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Knowledge Gain and Behavioral Change in Citizen-Science Programs

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Abstract: *Citizen-science programs are often touted as useful for advancing conservation literacy, scientific knowledge, and increasing scientific-reasoning skills among the public. Guidelines for collaboration among scientists and the public are lacking and the extent to which these citizen-science initiatives change behavior is relatively unstudied. Over two years, we studied 82 participants in a three-day program that included education about non-native invasive plants and collection of data on the occurrence of those plants. Volunteers were given background knowledge about invasive plant ecology and trained on a specific protocol for collecting invasive plant data. They then collected data and later gathered as a group to analyze data and discuss responsible environmental behavior with respect to invasive plants. We tested whether participants without experience in plant identification and with little knowledge of invasive plants increased their knowledge of invasive species ecology, participation increased knowledge of scientific methods, and participation affected behavior. Knowledge of invasive plants increased on average 24%, but participation was insufficient to increase understanding of how scientific research is conducted. Participants reported increased ability to recognize invasive plants and increased awareness of effects of invasive plants on the environment, but this translated into little change in behavior regarding invasive plants. Potential conflicts between scientific goals, educational goals, and the motivation of participants must be considered during program design.*

Keywords: conservation education, early detection, invasive plants, monitoring, rapid response

Obtención de Conocimiento y Cambio Conductual en los Programas de Ciencia-Ciudadana

Resumen: *Los programas de ciencia-ciudadana a menudo son vendidos como útiles para que el público avance en sus conocimientos sobre conservación, en su conocimiento científico y en el incremento de las habilidades de razonamiento científico. No existen directrices para la colaboración entre científicos y el público y casi no se ha estudiado el grado en que estas iniciativas ciudadanos-ciencia cambian el comportamiento. Durante dos años estudiamos a 82 participantes en un programa de 3 días que incluía educación sobre plantas invasoras no nativas y la recolección de datos sobre la ocurrencia de estas plantas. A los voluntarios se les proporcionó conocimiento básico sobre la ecología de plantas invasoras y fueron entrenados en un protocolo específico para la recolección de datos de plantas invasoras. Posteriormente recolectaron datos y se reunieron para analizarlos y discutir sobre comportamiento ambiental responsable en relación con plantas invasoras. Probamos si los participantes sin experiencia en la identificación de plantas y con poco conocimiento de plantas invasoras incrementaron su conocimiento de ecología de especies invasoras, si la participación incrementó su conocimiento de métodos científicos y si la participación afectó su comportamiento. El conocimiento de plantas invasoras incrementó 24% en promedio, pero la participación no fue suficiente para incrementar el entendimiento de cómo se lleva a cabo la investigación científica. Los participantes reportaron incremento en su habilidad para reconocer plantas invasoras e incremento en la conciencia sobre el efecto de las plantas invasoras sobre el ambiente, pero esto se tradujo en pocos cambios en el comportamiento respecto a las*

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plantas invasoras. Los potenciales conflictos entre las metas científicas, las metas educativas y la motivación de participantes deben ser considerados durante el diseño del programa.

Palabras Clave: educación para la conservación, monitoreo, plantas invasoras, respuesta rápida de detección temprana

Introduction

Many conservation challenges have direct links to human behavior. Although resolutions to these complex issues are not always clear, public engagement in conservation efforts and policy formulation is considered desirable by many conservation professionals. Professionals engaging the public often include education as a major goal in their projects because some understanding of biological diversity and ecology and problem solving skills are requisite for conservation literacy (Berkowitz et al. 2005). One approach to this engagement is public participation in research, commonly termed *citizen science* (Bonney et al. 2009), which we define as partnerships initiated by scientists that involve nonscientists in data collection. The amount of collaboration and the degree to which either the scientist or the community drives the partnership varies (Bonney et al. 2009). We acknowledge that learning in projects in which scientists choose the research question can sometimes follow a top-down approach because participants lack ecological understanding. Such an approach is viewed as disadvantageous by project designers (Lehr et al. 2007). This disadvantageous model is avoided in projects in which there is a mutual exchange of knowledge (e.g., McCallie et al. 2009; Kelsey & Dillon 2010).

