eeWORKS

From Anecdotes to Evidence: Demonstrating the Power of Environmental Education

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EXECUTIVE SUMMARY

UC Davis Analysis of 100 Studies Finds Community and Citizen Science Supports Environmental Education Objectives

Researchers at University of California, Davis identified and reviewed 100 studies of community and citizen science programs (those that involve members of the public in scientific research that is led by either community members or scientists) to explore whether they achieve environmental education outcomes.[1] The findings suggest that not only do such programs increase participants' knowledge of ecology and environment, but they can also enhance science inquiry skills, stewardship and environmental behaviors, and improve self-efficacy for using science to solve environmental problems. Every program does not achieve all these outcomes, of course, but there is substantial evidence that engaging people in collecting, analyzing, and sharing data helps address important environmental problems and holds great promise for environmental educators.

Citizen science programs have long been seen as a strategy of science education—where the goal may be to assist scientists by reporting information such as the date certain flowers bloom, the level of dissolved oxygen in a lake, or the number of bird species seen in one day. By increasing the number of people looking for evidence, scientists obtain a larger pool of data to better understand how the natural world functions. With a combination of making close observations, local knowledge, and training to reliably collect valid data, it stands to reason that participants will be learning something about the species they are observing, the tools they are using, and the system they are monitoring. In fact, they often learn much more. These programs vary in their geographic coverage (from local to international), period of data collection (from one day to years), and topic (from watching online wildlife camera feed to interviewing neighbors about wildfire risk).

Some programs additionally engage the public in more aspects of the process of science, which can build capacity for using science to discover, explore, and solve challenges. These programs are more likely to engage people in more than data collection—participants may work with scientists to identify the problem, plan the data collection activities, analyze data, identify findings, and report those insights to others.

The continuum of tasks across both types of programs that involve the public in science defines ***community and citizen science*** as a range of participatory approaches where the purpose may be in support of a scientist-led endeavor or a co-created c ommunity process.[2]

Environmental educators also design programs to increase awareness and knowledge of environmental issues and build skills to support participation in community issues, and some have been using the strategy of engaging learners in collecting environmental science data.[3] Indeed, the broader goals of science education are similar to environmental education, making community and citizen science a link between these fields.[4]
UC Davis researchers synthesized the literature that reported the measured outcomes of environmentally-related community and citizen science programs to understand how they support environmental education objectives. Their synthesis speaks to the outcomes that environmental educators could achieve were they to use well-designed, effective community and citizen science strategies. A full report of the methods used to conduct this review can be found in the original paper [Link to Ballard et al. when published].

Researchers identified seven key findings from the review of environmentally focused community and citizen science programs. Two findings describe the breadth of the programs that were captured in the review: (1) programs cover a range of topics, participants, and places; (2) programs involve people in a wide range of scientific activities. Five findings describe the outcomes that were attributed to participation in the programs: (3) science content knowledge; (4) science inquiry skills and understanding the nature of science; (5) positive attitudes about science, the local place, and the environment; (6) community connectedness and cooperation; and (7) efficacy, identity, environmental behavior and stewardship.

What is the breadth of the programs?

KEY FINDING #1

Programs cover a range of topics, participants, and places.

Many of the articles focused on programs that addressed biodiversity, from specific organisms (38 articles on insects, birds, mammals, or plants; and 12 on biodiversity) to general issues such as habitat loss (9 articles) or invasive species (7 articles). The remaining third were focused on socio-environmental issues, such as human exposure to pollutants and air and water quality monitoring (15 articles), disaster preparedness or ecosystem restoration (15 articles), and agriculture or food-related conservation issues (7 articles). Some of the environmental health programs focused on environmental justice issues and some of the community-focused social science programs involved collecting information from residents.

Recognizing the potential for life-long education, a bit over half of the studies (54) in this review captured programs that engaged adults in environmental observations. Several of the papers reported on online programs, such as iNaturalist, which did not report the participants' age but which reaches youth and adults. Only about one-third of the reports focused on school-aged youth, with most of these engaging either middle school (11 articles) or high school (10 articles) students.

