade bird monitoring project using BirdSleuth (see Internet Resources), students learned how to identify birds by observing their colors, flight, size, and song during weekly observations. Second, activities where students *contribute data*, by collecting and submitting data to an established

TABLE 1.

Core citizen science activities and examples. Adapted from Fee (2005) and Herszenhorn, Johnson, and Young (2015).

Community and Citizen Science Core Activities	
Activity	**Examples**
Develop expertise Develop youth interest and gain proficiency with data collection	• Introduce the project • Learn from field guides • Observe and sketch specimens • Practice collecting or identifying organisms • Work with a local expert
Contribute data Collect and upload data	• Small group practice • Develop specific roles • Develop peer leaders • Review and compare data • Investigate monitoring site
Make meaning Reason and reflect about the data and experience	• Analyze data by identifying species, describing patterns, and making graphs • Further investigate based on youth questions • Reflect on experiences
Share the work and take action Apply understandings and extend the work beyond the classroom	• Present to other classes • Talk to local citizen scientists • Share findings with stakeholders such as local organizations, school leaders, city council, and parents

CS project, set CS apart from other quality science learning activities. Collecting data in small teams of two or three allows students to access materials and take on specialized roles. Parent volunteers can help reduce group size and increase student participation. Third, follow-up activities where students *make meaning* of the data offer rich oppor-

TABLE 2.

Core CS activities and examples from the ladybug unit.

Activity	Specific activities from the ladybug unit
Develop expertise Develop youth interest and gain proficiency with data collection	• Introduce the LLP and the problem scientists are trying to address. • Introduce a local driving question for the unit "What ladybugs are in our garden?" • Read expository text about ladybug life cycles and habitat • Sketch ladybug specimens • Observe live ladybugs under the overhead projector • Use ladybug field guides to practice identifying ladybugs • Look online at the LLP data visualization tool to see ladybug species around the world
Contribute data Collect and upload data	• Practice finding and collecting ladybugs in the garden • Learn what constitutes a good photograph • Practice photographing ladybugs • Designate roles during data collection including: finder, notetaker, and collector
Make meaning Reason and reflect about the data and experience	• Compare species found in the garden to species found by other citizen scientists nearby • Generate new questions about ladybugs for investigation
Share the work and take action Apply understandings and extend the work beyond the classroom	• Work in groups of four to create posters for showcase presentation • Practice presentations with a second-grade class • Present to district administrators, parents, and master gardeners • Develop recommendations on what to plant to increase ladybug habitat in the garden

tunities for student reasoning and reflection. For example, students can review their data, compare it to data gathered by other CS participants, discuss if these data are good enough for scientist to use, and analyze larger datasets. Finally, activities where students *share the work and take action* allow students to apply new understandings and extend their work beyond the classroom. This might include making land management recommendations, writing a letter to city council, or sharing surprising discoveries with family members. Practicing oral presentations or writing letters can help students develop confidence in their voice. Table 2 provides examples from the ladybug unit.

Designing and Facilitating CS

Doing Core CS activities alone won't necessarily be meaningful for students. CS data collection can easily become a mundane science lab or be perceived as rote work done for distant scientists with esoteric questions. What practices can students and teachers engage with to ensure that CS can achieve meaningful student learning?

Key Youth Practices

We identified three key youth practices that, when students experience them, can support their development of ESA (Figure 1, p. 32). We found that when students are able to take ownership of data quality, it positions students as experts and encourages investment in the scientific work. In Jessica's case, her teacher demonstrated what constituted high-quality LLP data—a clear, large photo of the ladybug—and then gave her responsibility to make sure quality photographs were taken. In another case, it meant students ensuring correct bird species identifications or accurate counts of individual birds. As a teacher, get to know what high-quality data looks like for your chosen CS project. Then, pose open, critical questions to help students evaluate and come to their own understandings of what information they need to collect and submit quality data (Figure 2).

We found that when students *share findings with outside audiences*, such as administrators, scientists, and community stakeholders, it can motivate student ownership of their work. Recognition from local governments or members of the public helps students start seeing themselves as experts, which is an important foundation for individual and community action. For example, presenting at the showcase allowed Jessica to lead science communication, when she otherwise might have been overshadowed by more talkative peers.

Finally, *engaging with complex social-ecological systems* involves students thinking about the interactions between humans and nature and their own role in those systems. We found this helps students realize that impacting the environment is not a choice, but impacting it positively can be. Through garden visits and classroom conversations, Jessica, for example, came to see that she could play a role in improving ladybug habitats at school through garden management decisions.

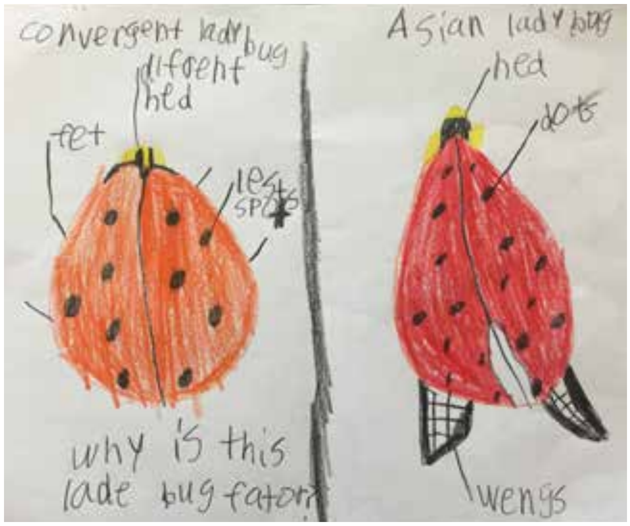

FIGURE 2.