Nonetheless, citizen-science projects are becoming increasingly popular, raising questions about how to capitalize effectively on opportunities to engage the public in research while achieving broader goals such as increased conservation literacy. Such programs can promote both science and conservation literacy (McCormick et al. 2003; Bonney et al. 2009). Participant knowledge of ecological systems usually increases even if citizen scientists simply make the systematic observations required (Nerbonne & Nelson 2004; Pattengill-Semmens & Semmens 2003). Evans et al. (2005), for example, found that participants monitoring success of bird nests increased their knowledge of avian ecology and local ecology. Trumbull et al. (2000) found that almost 80% of their 700 participants engaged in thinking that resembled aspects of the scientific process in addition to gaining ecology content knowledge while observing birds at feeders.

Citizen-science initiatives can promote active engagement in policy making, as opposed to passive engagement such as voting, even when designers of programs did not explicitly pursue active engagement as a goal (Weber 2000). In a review of citizen macroinvertebrate monitoring programs, there are several examples of programs that not only resulted in the collection of data, but also increased participant knowledge of civic processes and their involvement therein (Nerbonne & Nelson 2004). Participants may also become involved in the policy process after participation in a citizen-science project (Dunlap 1992; Marcinkowski 1993).

The factors that account for the variation in the behavioral effects of citizen-science programs are unknown. Differences in program benefits have been attributed to factors such as participant diversity, project goals, and project design (Volk & McBeth 1997; Nerbonne & Nelson 2004). Clearly, there is a need for more program-evaluation metrics (Bonney et al. 2009).

We investigated whether participants gain scientific-content knowledge, scientific reasoning skills, and knowledge of the nature of science when their motivations and knowledge are diffuse and the project is short term; whether participation in data collection increases participant understanding of how and why science is done; and whether participants change their behavior. The subjects of the investigation were volunteers who mapped and estimated the abundance of non-native invasive plants along hiking trails.

We believe content knowledge (in this case general ecology and effects of non-native invasive plants) is important because we assumed that behavior will not change unless some level of knowledge is acquired (Oskamp et al. 1991). It was once assumed that the public need not understand the science that generates the knowledge about environmental problems, but models of collaborative knowledge exchange have emerged that integrate science with local knowledge (Lehr et al. 2007). For knowledge exchange to occur, scientists and members of the public need to have a somewhat shared vocabulary, and the public needs to be somewhat aware of the context of the message they are receiving from scientists. Communication under these conditions (i.e., collaborative exchange) can promote trust between the 2 groups and perhaps greater and longer lasting behavioral change. To examine the effects of collaborative exchange, we analyzed data collected by volunteers on non-native plant species in a group session. We attempted to promote change in participant behavior by providing explicit instruction on the issue of invasive plants both nationally and locally and by encouraging volunteers to develop specific, personal plans of action related to invasive plants (Hungerford et al. 2001). Our instruction was based on learning theory that targeted the learner as the active agent (i.e., the cognitive perspective), but we integrated socially mediated (i.e., the situative perspective) activities (Stevenson & Stirling 2010).

Methods

Participant Pool

During February 2006 and 2007, we recruited 58 and 35 volunteers, respectively, through the New York–New Jersey Trail Conference, a hiking association with 10,000 members. Through an initial questionnaire we found that most of them had little knowledge of forest ecology, botany, or plant identification. Of the 93 volunteers, 82 participated in the educational portion of the study. The other 11 did not complete all questionnaires.