The majority of papers (81) addressed programs that involved participants outdoors with a few exclusively online (such as wildlife camera observations). A small group (14) combined field data with online mapping tools, such as Geographic Information System (GIS) apps. While the traditional citizen science activity might be observing nature in the wild, this set of programs also included urban and agricultural explorations.

- Participants of the Coastal Observation and Seabird Survey Team (COASST) program identified dead bird species along the Pacific coast in California and Alaska. The intensive training included mastering carcass identification, beach sampling and data-sheet completion, and information on how the data are being used in resource management. During the program, participants linked their individual experiences with broader environmental challenges and developed an understanding of how their data collection informs local, regional, and global environmental conservation.[5]

While most citizen science projects take place within problem-focused natural sciences, social sciences and humanities help understanding the human dimension and open a broad methodological spectrum for enriching scientific research with new approaches and for boosting public participation.

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- An after-school program in a southern U.S. city engaged six teens in bicycle building and then riding to map their neighborhoods' resources. While increasing their personal mobility by making bicycles available, the program taught youth about spatial concepts and geospatial information as they imagined the future of their urban neighborhood. By creating and analyzing existing maps of neighborhood spaces, participants developed a deeper understanding of urban geography and spatial justice and enhanced their engagement with the community and urban planning.[6]

KEY FINDING #2

Programs involve people in a wide range of scientific activities

The programs captured in this review involved participants in more than data collection. Many people worked with researchers to analyze data and shared their findings with others. Some presented results to decision makers. Others worked with researchers from the initial inception to identify the problem and frame a program. This breadth of engagement was particularly important to achieving the outcomes that environmental educators care about, such as efficacy and stewardship. Of the 10 programs where participants engaged in all four categories of the research process (planning, data collection, data analysis, and reporting), half of the studies reported behavioral and community connectedness and cooperation.

- A program in Bogotá, Columbia demonstrated that urban residents can gain scientific knowledge and deeper understanding of their communities through participation in a range of activities working with and presenting their data. Participants worked together to map their community, assessing the risk of landslides and mapping rainwater paths and waste disposal locations. They were able to use these data to engage with authorities and influence urban policy development.[7]

In a short space of time, local mappers were able to engage with complex planning decisions and ethical questions concerning the social function of the land, the contention of further sprawl and ecological carrying capacity of the territory.

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- A role-playing activity with shrimp farmers in the Mekong Delta enabled them to better understand the tradeoffs associated with economic development, sustainable farming, and climate change and improved their ideas about the future. Scientists used the activity for scenario planning and aquaculture modelling with input from the farmers, and the scenarios helped farmers discuss their insights with decision makers and planners.[8]
- In a critique of community monitoring programs along Tanzania's coastal mangrove forests, researchers learned from fishers and elders that when local people can determine their level of participation and co-create the monitoring tools, particularly the observable indicators of environmental change, they are more likely to be actively engaged in mangrove stewardship. This level of collaboration is essential to respecting the locally available ecological knowledge.[9]

What outcomes do these programs achieve?

KEY FINDING #3

Science content knowledge.

Participating in data collection was a function of nearly every article collected in this review (97 articles) and tended to result in important learning outcomes. Participants acquired factual and theoretical knowledge about the environment. This included an understanding of ecological processes, phenomena, and local species. Many of the reports (56) confirmed that participants gained science content knowledge about the organism or system they were exploring, as one might expect. In this way, community and citizen science programs have the potential to deepen participants' connection to local environments, fostering a sense of place and interest in science (see finding #5).

- Participants in five, one-day workshops held over one year in British Columbia, Canada, learned about watershed management and helped create a model to consider future water resources. This participatory modeling process gave researchers and participants new insights into the complexity of water management and opportunities to discuss common concerns with other participants.[10]
- Research River Biomonitoring Stream Assessment (RRBSA) involved adult volunteers in collecting and interpreting data such as stream substrate, turbidity, and macroinvertebrates. The stream study took place while working alongside scientists and naturalists. The program significantly enhanced participants' understanding of stream ecology and science.[11]

KEY FINDING #4

Science inquiry skills and understanding the nature of science.

