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RESEARCH REPORT

Scientific knowledge and attitude change: The impact of a citizen science project

Dominique Brossard[a,*] Bruce Lewenstein[b] and Rick Bonney[b]
[a]*University of Wisconsin-Madison, WI, USA;* [b]*Cornell University, NY, USA*

This paper discusses the evaluation of an informal science education project, The Birdhouse Network (TBN) of the Cornell Laboratory of Ornithology. The Elaboration Likelihood Model and the theory of Experiential Education were used as frameworks to analyse the impact of TBN on participants' attitudes toward science and the environment, on their knowledge of bird biology, and on their understanding of the scientific process. The project had an impact on participants' knowledge of bird biology. No statistically significant change in participants' attitudes toward science or the environment, or in participants' understanding of the scientific process, could be detected. The results suggest that projects must make explicit to participants the issues that they are experiencing. In addition, the results suggest that more sensitive measures need to be designed to assess attitude change among environmentally aware citizens.

Introduction

The need to encourage public understanding of science is rarely contested. In societies more and more technological, individuals must be able to make informed decisions regarding scientific issues that affect their personal lives, the well-being of their communities, and national issues such as health care and energy policy. Research has shown, however, that in the United States, the general level of understanding of basic scientific concepts and of the nature of scientific inquiry may be insufficient for the average citizen to be able to make informed decisions (National Science Board, 2002). In this context, efforts have been made in the last decade not only in reforming science education in the nation's school system (National Research Council, 1996), but also in promoting informal science education, or science education outside the classroom (Crane et al., 1994; Falk, Donovan, &

*Corresponding author. 5168 Vilas Hall, University of Wisconsin Madison, 821 University Ave, Madison WI 53706, USA. Email: dbrossard@wisc.edu

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Woods, 2001). Although good baseline data exist at the national and international levels for documenting public knowledge and attitudes toward science (National Science Board, 2002), evaluations of specific informal science education projects rarely compare their results to that baseline data. The effectiveness of those projects in changing participants' knowledge and attitudes is often measured only in relative terms, and the results of those studies are either published only as 'grey literature' evaluation reports or as articles in trade journals and sometimes scholarly journals that do not provide scales or other tools that would allow for comparison of effectiveness across studies. The paucity of published data is due in part to the difficulty of isolating the effects of informal activities among a host of influences that may shape knowledge and attitudes (Lewenstein, Brossard, & Bonney, 1997). Nevertheless, if evaluation of informal science education projects is to advance, studies must attempt to create replicable measures that can be applied across different projects.

The summative evaluation presented here of a specific type of informal science education project, a 'citizen science' project, was conducted with a dual goal. First, we wanted to assess the effects of the project, The Birdhouse Network (TBN) of the Cornell Laboratory of Ornithology (then known as the Cornell Nest Box Network, CNBN) on participants' knowledge of bird biology and of the scientific process, and on their attitudes toward science and the environment. Second, we wanted to compare the knowledge and attitudes of the participants with available national norms. Our intention was that by using scales that had produced national norms we could create instruments that would allow for valid comparisons across other citizen science projects, and perhaps across differing kinds of informal science education projects, as well. Although various evaluations of the impact of informal science projects on scientific knowledge and attitudes toward science have been published (e.g., Crane et al., 1994; George & Kaplan, 1998), most literature is devoted to learning in the context of science museums (e.g., Borun, Cleghorn, & Garfield, 1995; Borun, Chambers, & Cleghorn, 1996; Borun & Dritsas, 1997; Anderson, Lucas, Ginns, & Dierking, 2000; for reviews see Dierking & Falk, 1994; Falk, 1997; Medved & Oatley, 2001). The impact of visits to zoos and aquariums on knowledge and attitudes has also been documented (Adelman, Falk, & James, 2000; Dierking, Burtnyk, Buchner, & Falk, 2002). However, informal learning institutions constitute only one context in which informal science education takes place. For example, few published studies have looked specifically at the effect of conservation programs on attitudes and knowledge toward science (for an exception in a school setting, see Bogner, 1999). Also, although citizen science projects such as the one discussed in this paper are rapidly increasing in number (Cohen, 1997; 'Be a Citizen Scientist!', 2003; Pathfinder Science, 2003), the effect of such projects on participants' knowledge and attitudes toward science are yet to be documented.

Two additional issues emerge from a review of informal science education project evaluations. First, few evaluations rely on standardized scales. While observations and measures of achievement within a project may demonstrate progress, the lack of standardized comparable data makes it difficult to decide, for example, that one project achieves particular goals better than another project—both may be deemed 'successful' based on internal evaluations, but without standardized data, an administrator or funder may have no clear basis for choosing between them in the real-world situation of having limited time and resources. Moreover, the lack of data tied to national norms that were established with standardized scales precludes evaluating projects with respect to those norms. While the increasing reliance on testing and quantitative measures in educational policy has many drawbacks, it does represent national policy; to justify continuing investment, informal science education projects must adapt at least in part to national priorities. Using standardized scales and national norms might allow a program to understand more about its particular audience and the particular challenges that it faces.

Second, because informal science learning is under-theorized (Crane, 1994; Falk et al., 2001; Falk & Dierking, 2002), evaluations often are performed without a conceptual framework that could support the development of working hypotheses. By drawing on theoretical frameworks used in other learning or communication contexts, both researchers and practitioners can develop hypotheses that would help in implementing sound evaluation plans. We attempted to address both of these issues in the analysis presented here.

