A CASE STUDY OF CITIZEN SCIENCE

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ABSTRACT
Citizen science is a research/education technique, pioneered by the Cornell Lab of Ornithology (CLO), aimed at increasing public understanding about biology, ecology, and the scientific process. Broadly defined, citizen science engages the general public in professional scientific research. Through its Citizen Science Program, CLO has involved thousands of people across North America as they collect and examine data in partnership with CLO scientists. Citizen Science projects such as The Birdhouse Network (TBN) have been shown to be successful at teaching the public about bird biology and the conservation needs of birds, while also providing scientists with valuable data that have been used to study bird populations and which are published in peer-reviewed journals. Evidence is less clear that this type of project can influence participants' understanding of the process of science. This case study uses qualitative and quantitative data to demonstrate the ways in which a citizen science project—through its research, education, and conservation goals—may help enhance science as well as scientific literacy.

INDEX TERMS
citizen science, informal science education, science literacy, public understanding of science.

INTRODUCTION

It is estimated that less than 20% of American adults are scientifically literate, and that number is fewer still for citizens of Europe, Canada, and Japan (Miller 2004). According to the Program for International Student Assessment (PISA), fourth grade students in the United States achieved about the same level of scientific literacy as other students from countries belonging to the Organization for Economic Cooperation and Development (Lemke et al. 2004). But by the time that US students reach the eighth grade, they show significantly lower levels of scientific literacy than eight graders in those countries. Smaller scale studies have shown that students have inadequate knowledge about scientific inquiry and the nature of science (Aikenhead 1973, Lederman 1992). Miller (2004) identifies two main factors that positively affect scientific literacy in individuals who have completed secondary education. The first and most influential factor is the number of college science courses taken. However, Miller also found that informal science education resources such as science museums, science magazines, home computers, and science books and websites had a relatively strong effect on enhancing scientific literacy. This has led many institutions with educational missions, including the Cornell Lab of Ornithology (CLO), to develop various "informal science education" (ISE) programs to help increase scientific literacy among the public.

The definition of scientific literacy has evolved through the last fifty years, reflecting the predominant images of science and the revolutionary changes occurring in society (Hurd 1998). For the purpose of this paper, we refer to Lederman's (1998) definition of scientific literacy (sometimes also referred to as "civic scientific literacy") as "the ability to use scientific knowledge to make informed personal and societal decisions." According to this definition, societies that invest in a scientifically literate population produce critical thinkers and creative habits of mind among citizens, which benefit the overall society. It should be emphasized that scientific literacy is distinct from "science literacy", which focuses on the accruement of technical or scientific knowledge and facts.

During the past two decades, reform efforts in the United States have been in place to identify and address critical thinking skills associated with scientific literacy. Movements such as the *National Science Education Standards* (National Research Council 1996) and *Benchmarks for Science Literacy* (American Association for the Advancement of Science 1993) encourage curricula that employ critical thinking skills in primary and secondary education classrooms. These reform documents have defined common themes central to the scientific literacy debate, mainly the social function of science and the ability to make informed decisions. The documents have become widely accepted by the U.S. science education community and have resulted in a surge of "inquiry-based" interventions that aim to increase scientific literacy. Consequently, there have been numerous empirical studies conducted on formal science education interventions (Lederman 1992, Akindehin 1988, Schwartz et al. 2004, Abd-El-Khalick 1998, Crawford et al. in press). In contrast, the informal science sector has fewer published studies that evaluate specific informal science projects (Brossard et al. *in press,* Crane et al. 1994). This case study uses qualitative and quantitative evaluation data to examine whether participating in an informal science education project called The Birdhouse Network, a citizen-science project developed by the CLO, can increase scientific literacy.

Citizen science is a research/education technique, pioneered by the CLO, aimed at increasing public understanding about biology, ecology, and the scientific process. Broadly defined, citizen science engages the general public in professional scientific research. Unlike many other ISE projects, citizen science projects have the additional goal of allowing scientists to gather data that are both temporally and spatially robust. These large data sets are used to answer biologically relevant research questions, with the ultimate goal of publication in peer-reviewed journals (see Hames et al. 2002, Hochachka et al. 1999, Hochachka & Dhondt 2000, Rosenberg et al. 1999). Through its Citizen Science Program, CLO has involved thousands of people across North America as they collect and examine data in partnership with CLO scientists (Bonney 2004). In addition, citizen science projects have provided a platform for scientists to become involved in outreach activities, which have benefits for both scientists and local communities (Krasny & Bonney 2005).