Community and citizen science programs can engage participants in formulating important questions, planning how to collect and analyze data, and critically thinking about the data they collect. It provides direct experience in the process of science and opportunities to practice scientific reasoning. The literature reported that participants gained science inquiry skills (32 articles) such as using equipment and reading maps through the process of actively planning for, monitoring, or interpreting data.

The recent interest among science educators in teaching about the nature of science[12] might have influenced researchers in 17 of the studies to assess participants' understanding the process of doing science, resulting in an increase in this outcome for 15 studies and 2 that reported no change. Programs that achieved this outcome tended to include time to reflect on what the data meant or ask participants to convey findings to others. This outcome is notoriously hard to measure, and in two adult programs no significant change in the understanding of the nature of science was detected.

- In an Australian phenology (study of cyclical and seasonal phenomena) citizen science program called ClimateWatch, students engaged in data collection and analysis related to climate change. They gained the ability to critically assess the data, enhancing their understanding of scientific processes and becoming adept at critiquing the value of citizen science findings.[13]
- In the Dutch iSPEX Project, adult participants used smartphones to measure atmospheric aerosols. Research showed that this program fostered increased awareness and knowledge of air quality, a positive attitude toward science, and enhanced trust in scientific methods and findings among participants. Participants who had little involvement with science in the rest of their lives reported that science can be beneficial.[14]

KEY FINDING #5

Positive attitudes about science, the local place, and the environment.

Some articles (16) reported that participants increased positive attitudes toward science and the environment, even among people who began the program with those attitudes, suggesting the program added value and commitment. Programs also helped participants build trust in science. Several participants who had brief involvement or who only contributed data through smartphones, reported that "science can have a positive impact on our lives."[15]

Nine papers reported positive changes in the way people related to their own places, connecting to their communities and to nature. Programs that engaged people in exploring their environment, mapping locations of wildlife, or monitoring water quality demonstrated gains in these place-based values.

- The Sea Search program, based in Victoria, Australia, engaged volunteers in identifying and monitoring plant and animals along a rocky coast in marine protected areas. This hands-on participation contributed to the planning and management in conservation areas. Volunteers reported emotional and mental wellness benefits from their involvement, experiencing a sense of calm and satisfaction in the marine environment. Additionally, the program fostered a strong connection to the marine environment, enhancing volunteers' desire to protect and preserve it.[16]
- In northeastern England, urban residents collaborated with researchers to study hedgehog habitat in urban areas. They helped track the animals that were fitted with radio collars. Researchers found the program increased participants' engagement with nature and fostering community connections. They particularly liked meeting other volunteers and doing something useful to help wildlife.[17]
- In Nebraska, six different entomology citizen science projects were assessed for their contributions to interests and beliefs about science, nature, and environmental action. Participants received training and equipment (nets, traps, and handouts) for capturing or observing insects. Qualitative data revealed an enhanced connection with nature and a growing interest in science and environmental action as the result of this program.[18]

KEY FINDING #6

Community connectedness and cooperation.

By participating in some types of community and citizen science, learners strengthened community networks, shared knowledge, and improved their capacity to participate in environmental governance. Thirty articles in this review reported, for example, increases in community-level outcomes such as social connectedness and social learning. Some of these programs collected data through a participatory workshop design that engaged people in discussing their observations and perceptions about things like wildfire risk or local wildlife. Other programs focused on human health concerns or disaster planning. Both individual reflection and group deliberation were part of these activities, which facilitated social learning to manage uncertainty and increase adaptive capacity. Community and citizen science activities that were designed to empower a community to advocate for their interests helped people see connections and share experiences. More often than not, these projects involved participants in a variety of scientific tasks, such as choosing the question, identifying the problem, analyzing the data, and reporting the results.