The citizen-science projects at the Cornell Laboratory of Ornithology (CLO) are part of a growing movement of public–professional partnerships that give individuals of all ages an opportunity to participate in real scientific research and to interact with scientists in the process (Cohen, 1997; 'Be a Citizen Scientist!', 2003; Pathfinder Science, 2003). Based on active partnerships between CLO scientists and volunteers across North America, CLO citizen-science projects differ from other informal science education projects by having a dual purpose. First, like many other projects, citizen-science projects aim to increase participants' knowledge about science and the scientific process, and to change their attitudes toward science and the environment. These changes are supposed to be achieved through the combination of direct participation in a scientific study, interaction with scientists during the project, and use of high-quality educational materials provided to participants by CLO. Second and less common, these projects allow scientists to gather large sets of data, based on participants' observations, which can be used for research ultimately published in peer-reviewed journals. Substantial benefits are therefore provided to all citizen-science participants, both professional and non-professional (Bonney, 2001; Bonney, & Krasny, 2004).

Although earlier CLO citizen-science projects were evaluated both at the formative and summative levels (Bonney, & Dhondt, 1997; Lewenstein et al., 1997; Trumbull, Bonney, Bascom, & Cabral, 2000), these evaluations, while supplying interesting background information, provided little detail on knowledge and attitude changes because they were based on participants' self-reports (Lewenstein et al., 1997). More recent projects such as TBN, which was initiated in 1997, adopted an entirely new approach for their summative evaluation, seeking to address the problems identified above: standardized scales, comparisons to national norms, and theoretically-driven evaluation questions.

Among the more complex of CLO's citizen-science projects, TBN focuses on studies of cavity-nesting birds such as bluebirds, tree swallows, and American kestrels. Such species depend on the presence of dead trees and other dead wood for 'cavities' in which to build their nests. Because of the dramatic decline in standing dead trees in the United States over the last two centuries, habitat for cavity-nesting birds has been severely reduced. However, human intervention can help these birds; artificial nest boxes (known colloquially as 'birdhouses', thus leading to the revised project name) provide good locations for nests and have been put up in many locations.

TBN participants are asked to put up one or more nest boxes in their yards or neighbourhoods, then to observe and report data on the nest boxes and their inhabitants while following one or more of four different protocols focusing on the clutch size of each nest; the calcium intake by the birds; the feathers used in the nests; and the nest site selection. Participants receive detailed explanations of the scientific protocols to be followed, biological information about cavity-nesting species, and practical information concerning nest box design, construction, and monitoring. Interaction with TBN staff by phone, email, or through an electronic mailing list is strongly encouraged. Participants are recruited through a variety of media, such as press releases, TV shows, electronic mailing lists, or articles in local newspapers.

What kind of impact does this type of project actually have on adult participants' knowledge of bird biology and science and their attitudes toward science and the environment? We began by seeking a theoretical framework that would motivate more specific hypotheses. While the framework below, drawing on theories of experiential education and theories of attitude change, is necessarily preliminary, we present it here both to document our reasoning and as a resource for others planning evaluations.

Experiential education has been described as student engagement in problem solving requiring the generation of solutions that do not exist before the problem-solving process has been completed. According to experiential theory, 'information gained through experience provides a requisite contextual base for assimilating information obtained through symbolic, vicarious, and other indirect means' (Tuss, 1996: 443). Experiential theory can be contrasted to the information assimilation process, typically employed in traditional classrooms, in which information is conveyed to the student through a symbolic medium, and assimilated before being applied (Tuss, 1996). In the experiential model, students progress from action, to understanding the consequences of the action in a particular context, to generalization to a broader context (Tuss, 1996).

Citizen-science projects are designed to be instances of experiential education (Palmer, 1992; Messmore, 1996). In the case of TBN, participants engage in authentic scientific studies of bird biology, in which real research questions are explored through systematic scientific processes, and for which real answers are identified through the research process and eventually reported in scientific articles. Therefore, in our study we hypothesized that (1) participation in the TBN citizen-science project will result in positive effects on the knowledge of bird biology among adult participants, and (2) participation in the TBN citizen-science project will result in increased knowledge of the understanding of the nature of scientific inquiry among adult participants.

We also were interested in investigating whether citizen-science participation could affect attitudes toward science and the environment, and thus drew on theoretical concepts of 'attitude'. Attitude is defined as 'a learned predisposition to respond in a consistently favourable or unfavourable manner with respect to a given object' (Fishbein, & Ajzen, 1975: 6). Previous research has shown that direct participation in science activities has a positive impact on the attitudes of children and young adults toward science (George, & Kaplan, 1998). However, the impact of direct participation in science on adults' attitudes has rarely been explored (Cullen, 1998).

To explore attitudes, we used a psychological theory, the Elaboration Likelihood Model (Petty, & Cacioppo, 1981, 1986) to formulate working hypotheses. This theory, largely used in the context of communication and persuasion, argues that thoughtful attention to stimuli will activate a central or main route to persuasion. This seems particularly useful for the citizen-science context: because the participants are all volunteers and are thus highly motivated to engage in the project, making them more likely to read the educational material in a thoughtful manner, and thus activating the central route to persuasion. Then, if their preliminary analysis of the material's persuasive content indicates that the arguments (for example, for adopting a commitment to environmental conservation) are strong, the participants' attitudes toward science and toward the environment should change in a positive direction (Petty & Cacioppo, 1981, 1986). This reasoning led us to hypothesis (3): participation in the TBN citizen-science project will result in positive effects on attitudes toward science and the environment among adult participants.

Because one of our goals was to gather data that could be compared to national data, we chose to use mostly existing scales to gather data to test our hypotheses. We were aware that normative instruments designed for national random-samples might not be fully appropriate for evaluating a specific project with a highly self-selected audience. However, we believed that it was a necessary first step for gathering data that would allow us to compare the project participants with the general population, and thus to understand the relationship between our participants' knowledge and attitudes and those of the population at large.