The volunteers attended one 8-hour training session led by the authors in early June and a 4-hour discussion in early July, after data were collected. We mailed a follow-up questionnaire to each participant in December. In the training session, participants were given information about the ecology and effects of invasive plants. The participants then received hands-on training in identifying a set of non-native invasive plants, and they practiced the protocol with trainers along trails similar to project trails. The protocol, available in the Supporting Information, involved pairs of volunteers hiking an assigned 3.2-km (2 mile) stretch of trail, stopping every 0.3 km (0.1 mile) to record presence and relative density (low, medium, high) of the set of plants in a defined plot (6×2 m) along the trail.

Questionnaires

We used hardcopy questionnaires to collect data from project participants so that data collection could be completed during the training session and thus response rate would be high. Interviewing was impractical because it would have required volunteers to gather again 6 months later for a follow-up meeting. Also, the sample size would be too small given the high volunteer to staff ratio.

We tried to balance questionnaire completeness with time constraints for completion and comfort of the volunteers. We developed the questionnaires through the following steps: (1) we determined constructs to be tested, (2) we generated general questions and used them in semistructured interviews with New York–New Jersey Trail Conference members not in the project, (3) we coded interview data from step 2 following Chi (1997) and devised questions on the basis of our research goals and then reframed them in light of ideas elucidated from interviewees in step 2, (4) we tested the questionnaire developed in step 3 on a subsample of New York–New Jersey Trail Conference members not in the project and refined questions, (5) we tested the questionnaire on 19 undergraduate students, and approximately 90% of them were able to complete each of the questionnaires in 15 min, and (6) we assessed all qualitative responses from participating volunteers according to a coding scheme we developed after reviewing a subset of the collected responses (following Chi 1997). Interview and questionnaire methods are described in Bell et al. (2009). We used open-ended questions, or when possible, short-answer or rating-scale responses to make analysis easier. The latter were used when interview responses varied little. We used a 4-point scale in questions about invasive plant knowledge (1, a lot; 2, a fair amount; 3, only a little; and 4, nothing). For other questions, we used a 5-point scale (1, great extent; 2, moderate extent; 3, some extent; 4, minimal extent; and 5, no extent). The complete set of questionnaires and responses are available in the Supporting Information.

The volunteers filled out questionnaires prior to instruction during the initial training session (pretest), during the discussion meeting at the end of the project, and by mail 6 months later (follow-up). Each volunteer was given a unique code to enable anonymity yet allow us to track individuals. We administered questionnaires in 3 parts at the initial training session. There was time between parts so that volunteers would not be overburdened. Part 1 contained demographic questions and questions related to environmental sensitivity (i.e., an individual's sense of concern for the environment) (Marcinkowski 1993). Part 2 included questions related to content knowledge of ecology and invasive plants and questions about attitude and behavior in regards to invasive plants, including the respondents' sense of locus of control. The latter refers to the sense that an individual can have an effect in resolving an issue, and our questions were formulated specifically in the context of invasive plants. Part 3 included questions exploring respondents' understanding of the nature of science and attitudes toward science. We included scenario-based problems modified from Etheredge and Rudnisky (2003) to assess skills in recognizing and controlling confounding factors and differentiating between causation and correlation.

We discussed those 2 process skills with the participants at the project-completion discussion. We also discussed the value of model-based inference in science because we intended to create models with the data they collected. At the end of the project-completion discussion, we focused on behavioral change. We discussed a variety of ways people could respond to the problem of invasive plants, such as purchasing only noninvasive plants for their yard, removing existing invasive plants from their yard, sharing ideas with others, participation in invasive-plant response teams in the area, contacting legislators and government officials, and involvement in local conservation organizations. The volunteers then generated individual plans for future action.