- Researchers used participatory research with coastal communities in O'ahu, Hawai'i, to build relationships and collect data on potential risks of tsunamis. This social learning framework offered opportunities for residents to contribute information and challenge norms and policies. Scenario modeling and mapping the potential impacts of a tsunami enabled participants to discuss risks, compare trade-offs, and question their beliefs. This process enhanced disaster preparedness and community resilience at both individual and institutional levels.[19]

Committee members felt they knew which adaptation strategies would be most effective a priori based on their own knowledge, yet their expectations did not prove correct. The information provided by the model could not be ignored because they built the model themselves. They also felt more empowered to explore other options.

Sarah Henley-Shepherd, Disaster Resilience in Honolulu, et al. page 119.

- A group of residents organized an environmental justice group to oppose a new regional waste transfer station in their California city. They identified three concerns to the plan: the location near residents and within 1 mile of 9 schools; the size of the facility, which would mean more trucks on local streets; and health concerns from diesel trucks. The group reviewed documents, made presentations, educated the community, took photographs, contested data, submitted evidence, and met with decision makers. The project was ultimately approved at a much smaller scale with waste hauled by trucks that did not use diesel fuel in a partial victory for the local community.[20]

KEY FINDING #7

Efficacy, identity, environmental behavior and stewardship.

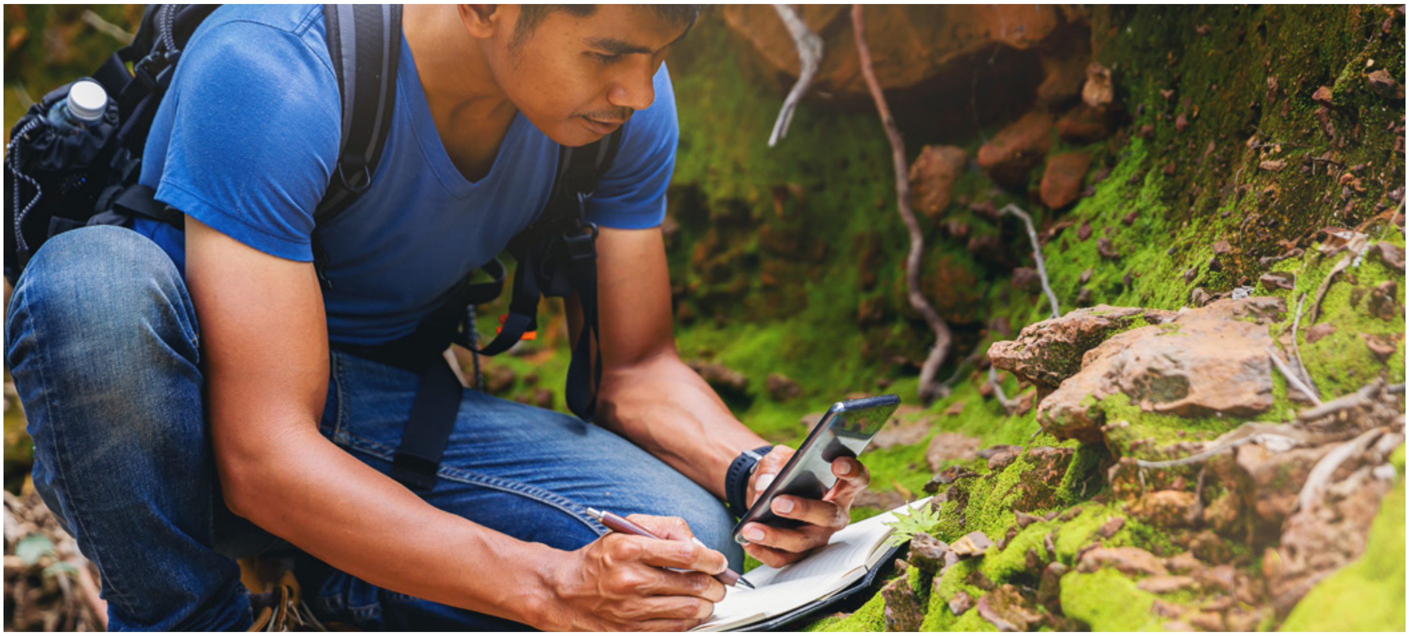
Participation in community and citizen science programs may contribute to participants' commitment to improving ecosystem health, and a belief that they are able to solve problems and take action. Several papers (11) reported positive gains in participant self-efficacy and 4 of these reported increases in science-related identity and agency. These four programs changed how participants see themselves—they were more likely to say they are people who understand and do science. It is possible that these outcomes will be more likely in programs that include participants in more science tasks than solely data collection.