Research methods

Design

Because TBN participants are volunteers (who in fact have paid to receive project materials), the evaluation team had to be careful about requiring of them too much time or effort for evaluation. The perspective of many of the participants is recreational, so that 'the process of evaluation must be both brief and engaging'

(Nicholson et al., 1994: 111). Also, because the participants have paid for enrolment, it was not possible to create a directly-comparable control group (as the decision not to pay might have masked other variables). We therefore used a pretest–post-test non-equivalent groups design (Trochim, 1997), for which measures were administered twice: a pre-test before participants received the educational material and protocols (from March to June 1998), and a post-test at the end of the field season (October to December 1998).

Sampling

Our total study population, which included all new TBN participants—i.e. all those who had not participated in 1997—included 798 individuals by July 1, 1998. Different sampling procedures were used for the pre-test and the post-test. For the treatment pre-test, we used a non-random sampling of the first 300 participants to sign up. The non-random sampling was required because participants began to use the educational materials shortly after receiving them; had we waited until the full sign-up period ended before drawing a sample, many of the participants might have already started using the materials (see 'Procedures and limitations', below). For the control group pre-test we randomly selected 400 members of the CLO who were not participating in TBN or any other CLO citizen-science project. While not directly equivalent, we believed that this group would adequately represent people with knowledge of and attitudes toward birds, the environment, and science.

For the treatment post-test, we used the following sampling procedure: 200 randomly chosen participants who had received the pre-test and 200 randomly chosen participants who had not received the pre-test. This method was chosen to allow us to test for any bias introduced by participants' having taken the pre-test. The control group at post-test was composed of a new set of 400 randomly selected CLO members not participating in any CLO citizen-science project, none of whom had received the pre-test.

We obtained reasonable responses rates from the treatment group (67% for the pre-test, 55% for the post-test). The response rate from the control group was disappointing for the pre-test (29%), but average for the post-test (53%). The low response rate on the pre-test may be explained by our limited follow-up of the pre-test mailing.

The 1998 TBN participants were a relatively homogeneous group: 98% were white, 65% were between 30 and 60 years old, 79% had a 4-year college degree or higher, and 83% had taken at least 2 science classes in college; also, 50% were engaged in a profession related to education. This demographic distribution was not surprising: science museums, public television science programs, and other informal science education programs generally attract the same type of educated and science-oriented audiences (Nicholson, 1994; National Science Board, 2002). No statistically significant differences were found between treatment and control groups as far as demographics are concerned.

Measures

To address our goal of collecting data that could be compared with national norms on knowledge and attitudes towards science and the environment, this study employed primary existing instruments, well documented in the literature. We developed one instrument to measure the specific knowledge of bird biology conveyed by the project materials. Attitude toward science was assessed with a modified version of the attitude toward organized science scale (ATOSS) developed by the National Science Foundation (National Science Board, 1996). The original ATOSS scale used by NSF until the late 1990s and used in our 1997 pilot study included 4 items, each with 2 potential response choices 'agree' or 'disagree' (see Appendix, Section A). The value of each of the four items (i.e., 0=disagree; 1=agree) in the ATOSS scale were summed to obtain a total score representing that respondent's general attitude toward science, ranging from 0 (anti-science) to 4 (pro-science). Because 28% of the responses to the ATOSS scale used in the 1997 pilot study were missing, we hypothesized that respondents may have chosen an 'undecided' option, if offered. We therefore included a larger range of potential responses ('strongly agree'=–2, 'agree'=–1, 'neither agree nor disagree'=0, 'disagree'=1, 'strongly disagree'=2) in the 1998 measure, which we called ATOSS modified (MATOSS). For each respondent, the total score was computed by summing the response for each item after reversed items had been recoded. Therefore, the score for MATOSS ranged from –8 (anti science) to +8 (pro-science).

MATOS and ATOS are identical as far as items are concerned. Because the ATOS scale has been repeatedly tested at the national level for the NSF's Science & engineering indicators series, we can assume that both ATOS and MATOS are face valid and content valid. Construct validity of the ATOS scale was assessed in our 1997 pilot study (Lewenstein et al., 1997). Although the reliability of the scale was surprisingly low for a well-used scale when calculated with our 1997 data (standardized alpha=0.57), we nevertheless decided to continue using the scale because of our goal of comparing our data with national norms. No data could be found in the literature in terms of discriminant and convergent validity.

Attitude toward the environment was assessed with a sub-scale of the most frequently used measure of public environment concern (Stern, Dietz, & Guagnano, 1995), the new environmental paradigm (NEP) scale, originally developed in 1978 (Dunlap, & Van Liere, 1978) and revised in 1992 (Dunlap et al., 1992). We could not use the complete NEP scale that includes 12 items because it was essential to limit the total length of the survey instrument for the reason noted above. We therefore included only the NEP/humans-with-nature subscale, a 3-item scale (see Appendix, Section B) with a Likert-type format (strongly agree, agree, disagree, strongly disagree). The initial scale was modified in the following way: a neutral point was added to the Likert scale and some statements were reworded slightly to avoid a gender bias, as suggested by Scotts and Willits (1994). Because the scale has been widely used and validated by a panel of researchers in the field of environmental attitudes, we make the assumption that it is face valid and content valid. Convergent validity of NEP was assessed in 1995, with the parallel use of a general awareness of consequences (GAC) scale (Stern et al., 1995). No data could be found on discriminant validity. The alpha-Cronbach reliability of the NEP/human-with-nature subscale we used is 0.54.

