Key issues and new approaches for evaluating citizen-science learning outcomes

Rebecca C Jordan[1*], Heidi L Ballard[2], and Tina B Phillips[3]

Ecologically oriented citizen-science experiences engage the public in learning while facilitating the achievement of robust scientific program goals. Evaluation of learning outcomes has become increasingly prioritized, requiring citizen-science program managers to understand key issues in evaluation. We argue that citizen science can have other, more far-reaching community-level outcomes, which have received less attention but warrant consideration for continued programmatic improvement.

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Although citizen science – often termed public participation in scientific research – is variably defined, here we use a broad definition: partnerships between scientists and non-scientists in which authentic data are collected, shared, and analyzed. In the context of ecology, citizen science, in addition to enhancing the research effort, can also have broader educational impacts (reviewed in Bonney *et al.* 2009). What distinguishes citizen science as an informal learning experience is its engagement in several aspects of authentic science (eg modeling, gathering evidence, testing ideas). Citizen science can foster ways of thinking in volunteers that are consistent with those of scientists, are crucial for decision making in modern society (eg Trumbull *et al.* 2000; Jordan *et al.* 2011) and are important for developing ecological literacy (Jordan *et al.* 2009). Below, we focus on the evaluation of learning (considered here in the broadest sense – the cognitive, affective, and behavioral dimensions thereof), which has become an important component of many citizen-science programs.

We define evaluation as the systematic collection and analysis of data needed to assess the "strengths and weaknesses of programs, policies, personnel, products, and organizations" so as to improve their overall effectiveness (American Evaluation Association; www.eval.org). An evaluation of individual learning outcomes, in particular, can help project managers improve overall project outcomes, reach new audiences, promote learning opportunities, and increase project longevity and impact. A comparison of learning gains for individuals through citizen-science participation is critically important for understanding whether the program is meeting its educational and volunteer engagement goals (Bonney *et al.* 2009; Phillips *et al.* 2012). Here, we focus on key issues for evaluating individual learning outcomes and then challenge the discipline to consider broader, community-based outcomes stemming from citizen science.

[1]*Department of Ecology, Evolution, and Natural Resources, Rutgers University, New Brunswick, NJ* [*]*(jordan@aesop.rutgers.edu);* [2]*School of Education, University of California, Davis, Davis, CA;* [3]*Cornell Lab of Ornithology, Cornell University, Ithaca, NY*

Key elements for conducting evaluations of learning

Several resources are now available to help scholars and practitioners define, clarify and measure what individuals learn from participating in citizen-science projects (WebTable 1). We highlight key considerations here.

Regardless of the type of program, citizen-science practitioners should carefully consider and plan for quality evaluation of learning outcomes. After establishing learning goals, which tend to be broad and abstract, practitioners should focus on developing an evaluation plan. This plan should ensure that (1) learning goals are aligned to project activities (and vice versa), (2) learning outcomes are well-articulated, and (3) both are attainable through identification of relevant indicators (measures of success for achieving desired outcomes) (Phillips *et al.* 2012).

In considering learning goals as they relate to project activities, citizen-science projects must strike a balance between the data collection to be accomplished and expected broad learning goals. Learning goals may focus on increased scientific reasoning and process skills for participants, but scientific goals for the project may only warrant training on narrow data collection skills (eg identifying presence/absence of specific taxa). Citizen-science program leaders and scientists must clearly define the desired balance between learning goals and scientific goals. If broader learning goals are a priority, then that should be reflected in the activities of participants, and these goals should be stated explicitly.

Once the broader learning goals for the program are established, program leaders should isolate the essential outcomes of what is to be learned. These learning outcomes should be specific, measurable, attainable, relevant, and timely. Some projects may want to consider different types of learning outcomes for different levels of participant engagement. For example, it may be worth the time investment to engage long-term volunteers in more extensive training, given that such volunteers may have greater decision-making power. In contrast, a one-day volunteer may require less training, and indeed a more in-depth educational program may only serve to distract from