Table 1. Questionnaire results related to foundational knowledge of general ecology and invasive plant ecology, environmental sensitivity, and sense of locus of control (the sense that an individual can have an effect in resolving an issue) in pretest (n = 82) and follow-up questionnaires (n = 33).*

Construct	*Question*	*Mean pretest (n = 82)*	*Mean follow-up (n = 33)*
Foundational knowledge (e.g., environmental science, ecology)	To what extent are you knowledgeable about environmental science?	2.29	2.66
Foundational knowledge (invasive plant issue)	How much do you know about the problem of invasive plants?	2.6	2.3
Environmental sensitivity (empathy toward the environment)	To what extent do you feel a sense of empathy toward the natural environment?	1.30	1.22
Locus of control (personal effect on an environmental issue)	To what extent do you believe you can influence how environmental problems and issues are resolved?	2.83	3.06
Locus of control (personal effect on invasive plant issue)	To what extent do you feel personally that you can help control the spread of invasive plants?	2.5	2.2
Civic and regulatory awareness (awareness of how issues are resolved)	To what extent are you knowledgeable about the research and regulatory infrastructure as they relate to environmental issues?	3.54	3.39

**For the first 3 questions, response options were 1, a lot; 2, a fair amount; 3, only a little; 4, nothing. For the last 3 questions, response options were 1, great extent; 2, considerable extent; 3, moderate extent; 4, slight extent; 5, no extent. Response options were different to allow for comparison with other studies that obtained answers to similar questions.*

The follow-up questionnaire closely resembled the questionnaires from the initial training session, although we used new scenarios in the questions that assessed the process skills. We also added questions that asked about attitudinal changes resulting from participation in the project, and we asked respondents to report behavior related to invasive plants in which they had engaged since their time in the project. The full protocol and questionnaires are available in the Supporting Information.

To analyze results from the content-knowledge questions, we used a nonparametric test (Wilcoxon signed-rank test) because the number of comparisons was low and behavioral data tend to be non-normally distributed. For coded responses for certain open-ended questions and rating scales, we report proportions and percentages. Here, we report only results from key questions related to environmental sensitivity, knowledge of content and nature of science, science process skills, and behavior.

Results

We combined the 2006 and 2007 groups because we noted no significant differences in demographics or clustering of data between years and the training did not change (t tests, $n = 82$, age, $p = 0.21$; income, $p = 0.67$; education, $p = 0.10$; percentages 2006:2007, gender male 46:46%, retired 11:14%, science-related careers 25:24%). Average age was 51.2 (SD 14.89). Median income fell between US$50,000–75,000, and 66% of participants had a bachelor or higher degree. We received 33 responses to the 6-month follow-up questionnaire (18 from year 1 and 15 from year 2). A 40% response rate is not atypical for questionnaires sent in the mail.

Attitude toward Environmental Issues

Participants, on average, reported being fairly knowledgeable about environmental issues, and changes in such knowledge were moderate over the course of the project (Table 1). Participants initially reported being less knowledgeable about invasive plants than environmental issues in general, but after 6 months, this gap narrowed. On our 5-point scale, with 5 being no extent, we detected an increase (on average from 2.5 to 2.2) in individuals' locus of control with respect to minimizing the spread of invasive plants. There were decreases in knowledge about environmental issues (2.3 to 2.7) and locus of control with respect to environmental issues in general (2.8 to 3.1).

Content Knowledge

Correct responses on content-related questions increased significantly by 24.0% on average between the initial and the follow-up questionnaires (Table 2) (Wilcoxon $T = 0$, $n = 10$, $p < 0.01$). The largest increases were in knowledge of the mechanisms of ecological effect of invasive species and the potential for native species to cause environmental problems. When asked about the extent of their knowledge gain during the

Table 2. Correct responses (%) to questions about invasive plants in pretest ($n = 82$) and follow-up questionnaire ($n = 33$) (T/F, true or false).

Question	*Pretest*	*Follow-up*
What is an invasive species?	75	88
What is an exotic species?	72	88
What is a native species?	81	90
How do invasive species cause problems?	60	92
How do we control invasive plants?	80	92
Do all introduced species become invasive?	68	100
T/F: Invasive plants always cause environmental problems.	68	100
T/F: Exotic plants always cause environmental problems.	94	97
T/F: Native plants can cause environmental problems.	12	71
T/F: Invasive plants are a serious problem in New York and New Jersey.	68	100

project in general, 71% of participants reported they substantially increased their content knowledge about invasive species.