Understanding of the scientific process was assessed with both a closed-ended question and an open-ended question as previously done by the Science and engineering indicators (National Science Board, 1996) (see Appendix, Section C). In a first section of the survey, respondents were asked to rate their level of understanding of the term ‘scientific study’. In a following section, respondents were asked to describe what they thought it means to study something scientifically. No information on the construct validity of this measure is given in the literature.

Knowledge of bird biology was assessed with a scale specifically developed for this study (see Appendix, Section D). The 10 items were developed by a panel of science communicators, science educators, and scientists from the TBN team. The scale was specifically built to assess knowledge of information presented in the educational material provided to the participants. The score for the knowledge of bird biology scale was computed (after the reversed items have been recoded) by adding the responses for each item. The total score ranges from 0 (no knowledge) to 10 (high knowledge). The alpha-Cronbach reliability coefficient is 0.65.

Procedures and limitations

Immediately after enrolment but before receiving any CLO material (winter and early spring 1998), the treatment group received by mail a packet containing a cover letter, a survey instrument, and a stamped, addressed return envelope. A single mailing to the control group in early Spring 1998 contained the same packet. The survey instrument requested some demographic information and included the four measures described above. Individuals were asked to return their completed surveys as soon as possible. TBN participants then spent late spring, summer, and early fall observing nest boxes and birds, recording data according to the different protocols, and interacting with TBN scientists if they chose. At the end of the field season (October 1998), after the participants’ data had been collected by TBN staff, a second packet—including a cover letter, the same survey, and a stamped, addressed return envelope—was mailed to both treatment and control groups to collect the post-test data. Dillman’s (1978) procedures were followed as much as possible to ensure reasonable response rates.

Some limitations of the methods need to be pointed out. First, the pre-test treatment group should have been selected randomly from the study population. Such selection was impossible, however, owing to the timing of the project. Participants enrolled in the project from January to June, and needed to receive their research materials quickly to begin their observations on time. If we had waited until all participants had enrolled to perform a random sampling, most of the participants would have received and studied their educational material by the time they received

Table 1. Frequencies of responses for the MATOSS for 1998 TBN evaluation pre-tests (treatment and control groups), and 1996 NSF data

	TBN treatment group (n = 300)			TBN control group (n = 400)			NSF 1996 (n = 2006)		
Item of ATOSS scale	Agree	Disagree	Undecided	Agree	Disagree	Undecided	Agree	Disagree	Undecided
‘Science and technology are making our lives healthier, easier, and more comfortable’	72.7%	7.1%	20.2%	73%	9%	18%	86 %	NA	NA
‘The benefits of science are greater than any harmful effects’	26.6%	38.7%	34.7%	31.9%	36.2%	31.9%	72%	NA	NA
‘Science makes our way of life move too fast’	29%	36.5%	34.5%	23.9%	39.8%	36.3%	NA	60%	NA
‘We depend too much on science and not enough on faith’	21.4%	40.6%	38%	26.3%	48.7%	25%	NA	44%	NA

Note: Original 1996 NSF data were drawn as responses to the following statement read over the phone: ‘Now I would like to read you some statements like those you might find in a newspaper or magazine article. For each statement, please tell me if you generally agree or disagree. If you feel especially strongly about a statement, please tell me that you strongly agree or strongly disagree’. Only one percentage was reported for each item (National Science Board, 1996: appendix table 7–20). In the TBN study, the same question was presented on a paper survey, with an additional option of ‘undecided’. NA, data not available.

the pre-test, thus biasing the results. Second, anonymity concerns prevented us from tracking changes in knowledge and attitudes specifically for each individual. We therefore could not perform a paired-data analysis. In order to avoid pre-testing bias, we did not include individuals who had performed the pre-test in our analysis of the pretest–post-test changes of attitudes and knowledge. Third, budget restrictions prevented us from strictly following Dillman's procedures for the follow-up of the control group pre-test survey, which impacted the response rate for that group. Finally, it is important to point out that our concern was to assess the TBN project and to test the possibility of using standardized scales; because our study population was so specific, we knew that our results might not be generalizable. We suggest, however, that the results of our study may be generalized to other citizen-science projects that are similar to TBN and that involve participants with the same profile as TBN participants.

Results and discussion

Attitude toward science

In contrast with our 1997 results, we obtained an extremely low number of missing values in 1998, a result that was consistent with our hypothesis that a modified ATOSS scale allowing for 'undecided' answers was appropriate. We did in fact obtain a high number of undecided responses, as shown in Table 2.

However, direct comparison of the 1998 TBN MATOSS results and the 1996 NSF ATOSS results drawn from the general population is not possible, because computing ATOSS in the 1998 TBN data would leave out of the analysis all respondents who answered 'undecided' on at least one of the items of the scale. This would amount to 71% of the returned surveys for the treatment pre-test, a much higher percentage than we had expected.

Table 2. Means for MATOSS for 1998 pre-test and post-test treatment and control groups

Level	Number of surveys sent	Overall response rate (%)	Usable responses (%)	Mean[a]	Standard deviation
Treatment group pre-test	300	67	65	$m_1 = 1.031$	2.670
Treatment group post-test	200	55	49.5	$m_2 = 1.374$	2.566
Control group pre-test	400	29	27.5	$m_3 = 1.391$	2.679
Control group post-test	400	53	44.5	$m_4 = 1.213$	2.484

Note: Statistical test: contrast $l_1 = (m_2 - m_1) - (m_4 - m_3)$, Ho: $l_1 \leq 0$ versus Ha: $l_1 > 0$, $t = 1.155$, $p = 0.12$.

[a] Total score ranging from –8 (strong negative attitude toward science) to +8 (strong positive attitude toward science).