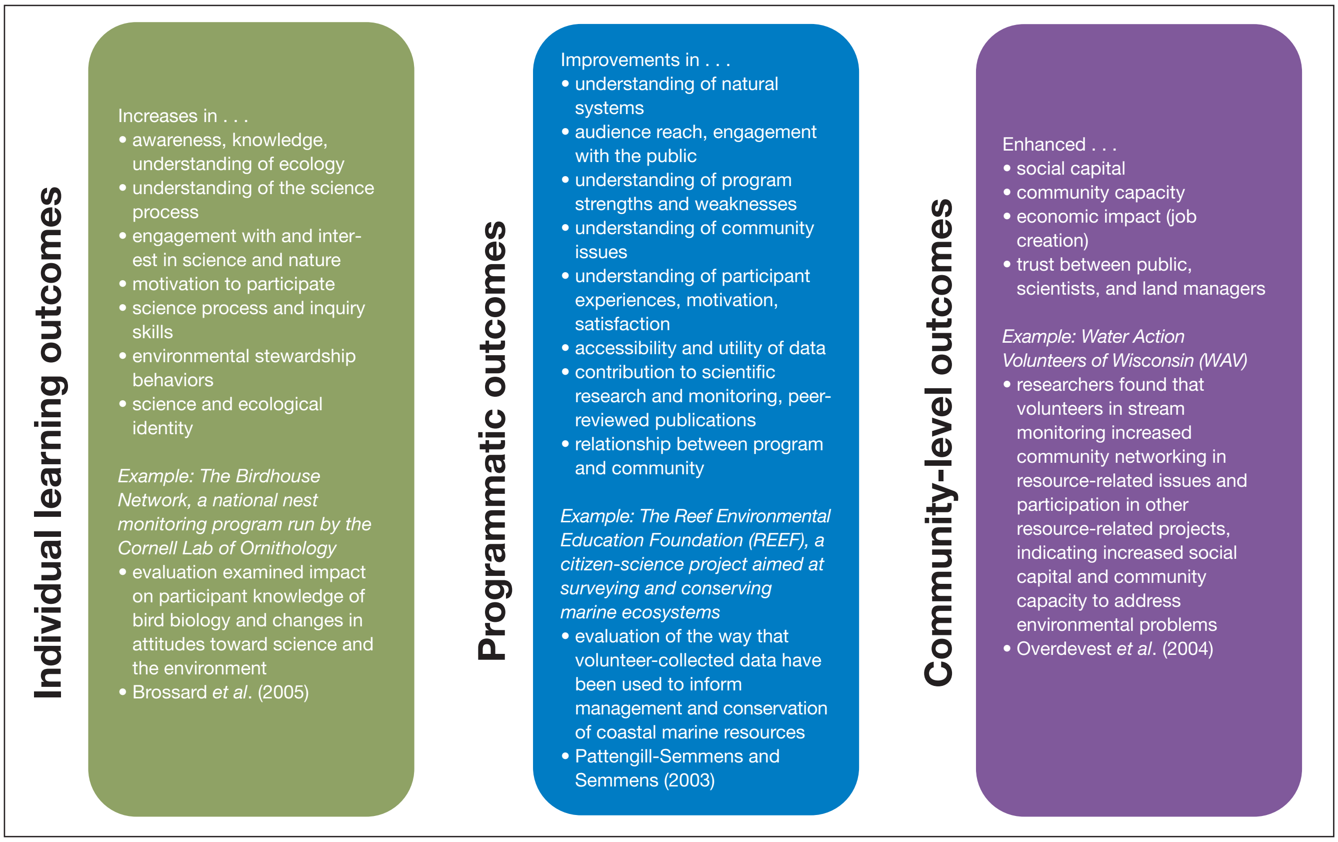

Figure 1. *Framework with examples for evaluation of citizen-science programs: individual learning, programmatic, and community-level outcomes.*

the data collection goals for that given day.

Furthermore, selecting appropriate indicators or "measures of success" to ensure that desired outcomes are achieved is critical. Such indicators (ie content-appropriate criteria often assessed through questionnaires or interviews) need to be targeted, feasible, valid, and reliable. For example, if a citizen-science participant demonstrates knowledge of a particular task through a written assessment, this does not mean that the participant has attained a particular skill or depth in understanding, nor can we be certain that the assessment is reflective of the task in question.

■ Beyond evaluation of programs and individuals

As a final consideration, we suggest a more comprehensive approach – encompassing multiple scales of possible impact, at the individual, programmatic, and community level – to evaluate learning that results from citizen-science programs (Figure 1). Large-scale outcomes, in particular, could be crucial for examining the widespread and perhaps more substantial impacts of citizen-science programs on ecosystems and human communities.

Participation in collaborative and community-based monitoring has resulted in community-level outcomes, such as increased social capital (Adger 2003), community capacity (Donoghue and Sturtevant 2007), and trust between scientists, managers, and the public (Fernandez-Gimenez *et al.* 2008). Social capital includes formal and informal human networks, cultural and behavioral practices, and trust in societal systems, all of which facilitate the coordination and sharing of cultural, social, and natural resources for mutual benefit. Community capacity includes interactions between human, organizational, economic, or social capital in a community that can be leveraged to solve collective problems and improve or maintain community well-being. We propose that tools used by social scientists to assess impacts of land-use policies, for example, could be applied to evaluate impacts of citizen science at the community level.

We suggest that, in addition to considering social and community benefits, evaluation of citizen-science programs may help foster resilience – ie the capacity of a system to absorb shocks yet maintain function (Folke 2006) – in the interconnected ecological and social (socioecological) system. Key to resilience is this collective system's capacity for learning and adaptation (eg understanding how ecological and social systems respond and adapt to climate change and making management choices; Walker *et al.* 2002). When learning about an ecological system and its associated social institutions (eg policies, management practices) through citizen science, a group of individuals gains collective knowledge that increases the capacity of the socioecological community to reorganize and adapt to changes. In this way, learning through citizen-science projects may not only be an outcome to be measured but may also be a driving, or perhaps influential, force for meeting project goals, whether ecological or social.

Evaluating the impacts of citizen-science projects on learning at the level of the individual, program, or community may ultimately increase the chances of project success and contribute to socioecological system resilience. Although researchers have only recently begun to explore the integration of outcomes at multiple scales and resilience, we argue that this should be at the forefront of future citizen-science research.

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