Questions to help students evaluate data quality.

When collecting or submitting data

- Are these data good enough for a scientist to use for her/his/their research?
- How certain are you about [your methods, species identification, count ...]?
- What could we do to be more certain? What evidence would you need to be certain?
- What remains uncertain?
- Do others agree?

When reviewing data from other participants

- How do our data compare to the data [another project participant] gathered?
- How do you think [another project participant] collected their data?

When planning for data collection or analyzing existing data sets

- What do you want to find out?
- What data do you need to answer your question?
- Do you need data from additional sources?

TABLE 3.

Example projects for elementary students in the school yard.

Focus	Example CS projects
Insects	• Great Sunflower Project *www.greatsunflower.org* • Lost Ladybug Project *www.lostladybug.org* • Monarch Larvae Monitoring Project *www.mlmp.org*
Birds	• eBird *www.birdsleuth.org* • Feederwatch *http://feederwatch.org* • Celebrate Urban Birds *http://celebrateurbanbirds.org*
Plants	• National Phenology Network *www.usanpn.org/natures_notebook*
Weather	• GLOBE Cloud monitoring *www.globe.gov/web/s-cool/home*
Any living organism	• Bioblitz *www.iNaturalist.org*

Key Educator Practices

What can educators do to support students' development of ESA? What pedagogical moves did Jessica's teacher make? In our research, we identified three key educator practices that teachers can use to support student engagement in those key youth practices (Harris 2017).

First, teachers can *position youth as people who do science*. This involves helping students take on meaningful roles during CS investigations by engaging them in the reasoning practices of science. How educators frame the CS work—through words and actions—can shape whether students see themselves as having important roles in authoring scientific work. Consider the following two framings about who judges or evaluates data students are gathering—scientists or the students. *Could a scientist use this information?* This framing opens a conversation and invites students to evaluate the quality of the data they collected. Students are capable investigators alongside scientists. Consider a different framing: *You guys are going to help scientists by giving them information*. This positions students as scientist helpers. They are contributing but to someone else's intellectual work, not their own. This risks students feeling like automatons collecting data for scientists.

Second, teachers can *frame the work globally and locally*, as simultaneously part of broad scientific endeavors as well as locally relevant issues around the study site or community. As educators, we may care deeply that student contributions impact science on a global scale, and this may be meaningful to students who already identify with science. However, many children are also motivated to learn about and contribute to places they know intimately, such as their school yard or local park. Framing the work as important for global contribution *and* understanding local ecosystems helps motivate students with broad interests and allows students to draw on their lived experiences and existing knowledge of place.

Finally, teachers can *attend to the unexpected* by paying attention to surprises that emerge from the natural world or students and incorporating them into instruction. CS is unique because you don't know what will happen. For example, in Jessica's class, students observed a ladybug eating aphids on the overhead projector during a lesson on predator-prey dynamics. When a second ladybug climbed on top and started mating, students erupted with questions. The teacher pivoted to facilitate a class discussion about ladybug reproduction, leading to new student understandings. Adopting a "co-learner" orientation can help educators capitalize on rich teachable moments and work with students to figure out new understandings together.

Connecting to the *Next Generation Science Standards* (*NGSS*)

This article does not present a lesson with specific connections to the *NGSS* disciplinary core ideas (DCIs), crosscutting concepts (CCCs), or science and engineering practices (SEPs). Instead, it presents a framework for how teachers can think about designing a Citizen Science (CS) unit, which can support *NGSS* instruction. The notion of Environmental Science Agency as an outcome incorporates students learning science content (DCIs) and inquiry practice (SEPs). Using the key educator practices during CS activities can help teachers engage students in the SEPs and capitalize on the learning opportunities of real-world investigation. Educators should consider grade-level DCIs and relevant CCCs when selecting a CS project and integrate CCCs such as "patterns" or "stability and change" during data collection and meaning making activities. For example, in the ladybug unit, students came to understand DCIs, looked for patterns in the ladybug species they observed, and engaged in multiple SEPs.

These three educator practices are not novel; in fact, this pedagogy directly connects to the *NGSS*. The *NGSS* SEPs call for teachers to help students engage in the reasoning and meaning-making practices of science. This means positioning students to not only collect data but to look for patterns and develop explanations to reach deep conceptual understandings. Framing the work with both a global and local purpose connects directly to using real-world phenomena to motivate investigation, a foundational component of *NGSS* instruction. Attending to the unexpected means that it is okay to not know what will happen. A co-learner orientation can help teachers let students engage in the SEPs and drive conversations with their own ideas and reasoning.

Conclusion

At the end of the ladybug unit, Jessica reflected on her accomplishments. Despite feeling nervous, she felt proud presenting and seeing adult's interest in learning from her. She was surprised by their limited knowledge of ladybugs or the LLP and eager to share her expertise. She took pride in her essay and eagerly shared her writing and CS experiences with her parents and siblings. She continued leading her group with technology and during the subsequent weather unit, she monitored daily weather patterns with the iPad. In small but important ways, her CS experiences started to build a foundation where she identified with science and started to see it as relevant to her life.

Any grade-appropriate CS project has potential to support meaningful student learning (Table 3). The activities and practices outlined in our framework (Figure 1) can help educators design and facilitate CS experiences that engage students in science content and practice, help students begin to recognize themselves and be seen by others as experts, and take action with science in their lives and communities in personally consequential ways. ■

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Internet Resources

BirdSleuth
www.birdsleuth.org

Lost Ladybug Project
www.lostladybug.org

UC Davis Youth-focused Community & Citizen Science Research
https://yccs.ucdavis.edu