In sum, although a major goal had been to collect data on project participants' attitudes toward science that could be compared with data on attitudes toward science among the general American public, the combination of our 1997 and 1998 studies leads us to question whether existing national data can be used successfully for this goal. Though the national data is internally consistent and therefore provides a useful and powerful longitudinal data set, it is not sufficiently fine-grained to allow for more detailed explorations and comparisons with smaller data sets such as the ones we collected in the evaluation of TBN.

Moving to the results just of the TBN evaluation, the comparison between the mean attitudes toward science among pre-project and post-project respondents are presented in Table 3. The MATOSS score could range from –8 to +8, with a positive number indicating a positive attitude toward organized science. As noted earlier, the pretest–post-test non-equivalent groups design is susceptible to the internal validity threat of selection, because any prior differences between the control and treatment group may bias the conclusions of the evaluation (Trochim, 1997). However, our results avoided this threat, as no statistically significant difference between treatment and control group mean scores for MATOSS could be detected at pre-test (t=–1.13 p=0.26).

As shown in the 'mean' column, all groups tested had a slightly positive attitude toward science. However, after participating in the TBN program, the attitude toward science among the treatment group was essentially unchanged (see Table 3). Therefore, participation in the program did not change participants' attitudes toward science in any way measured by this test.

We offer two explanations for this finding, both of which should be investigated in further studies. One explanation is related to the persuasive content of the

Table 3. Means for NEP/humans-with-nature subscale for 1998 pre-test and post-test treatment and control groups

Level	Number of surveys sent	Overall response rate (%)	Usable responses (%)	Mean[a]	Standard deviation
Treatment group pre-test	300	67	47	$m_1 = 0.248$	0.55
Treatment group post-test	200	55	38	$m_2 = 0.421$	0.77
Control group pre-test	400	29	19.5	$m_3 = 0.192$	0.60
Control group post-test	400	53	34	$m_4 = 0.257$	0.70

Note: Statistical test: contrast $l_1 = (m_2 - m_1) - (m_4 - m_3)$, Ho: $l_1 \leq 0$ versus Ha: $l_1 > 0$, $t = 0.79$, $p = 0.214$.

[a] Score ranging from 0 (against human action on the environment) to 3 (pro human action on the environment).

educational materials that are used for this project, and the other is related to the attitude itself.

The persuasive content of the educational material

As explained earlier, our hypothesis that TBN would have an impact on participants' attitude toward science was based on the elaboration likelihood model (Petty & Cacioppo, 1981, 1986). Because we believed that participants were highly motivated to work on the project, we assumed that they would engage in a thoughtful process when reading the educational materials. The thoughtful process would activate the central route to persuasion, leading to a change in attitude. But was the central route to persuasion really activated among participants? To assess the strength of the arguments presented in the educational material, focus groups using thought-listing techniques should be conducted. If the central route to persuasion is not activated by interaction with these materials, they may need to be revised before they can successfully increase participants' positive attitudes toward science.

Examining attitude complexity

A second possible explanation for our findings is that respondents' attitudes toward science are more complex than we initially considered. Four arguments can be extrapolated from our results to support this hypothesis.

First, the large number of undecided responses on both pre-tests and post-tests for both treatment and control groups may indicate that respondents' attitudes toward science are complex. Some respondents wrote comments on their surveys explaining that choosing an answer was difficult because they had mixed feelings about the issue. In other words, some respondents may be ambivalent rather than truly undecided. Gardner (1987) discussed the complicated effect of ambivalence on the validity of science attitude measurement scales, suggesting that simple responses may miss the complexity of the underlying attitudes. Because we could not differentiate ambivalent responses from undecided responses in our results, we could not detect any possible changes in ambivalence. Future measures should therefore include a direct measure of ambivalence (e.g., include a response choice such as 'I have mixed feelings about this issue', as proposed by Gardner, 1987).

Second, we showed that participants' general attitude toward science stayed moderate at the post-test stage (see Table 3). Responses indicating moderate attitude have been associated in some instances with belief complexity (Eagly, & Chaiken, 1993), which addresses the different dimensions present in a person's set of beliefs (Ostrom et al., 1994). It could therefore be argued that the set of beliefs that influence participants' general attitude toward science is rendered more complex by participating in TBN, while the general attitude stays moderate. Again, this hypothesis should be examined in further studies.

Two further arguments address additional aspects of attitude complexity. It could be argued that participation in the project might have stabilized an attitude that could otherwise have deteriorated over time. The cumulative impact of the TBN project should therefore be assessed by measuring the impact of the project over several months or years, which was beyond the scope of this evaluation. Finally, our scale may not have been sensitive enough to detect changes in attitude in this specific population, as suggested by the large standard deviations for the means (see Table 3). However, we have no results to support such a hypothesis. Further studies should develop a more sensitive scale and compare the results obtained with that measure to the results presented here.

Attitude toward the environment

According to Dunlap and Van Liere, who proposed the New Environmental Paradigm (1978), the anthropocentric worldview that could be a source of the earth's ecological problems may be challenged by a new environmental paradigm, in which individuals believe in the limits of growth, in the necessity of balancing economic growth with environmental protection, and in the need for humans to protect the balance of nature. As explained earlier, we hypothesized that participation in TBN would lead individuals to subscribe more to the NEP, and therefore lower their scores on the NEP/humans-with-nature subscale.

Results of the participants' and control groups' responses to the NEP/humans-with-nature subscale are presented in Table 4. The subscale ranges from 0 (opposing human action on the environment) to 3 (favouring human action on the environment).