Table 3. Results from the questions assessing nature of science knowledge and scientific inquiry in pretest and follow-up questionnaires.

Question	*Pretest*	*Follow-up*
Nature of science (2006 and 2007)[a]		
To what extent must scientific theories be based on data that are visible (to the naked eye or using devices)?	2.23	2.23
How certain are scientific claims?	2.66	2.62
How often do the bulk of scientific claims change?	2.70	2.52
To what extent do scientists rely only on experiments to generate data?	1.99	2.26
To what extent should scientists share data with the public?	1.65	1.67
Scientific inquiry (2006)[b]		
Separating causation from correlation (2 essay questions)	27.6%	28.7%
Experimental controls (2 essay questions)	58.5%	56.0%

[a]*Means of responses range from 1 (great extent) to 5 (no extent)* (n = *82 pretest;* n = *32 follow-up).*
[b]*Percentage of responses considered sophisticated* (n = *39 pretest;* n = *18 follow-up).*

Nature of Science

We noted little change in knowledge of the nature of science between the pretest and the follow-up questionnaires, on which responses were scored from 1 (great extent) to 5 (no extent). For the question "To what extent must scientific theories be based on data that are visible?" the mean score from both questionnaires was 2.2. The mean score for the question "How certain are scientific claims?" changed from 2.7 in the pretest to 2.6 in the follow-up questionnaire. For "How often do the bulk of scientific claims change?" the mean score changed from 2.7 to 2.5. For "To what extent do scientists rely only on experiments to generate data?" the mean score changed from 2.0 to 2.3. For the question "To what extent should scientists share data with the public?" the mean was unchanged at 1.7 (Table 3).

Science Process Skills

Measuring change in the 2 science-process skills, controlling for confounding factors and discriminating between correlation and causation, was difficult because participants were reluctant to answer the scenario-based questions. Some respondents commented that the questions were difficult or esoteric, and others stated they did not like to write long answers. We also recognized that learning of science skills is tenuous even in a formal classroom with repeated instruction (Jordan et al. 2006). Thus, we excluded these questions in 2007. Slightly over half the respondents to the scenario-based questions in 2006 ($n = 39$ pretest, 18 follow-up) articulated the need to include a control during an experiment (58.5% pretest, 56.0% follow-up). Fewer (27.6% pretest, 28.7% follow-up) were able to clearly discriminate between causation and correlation.

Behavior

In the initial questionnaire, 78% of participants said that they considered whether plants were non-native invasive species when purchasing plants, and 30% replied "true" to the statement "I consider the issue of invasive plants when voting." The former increased to 86% in the follow-up questionnaire, but the latter did not change in the follow-up. In the follow-up questionnaire, 70% of participants reported that their behavior had changed in at least one way as a result of participation. Two people changed their planting habits, one joined an invasive plant removal project, and one did both. Most change was passive: 39% said they now noticed invasive plants and 43% reported talking to others about them. Twenty-eight percent said they had not changed their behavior as planned. The most common explanation for not doing so was, "no time", but many individuals also reported a sense of futility with comments such as, "My making a change wouldn't really matter given how widespread the problem is."

Discussion

We found that participation in a citizen-science data-collection project increased awareness of the issue of invasive plants and resulted in increased content knowledge of up to 6 months. Some individuals reported a change in their appreciation for science; however, instruction in the nature of science, such as what kinds of data scientists use and the certainty and durability of scientific inferences, did not result in change in participants' understanding of those subjects, and participation did not improve their ability to discriminate between causation and correlation or to control confounding factors in scenario-based questions.

A majority of participants reported a change in behavior with respect to invasive plants. The most common change was talking to other people about invasive plants. Four people reported taking direct action through either or both participation in projects related to invasive plants or through planting noninvasive plants in their yards.