Twenty-nine articles reported that participants engaged in environmental behaviors because of the community and citizen science program. This was often sharing information with others in their networks, informally; those participants who were more involved in the programs were often those who became spokespersons and worked to involve others. Some participants used data when meeting with regulators or writing to elected officials to request a change. Still others were engaged in habitat restoration or management as a result of their growing realization of ecological problems.

- The East Bay Academy for Young Scientists (EBAYS) program, in the eastern San Francisco Bay area in California, significantly influenced high school students' environmental stewardship. After discovering a lack of biodiversity and high pollution levels in a local urban creek, participants actively engaged in environmental remediation by removing trash and invasive species.[21]
- A long-standing citizen science program to map vernal pools in Maine and increase public awareness of these ephemeral ponds also engaged volunteers in working groups with scientists to consider management and policy. Since the vernal pools come and go rapidly, residents were key to identifying locations and characteristics. By producing knowledge, and by building relationships between citizens and institutions, this program and the volunteers played a significant role in shaping local planning and environmental policy. Because community members were involved, the public and the planners were able to trust the reports the program generated. Participants learned about the importance of vernal ponds to the ecosystem and biodiversity and built useful relationships with scientists.[22]
- A survey of participants in butterfly citizen science projects across the United States suggested that when they received information about conservation actions and were encouraged to become engaged, they were more likely to do so. Nearly all respondents (95%) reported that they increased their involvement in butterfly conservation.[23]

In addition to continually expanding restoration of the site, the EBAYS youth have begun to impact community perceptions of and use of the creek site, transforming it from an overgrown corridor that encouraged dumping … into a more park-like space frequented and protected by neighbors.

Heidi Ballard, University of California, Davis, et al., page 69.



Conclusion

Nearly all the programs involved participants in data collection and in some of these, participants were only engaged in data collection. In these programs, participants still gained positive outcomes in knowledge and attitudes, typically. Involvement in more ways of participating in science, however, generally opened the possibility of gaining a wider variety of outcomes, such as social learning and community connectedness, efficacy, identity, and stewardship behaviors. It is important to note, however, that since articles that reported behavioral and community changes were usually based on programs designed to affect these outcomes, every community and citizen science program should not expect to achieve the same results. Future research could begin to establish a more certain link between the characteristics of volunteer engagement and the environmental education outcomes of interest.

The literature published after this systematic review (from 2019 to 2023) suggests the same types of EE outcomes continue to be achieved by community and citizen science programs. In particular, research on learning outcomes for young people in and outside of schools has surged,[24] finding many of the same strong positive outcomes, particularly in understanding environmental science content,[25] positive attitudes about the environment,[26] and self-efficacy and interest in environmental science.[27] Further, studies are emerging that directly compare the learning outcomes for data collection-only projects with those where participants help or lead throughout the scientific process.[28]

In addition, several potential trends warrant future investigation, including increasing focus on the ways that CCS may or may not address equity and diversity issues in science and environmental education[29] and empower participants to address impacts of climate change.[30] Finally, there is growing evidence that community and citizen science programs impact broader socio-ecological systems through the combined positive outcomes for participants and more robust science.[31]

In an era when distrust of science is high and climate change impacts are emerging daily around the globe, we need environmental education programs that tackle both problems head-on. Community and citizen science strategies have the power to engage participants, both youth and adults, in authentic explorations that collect useful data to answer important questions about how the world is changing and how people are perceiving change. Additionally, participants are able to use these data to influence policy and practice. This research synthesis suggests that community and citizen science programs can effectively achieve environmental education outcomes with intentional program design. Context, place, issue, and age are not limitations. Even shorter-term, school-based programs can be engaging, educational, and empowering; longer-term adult programs have potential to make significant community and behavioral impacts.

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