After participating in TBN, individuals showed no statistically significant change in their attitude toward the environment compared with the control group. However, the results of the pre-test suggested that even before participating in TBN, respondents already were highly concerned about environmental conservation, a finding which clearly indicates the specificity of the population interested in participating in projects such as citizen science. This conclusion was confirmed by comparing the pre-test responses to the NEP/humans-with-nature subscale to results of a survey performed in 1990 in Pennsylvania on 3,600 randomly selected individuals (Scott & Willits, 1994).

The results show that the general population in the 1990 study gave much more anthropocentric responses than the TBN and CLO audiences surveyed for the 1998 study (for example, 27% agreeing that 'Humans were created to rule over the rest of nature', as compared with 9% and 12% for the treatment and control groups in the 1998 TBN study).

This suggests that both TBN participants and the general CLO population used as a control group subscribed to the new environmental paradigm whether or not they participated in the project. In our 1998 study, the frequency of undecided responses obtained for the NEP/humans-with-nature subscale was lower than the frequency obtained for the attitude toward science scale items (see Table 2), which may indicate that respondents were less ambivalent about the environment than about science.

Table 4. Frequencies of responses for NEP/humans-with-nature subscale for 1998 pre-tests (treatment and control groups), and 1990 Pennsylvania data

NEP/Humans-With-Nature subscale	TBN treatment group (n = 300)			TBN control group (n = 400)			Pennsylvania 1990[a] (n = 3600)		
	Agree	Disagree	Undecided	Agree	Disagree	Undecided	Agree	Disagree	Undecided
Item A	9.4%	84.8%	6%	11.6%	79.5%	8.9%	27.3%	60.6%	12.1%
Item B	10.6%	69.7%	19.7%	10.6%	73.5%	15.9%	15.8%	70.5%	13.7%
Item C	4.6%	89.4%	6%	5.4%	82%	12.6%	31.7%	57.4%	11%
Item D	2%	95%	3%	2.7%	92%	5.3%	9.3%	80.5%	10.2%
Mean total score[b]	0.248 (standard deviation 0.55)			0.192 (standard deviation 0.6)				NA	

Note: Item A, 'Humans were created to rule over the rest of nature'; item B, 'People have the right to modify the natural environment to suit their needs'; item C, 'Plants and animals exist primarily to be used by people'; item D, 'People need not to adapt to the natural environment because they can remake it to suit their needs'.

[a]See Scott and Willits (1994).

[b]Total score ranging form 0 (anti-human action) to 3 (pro-human action).

Table 5. Comparison of frequencies of responses for the meaning of 'scientific study' for 1998 treatment and control groups[a] at pre-test and post-test

Response category	Level			
	Treatment group pre-test	Treatment group post-test	Control group pre-test	Control group post-test
1: Theory development and testing	39.77% *(0.85)*	32.95% *(–0.46)*	42.27% *(1.04)*	28.67% *(–1.44)*
2: Experiment and controls	6.82% *(–1.77)*	9.09% *(–0.62)*	16.49% *(1.52)*	14.69% *(1.20)*
3: Rigorous measurements and comparisons	21.02% *(1.13)*	14.77% *(–0.60)*	17.53% *(0.02)*	14.69% *(–0.79)*
4: None of the aforementioned levels of understanding	32.39% *(–0.65)*	43.18% *(1.24)*	23.71% *(–1.92)*	41.96% *(1.34)*

Note: chi-square = 21.121, degrees of freedom = 9, $p = 0.012$. Standardized residuals presented in parentheses.

[a] Participants claiming to have a clear understanding or a general sense of what a scientific study is.

Considering this finding, it may be difficult, and even unnecessary, to change project participants' attitudes toward the environment, at least a population of TBN participants with the same profile as participants in 1998.

Understanding of the scientific process

Results for the first step of the assessment of the understanding of scientific process among our respondents are presented in Table 6.

More than 93% of the treatment group claimed to have a 'clear understanding' or a 'general sense' of what a scientific study is, while only 6.6% acknowledged having little understanding of the term 'scientific study' before participating in the project.

Next, participants who had claimed either a clear understanding of or a general sense about a scientific study were asked to explain 'scientific study' in their own words. Responses to this open-ended question were coded in four categories as defined by the NSF's science and engineering indicators (1996): 1) Responses describing a scientific study as theory building and testing; 2) Responses focusing on experimental studies that include the use of controls; 3) Responses describing careful and rigorous comparisons; 4) Responses showing none of the above levels of understanding. Figure 1 shows the results for the treatment group at pre-test.

A large proportion (32.7%) of the treatment group at pre-test who had claimed to have a clear understanding or a general sense of what a scientific study is could not give an acceptable explanation. This number was however substantially lower than

Table 6. Means for knowledge of bird biology for 1998 pre-test and post-test treatment and control groups

Level	Number of surveys sent	Overall response rate (%)	Usable responses (%)	Mean[a]	Standard deviation
Treatment group pre-test	300	67	63.7	$m_1 = 6.272$	1.826
Treatment group post-test	200	55	47.5	$m_2 = 7.179$	1.313
Control group pre-test	400	29	26	$m_3 = 5.990$	1.973
Control group post-test	400	53	42.75	$m_4 = 5.491$	2.129

Note: Statistical test: contrast $l_1 = (m_2 - m_1) - (m_4 - m_3)$, Ho: $l_1 \leq 0$ versus Ha: $l_1 > 0$, $t = 4.463$, $p = 0.000$.

[a] Score ranging from 0 (not knowledgeable at all) to 10 (excellent knowledge).

the 1996 NSF national data, in which 64% of the respondents could not give an acceptable explanation (National Science Board, 1996). Nevertheless, with our pre-test showing that more than half of the total treatment group could explain the scientific process only poorly or not at all, it appears that participation in TBN could provide a real potential for increasing many participants' understanding of the scientific process.

