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Citizen Science: Active, Inquiry and Service Learning for Environmental Educators

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Abstract. Citizen Science engages individuals who are not professional scientists in scientific research, providing an excellent tool for teaching natural history and science content through hands-on activities that often address critical questioning and analysis skills. We summarize outcomes of citizen science using two case studies, one that illustrates how an environmental education center (Great Smoky Mountains Institute at Tremont) uses a suite of citizen science projects to achieve its goals, and another that illustrates the educational benefits youth gain through their participation in a nation-wide citizen science project (Monarch Larva Monitoring Project). Citizen science has helped Tremont develop a deeper understanding of its location, fostered new partnerships, reached new audiences, and accessed new funding sources. Young volunteers in the monarch monitoring project gained an understanding of real scientific research and organismal biology, were encouraged to study science in school, gained leadership opportunities and enjoyed socializing with their friends outside. These case studies illustrate the benefits of using citizen science as a tool to engage youth and adults in place-based studies that foster connections with the natural world and enhance existing programming.

WHAT IS CITIZEN SCIENCE?

Citizen science is a tool for research, education, and community development that involves people who are not professional scientists in scientific study. Different scientific and educational goals and audiences call for varying approaches to citizen science, and the following

three examples highlight common but distinct models. They differ in audience and focus, but all meet their scientific and educational goals, and attract and retain participants.

The REEF Fish Survey Project involves volunteers as data collectors. Self-selected volunteer scuba divers record data on fish diversity and abundance while on recreational dives, and scientists and resource managers define the research questions and protocols, analyze the data, and apply the conclusions in management decisions. This project has aided in natural resource management and provides volunteers with skills and opportunities to enhance their diving adventures (Pattengill-Semmons 2007).

In contrast, the ALLARM program at Dickinson College in Pennsylvania involves every step of the research process, from defining research questions through applying the conclusions. The real focus is on involving the community in solving community environmental problems. Community-based watershed groups meet with ALLARM scientists to identify watershed issues and set water monitoring goals. The scientists then provide technical assistance to help the volunteers achieve their monitoring goals, and to develop action plans based on the monitoring results (Wilderman 2007).

In a third model, the University of New Hampshire ForestWatch program is focused on integrating science into K-12 classrooms. As in the REEF model, the participants are involved mainly in the data collection step of the process, but in this case they are students doing citizen science as a part of their schoolwork. Students follow defined protocols to collect data and samples to measure white pine forest health, developing important lab and field research skills while generating useful data on forest health (Forest Watch 2007).

Successful citizen science projects typically include four elements.

(1) They actively involve the public (K-12 students, nature enthusiasts, community stakeholders, etc.) This involvement may be voluntary (e.g. the REEF model) or not (e.g. the ForestWatch model), and may be limited to data collection or include more pieces of the scientific process.

(2) They involve professional scientists at some level. Even in the ALLARM model, scientists are involved as advisors and mentors who help to ensure meaningful research questions and appropriate protocols.

(3) They result in data that advance scientific understanding and can be applied to real world problems. While citizen science may be used for biological inventories, long-term monitoring or experimental research, the ultimate goal of using the data is critical, whether in a publication, a management plan, or to evaluate whether a more in-depth study is warranted.

(4) They have a clearly defined educational component. Successful citizen science projects include educational objectives and strategies for achieving them, ensuring that participants are more than unpaid data collectors.

CITIZEN SCIENCE AND ENVIRONMENTAL EDUCATION

Citizen science is an excellent tool for teaching natural history and science content through hands-on interaction with the subject at hand. For example, learners can develop an understanding of water quality by monitoring a stream and experiencing firsthand changes that occur as a result of sedimentation. Furthermore, citizen science can go beyond knowledge gain to address critical skills in questioning and analysis (Trumbull et al. 2000).

Citizen science can also reach new audiences. Much traditional environmental education is geared towards younger children, but citizen science can engage teenagers and adults in learning about the environment while making a very real contribution. Non-formal, place-based centers can use these projects to develop a deeper understanding of their own location, foster new partnerships, reach new audiences, and access new funding sources.