The clear gains in content knowledge, coupled with limited gains in understanding the nature of science or of the procedural aspects of science, has been documented in other citizen-science projects (e.g., Brossard et al. 2005; Evans et al. 2005) and are somewhat expected given what is known about undergraduate learning when lecture is the primary mode of instruction (e.g., Saunders & Dickinson 1979). What remains to be tested is how much and what content knowledge the general public needs to have to be able to make informed judgments about issues such as invasive plants. Increased content knowledge can reduce flaws in systematic reasoning about issues related to science. For example, undergraduate content knowledge of genetic engineering correlates positively with application of knowledge in the reasoning process and negatively with reasoning flaws (Sadler & Zeidler 2005).

In our study, participant knowledge of the nature of science and science-process skills did not change, despite explicit instruction. Although participants were motivated and were directly involved in data collection and analysis, more time for active learning may have been warranted. Teaching the nature of science often involves not only targeted instruction (e.g., Etheridge & Rudnitsky 2003), but also time for practice and reflection and time to test ideas, to discover errors, and then to refine ideas (Bransford et al. 1999). We did not allow time for these learning opportunities.

With regard to behavioral change, we found that most participants reported taking the indirect action of talking with others. If, however, individuals are expected to take direct action then it is likely that they will need more than content knowledge and nature of science skills. They will also need to be motivated and believe their actions matter (e.g., Stern 2000). Meinhold and Malkus (2005), among many others, found self-efficacy, which is related to locus of control, is positively correlated with proenvironmental behaviors. We found no change in locus of control. This lack of change may have been in response to a new awareness of the effects of non-native invasive plants, about which many participants remarked in their narratives. It is unclear, however, whether individuals felt overwhelmed by the actions necessary to combat non-native plants or whether they felt their actions would simply be ineffectual. Widespread establishment of non-native invasive plants may simply be an issue that inherently diffuses locus of control. Locally based issues in which change is tenable or observable over a shorter time might yield different results.

If one of the goals is behavioral change, then conservation-related citizen-science projects should perhaps move beyond the unidirectional dissemination of content toward active learning and approaches that reinforce the participants' belief that their behavior can contribute to the conservation effort. The motivational barriers of participants must be overcome if habits, such as planting invasive plants in the context of our invasive-plant project, are to be broken. Overcoming these barriers can be extremely difficult (Biel 2003). Our participants indicated high motivation to take action regarding invasive plants, but perhaps by pairing this motivation with strengthening their sense that specific behavior would benefit conservation, we might have elicited more habit-breaking and proactive behavior than we did. Projects with long-term and intensive engagement of public members or those that result in visible environmental changes have been associated with participant actions such as future engagement in projects or involvement in agencies that manage resources (Bonney et al. 2009).

The methods one might use in a citizen-science project may not be effective for achieving both educational and scientific goals. For example, deep learning benefits from practice, from discovering and working through mistakes, and from allowing ample time for reflection. The links between education and change in attitude, behavior, and support for science are not always direct, and knowledge of how people learn and the effects of their attitudes and beliefs on their decisions is imperative for selecting learning goals and designing the methods to achieve them. Furthermore, the participants must be interested in deep learning. Many people engage in projects to provide labor for a greater good or for a social experience, not to learn. The ecological data generated from the project described here have been submitted for publication and are being used by an invasive-plant task force.

Although it does not appear that participation in our project was associated with gains in science-process skills, even with explicit instruction, some volunteers entered our project with these skills. Across project types, these individuals may have the potential to act as deeply engaged citizen scientists who can help with project design and its undertaking; possibly furthering the reach of professional scientists. Roth and Lee (2004) suggest allowing scientific literacy to emerge from collective discourse and to be an element of lifelong learning. Such a collaborative approach to conservation science could educate the public and affect attitudes and motivations for action.

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