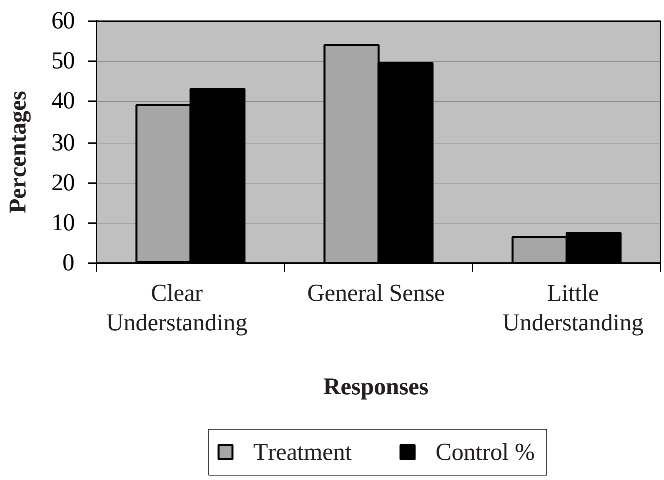

Figure 1. Frequencies of responses for the understanding of the scientific process for 1998 pre-tests, question 1 (treatment and control groups): 'When you hear or read the term "scientific study", do you have (please check one): (a) a clear understanding of what it means; (b) a general sense of what it means; (c) little understanding of what it means'. No data were available for NSF 1996.

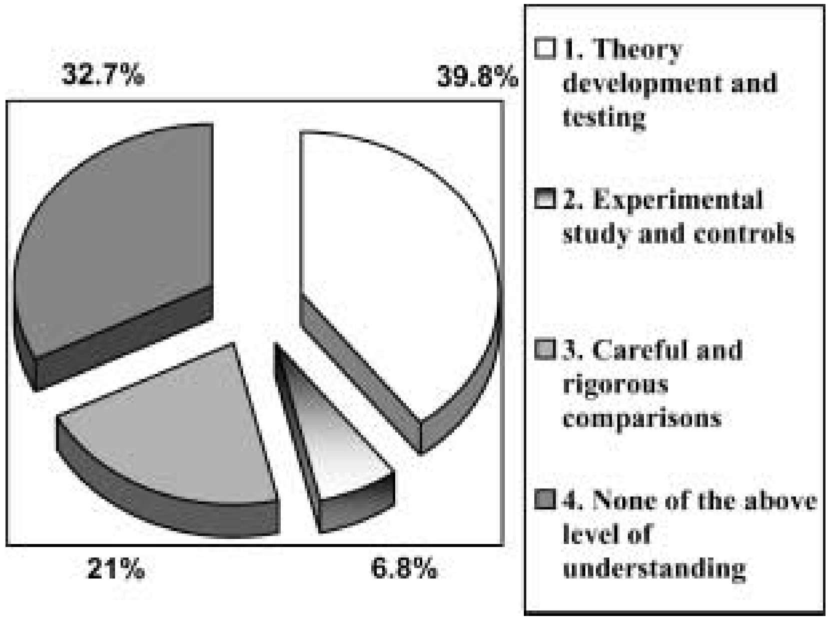

Figure 2. Frequencies of responses for the understanding of the scientific process for pre-test 1998 treatment group (participants who claimed to have a clear understanding or a general sense of what a scientific study is).

We thus examined the impact of participation in TBN on participants' understanding of the scientific process by analysing the change in proportions of responses for the four categories of responses (see Table 7). At p=0.05, some changes could be detected (chi-square=21.121, df=9, p=0.012), generally suggesting that respondents became *less* able to answer the question of what the meaning 'scientific study' is. However, analysing the residuals showed that the differences might be due to the control group proportions (standardized residual=–1.92 for control group pre-test response 4, which is lower than expected). Although a difference in proportions of responses between pre-test treatment and post-test treatment seemed to be present, a second analysis showed no statistically significant difference between the two groups (chi-square=4.237, df=3, p=0.237). Therefore, we found no statistically significant evidence suggesting that TBN participants changed their understanding of the scientific process.

As a tentative explanation for this result, we note that a primary motivation for participants to enrol in TBN was an interest in birds rather than a desire for involvement in a scientific project (Brossard, & Lewenstein, 1998). It could therefore be argued that participants, although involved in the scientific process, failed to concentrate on this process because they were focused on the subject itself, the cavity-nesting birds. Nothing in the experiential context stressed to the participants that they were involved in the scientific process. The results concerning the impact of TBN on knowledge of bird biology, presented next, seem to confirm this possibility.

Table 7. Comparison of frequencies of responses for the meaning of 'scientific study' for 1998 treatment and control groups* at pre-test and post-test.

Level Response Category	Treatment Group Pre-test	Treatment Group Post-test	Control Group Pre-test	Control Group Post-test
1: Theory development and testing	39.77% *(0.85)***	32.95% *(–0.46)***	42.27% *(1.04)***	28.67% *(–1.44)***
2: Experiment and controls	6.82% *(–1.77)***	9.09% *(–0.62)***	16.49% *(1.52)***	14.69% *(1.20)***
3: Rigorous measurements and comparisons	21.02% *(1.13)***	14.77% *(–0.60)***	17.53% *(0.02)***	14.69% *(–0.79)***
4: None of the above levels of understanding	32.39% *(–0.65)***	43.18% *(1.24)***	23.71% *(–1.92)***	41.96% *(1.34)***

Chi-Square = 21.121, df = 9, p value= 0.012
* Participants claiming to have a clear understanding or a general sense of what a scientific study is.
** Standardized residuals.