Citizen Science at Environmental Education Centers: a Case Study

Great Smoky Mountains Institute at Tremont is a residential environmental learning center in Great Smoky Mountains National Park (GSMNP) in Tennessee. Tremont host residential programs for 5th-12th grade classes, summer camps for youth, and nature programs for adults. In its citizen science program, it connects people with nature by involving them in scientific research, inventory, and monitoring in GSMNP. The citizen scientist audience includes one-time visitors, such as the K-12 school groups in the residential program, as well as volunteers from the local community. The program includes 15-20 projects, including established national projects (e.g. FrogWatch, Monarch Larva Monitoring Project) and projects developed in partnership with the GSMNP (e.g. inventories of moths, fungi, and reptiles). Some local students conduct spin-off projects that take them through the whole scientific process (Great Smoky Mountains Institute at Tremont 2007).

Adding citizen science to Tremont programs has opened several new avenues for grant funding, and has allowed Tremont to make connections to the local community by involving local teenagers and K-12 teachers as volunteers. It has also strengthened Tremont's relationship with the National Park Service, and fostered new partnerships with research scientists. Importantly, it has resulted in new information about the biology and ecology of GSMNP.

Recommendations for Environmental Education Centers.

An ideal way to begin to use citizen science is to tie into existing projects, such as the one described below. With help from scientists and other stakeholders, EE centers can also develop their own projects to meet specific educational and scientific goals. Centers are encouraged to share their citizen science successes and challenges so that we can continue to improve citizen science programming. Further guidelines for best practices for citizen science at EE centers are outlined in Prysby and Super 2007.

What Do Citizen Science Participants Gain? A Case Study

Background on the Monarch Larva Monitoring Project

The Monarch Larva Monitoring Project (MLMP: www.mlmp.org) was developed in 1996 to describe temporal and geographical variation in monarch butterfly egg and larval abundances, and quantify monarch egg and larval survival (Prysby and Oberhauser 2004). Volunteers choose and describe their own monitoring sites, which include backyard gardens, abandoned fields and pastures, and restored prairies. They estimate monarch densities weekly throughout the summer by examining milkweed and recording the number of eggs and larvae observed and the number of milkweeds examined.

Almost all volunteers enter their data into an on-line Microsoft Access relational database. They also send hard copies of the data, which are used to spot-check on-line data for validation. Project managers contact volunteers for additional information when values seem unusual.

Science education outcomes

In 2005, we assessed the contexts in which adults most successfully engaged children in the MLMP, and the scientific and social outcomes for children, as perceived by adults (Kountopes 2007). This mixed method evaluation used a quantitative survey tool and qualitative interview questions to solicit information on how to better implement monitoring activities with children, and the perceived value of monitoring with children.. Our findings are based on survey responses from 54 adults who monitor with children, and interviews with a subset of nine of these individuals. The interview group included individuals with the most experience monitoring with children, not a random subset.

Adults involved children in the MLMP in a variety of contexts (table 1), with the largest category being the volunteer's own children or other family members. There was a bimodal distribution of group size, with most groups containing one to two (43%) or three to five (43%) children, and 14% containing more than ten children; no groups contained six to ten children. Age ranges were five to six (12%), seven to nine (28%), ten to 12 (36%) and 13-16 (24%).

There were interesting contrasts in the activities that children liked most and least. While they liked using most research equipment, they were not as interested in some equipment, such as rain gauges. They enjoyed working with living monarchs, but were not as interested in milkweed. They loved to find monarchs eggs and larvae, but were discouraged when they did not find monarchs in their study sites. They liked to be outside, but were challenged by mosquitoes and hot weather. They enjoyed seeing their results displayed online, but many young children did not enjoy entering data onto the computer. Across the board, children enjoyed socializing with their co-monitors.

Adult research mentors made innovative protocol changes, and structured monitoring time in ways that made it more enjoyable for youth. They made training sessions and data sheets

more appropriate for children, using bigger spaces and color-coding. They developed explicit team roles, such as recording data, measuring plants, and looking for eggs and larvae, and developed project extensions, adding unstructured play-time, encouraging journaling and additional research projects, and taking field trips.

From a science education perspective, youth volunteers gained an understanding of real scientific research, and learned about the organisms in the environment they were monitoring. The project also was perceived as affecting their future directions, encouraging them to study science in school, and giving them leadership opportunities. Finally, adults felt that children gained affective benefits from the time to socialize and meet new friends and enjoy being outside.

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Table 1.
Type of youth group monitoring with MLMP (participants could give more than one response)

Children participating	**Number**	**Percent**
Family of adult volunteer monitors	31	57%
Neighbors/community children	17	31%
School group	9	17%
Homeschool group	5	9%
Nature center program	3	6%
Other summer program/camp	3	6%
Daycare	1	2%