Knowledge of bird biology

Participants' knowledge of bird biology was measured on a scale that we developed ranging from 0 (not knowledgeable at all) to 10 (very knowledgeable). No statistically significant difference between TBN and control group mean scores for knowledge of bird biology could be detected at pre-test (t=1.29, p=0.20). Therefore, as discussed earlier, we did not face a problem with the internal validity threat of selection.

Results for the knowledge of bird biology scale for the treatment and control groups, for both pre-test and post-test, are presented in Table 8.

After participating in TBN, participants increased their knowledge of bird biology by nearly one full point in their mean scores, a result that is statistically significant (t=4.463, p=0.000). The increase contrasted with a slight decline in the mean score of the control group (which was probably an artefact of the low response rate to the control group pre-test survey). Therefore, the project was successful at increasing participants' knowledge of bird biology. As mentioned earlier, participants' primary motivation for joining TBN was their interest in birds. Therefore, the experiential context was particularly relevant for the subject matter of 'bird biology', which may explain why TBN increased participants' knowledge of bird biology without significantly improving their understanding of the scientific process.

Conclusion

This paper describes the summative evaluation of a citizen-science project focusing on the study of cavity-nesting birds. We applied rigorous and standardized

Table 8. Means for knowledge of bird biology for 1998 pre-test and post-test treatment and control groups

Level	# surveys sent	Overall Response Rate	Usable Responses	Mean*	Standard Deviation
Treatment Group Pre-test	300	67%	63.7%	m_1=6.272	1.826
Treatment Group Post-test	200	55%	47.5%	m_2=7.179	1.313
Control Group Pre-test	400	29%	26%	m_3=5.990	1.973
Control Group Post-test	400	53%	42.75%	m_4=5.491	2.129

Statistical test:

Contrast $l_1=(m_2-m_1)-(m_4-m_3)$

Ho: l_1 <or=0 vs. Ha: $l_1>0$

t=4.463, p=0.000

* Score ranging from 0 (not knowledgeable at all) to 10 (excellent knowledge)

methodologies in an attempt to allow the results to be generalized beyond the specific project population.

We showed that the project increased participants' knowledge of bird biology. Such an impact of a complex citizen-science education project like TBN, which has never been documented in the literature, demonstrates that carefully designed citizen-science projects can be successful environments for increasing adult knowledge of factual science. However, no statistically significant change in participants' understanding of the scientific process, attitudes toward science and attitudes toward the environment could be detected.

Because participants' interest in the subject of study (such as birds in the TBN context) may move contemplation of the more general scientific process to the background of the project, citizen-science projects that hope to increase understanding of the scientific process should be framed in a way that makes participants particularly aware of the scientific process in which they are becoming involved. Only then will participants be experiencing an experiential context (Tuss, 1996), which could lead to a better understanding of the scientific process.

Considering changes in attitudes toward science, the high number of undecided responses to the attitude items may indicate that participants' attitudes toward science are complex and that citizen science participants hold ambivalent attitudes. Further studies should thus test scales that integrate ambivalent responses. In addition, the high standard deviations may indicate that the scale is not sensitive enough and that a four-item measure for such a complex dimension as attitudes towards science might be problematic. Ideally, individuals in future studies should either respond to more items or selected individuals could be interviewed about their beliefs as one means to confirm validity of multiple choice responses.

On attitudes toward the environment, the participants' scores on the NEP/humans-with-nature subscale already was low at pre-test. This may suggest that TBN participants were subscribing to the new environmental paradigm prior to project participation, a result indicating the specificity of the population interested in projects such as citizen science. The persuasive content of TBN educational material in terms of attitude messages therefore should be assessed in a rigorous way to more appropriately apply the elaboration likelihood model of persuasion (Petty, & Cacioppo, 1981, 1986).

Despite these issues, we clearly demonstrated that, while sensitive measurement tools still need to be developed, a citizen-science project such as TBN can be rigorously evaluated within theoretical frameworks. However, if new scales for the assessment of citizen-science participants' attitude toward science and the environment are designed, they should not be intended for use only in the context of a specific project. Rather, the informal science-education field should foster the use of measurement tools that can be used across multiple projects to compare their effectiveness. Such tools should therefore be tested not only with specific citizen-science project participants, but also with other citizen-science projects and with the general population.

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APPENDIX

A. <u>Attitude toward science scale items</u>:

- Science and technology are making our lives healthier, easier, and more comfortable.
- The benefits of science are greater than any harmful effects.
- Science makes our way of life move too fast.
- We depend too much of science and not enough on faith.

B. <u>NEP/humans-with nature subscale items</u>:

- Humans were created to rule over the rest of nature.
- People have the right to modify the natural environment to suit their needs.
- Plants and animals exist primarily to be used by people.
- People need not to adapt to the natural environment because they can remake it to suit their needs.

C. <u>Understanding of the scientific process items</u>:

- When you hear or read the term ‘scientific study’ do you have (please check one):
- a clear understanding of what it means
- a general sense of what it means
- little understanding of what it means
- If you checked a) or b) for the previous question, please tell us in your own words what it means to study something scientifically:

D. <u>Bird knowledge scale items</u>:

- Most songbirds lay one egg per day during the breeding season.
- Clutch size refers to the number of eggs a female bird can fit in her nest.
- All birds line their nest with feathers.
- Humans can handle nestlings with little fear of the nest being abandoned by the adult birds.
- The age of a female bird can influence the number of eggs she lays.
- Some birds need supplemental calcium to produce eggs.
- Most cavity-nesting birds eat primarily seeds.
- Cavity-nesting species that use nest boxes are safe from predators.
- Some species of warblers use nest boxes.
- Nest boxes should never be made of pressure-treated wood.