The Birdhouse Network (TBN) is one of the more complex citizen science projects in the CLO's Citizen Science Program. The project was initially funded from a U.S. National Science Foundation (NSF) grant (ESI-9627280). Since its inception, TBN has involved more than 5,000 participants across North America in its research. These "citizen-scientists"monitor anywhere from one to several hundred nest boxes in their yards and neighborhoods, collecting breeding bird data that they submit to CLO scientists over the World Wide Web. Participants collect data on nest location, species, first egg date, clutch size, number of nestlings, number of unhatched eggs, and other breeding variables. These data allow researchers to study breeding patterns of cavity-nesting birds over large spatial scales and across long periods of time. The data are used to answer questions related to clutch size variation, feather use in nests, the effect of pesticides on nesting success, patterns of female incubation behavior, and other breeding biology-related questions. Scientific findings are shared with participants, non-participants, and the scientific community through TBN's website; CLO's quarterly newsletter, *BirdScope*; a semi-annual newsletter specific to TBN participants; publications in popular magazines; and through technical journals. All ages and backgrounds are welcome to participate in TBN, but the majority of participants reflect a relatively homogeneous group of Caucasian, well-educated, middle-aged participants. This demographic distribution is similar to audiences that typically visit science museums and participate in other ISE programs (National Science Board 2002).

The specific objectives of TBN are to 1) involve people of all ages and backgrounds in valuable ornithological research; 2) gather long-term data about the breeding biology of cavity-nesting birds across a large geographic region, 3) teach people about cavity-nesting birds, their conservation needs, and nest box monitoring, 4) help people to understand and conduct scientific research, and 5) use the World Wide Web to facilitate citizen communication with scientists. Based on these objectives, we hypothesize that TBN participants engaged in the educational, research, and conservation objectives of the project will increase their knowledge of bird biology as well as their scientific literacy levels. The specific objectives of this evaluation are to: 1) describe the potential of informal science education interventions such as citizen science for increasing science and scientific literacy; and 2) examine data that evaluates whether or not scientific literacy was enhanced as a result of engaging in citizen science.

SCIENCE COMMUNICATION PROCESS

Although the concept of citizen science has existed for over a century (Krasny & Bonney 2005), the term "citizen science" is relatively new. A theoretical framework for the field is just now in development (Bonney and Phillips, in prep). A common theme central to citizen science, however, is that it educates through voluntary learning. This type of self-selected learning is often called “free choice learning” which, according to the Institute for Learning Innovation (2002), is "the most common type of lifelong learning" and is "self-motivated and guided by the needs and interests of the learner." Free choice learning is based on a contextual model of learning (Falk & Dierking 2002) that takes into account the interactions between the personal, sociocultural, and physical contexts that a learner experiences when engaged in learning. The contextual model presumes that learning starts with an individual's motivation, interest, and prior knowledge (personal context); that it is influenced by society and culture (sociocultural context); and that it requires a tangible setting (physical context).

Additionally, the expectations of what TBN participants will achieve is based on a “web” model of science communication (Lewenstein 1995), in which the distinctions between “science” and “popularization” are broken down and information is understood to flow both from science to the public and from the public to science. Thus we expect that TBN participants will learn both about the scientific process (“scientific literacy”) and about particular factual items in nature (“science literacy”). In addition, we expect that TBN will contribute in substantive ways to the creation of reliable knowledge about nature – that is, that it will contribute to scientific knowledge about the world.

TBN participants are recruited through various media including articles in newspapers and magazines, electronic mailing lists, press releases, direct mail campaigns, and the World Wide Web. These citizen scientists are volunteers who pay a small annual fee of $15 to participate. Before the spread of the World Wide Web, participants received a comprehensive 160-page research kit in the mail. The kit provided instructions for participating in the project, detailed descriptions of four scientific protocols, species accounts for 25 cavity-nesting birds, and practical information on monitoring nest boxes. In addition, participants are encouraged to communicate with staff by phone, e-mail, or electronic mail lists. Because of the high cost of printing and publishing the research kits, in 2000 TBN went completely online, replicating the research kit in digital form on TBN's website <http://www.birds.cornell.edu/birdhouse>. The website also allows participants to enter all of their nest-box observations via the "Data Gateway," where they can also query their personal data or the project-wide dataset. Also, a section called "News and Results" highlights technical and non-technical publications that have analyzed TBN data and showcases original scientific studies conducted by TBN participants. By far, however, the most popular pages on the site are in the Nest Box Cam section, which uses innovative technologies to send images of nesting birds inside their nest boxes over the Internet in real time. Additionally, TBN staff maintain a daily archive with images and text of each bird featured on the Nest Box Cams. These daily archives serve to communicate the nesting cycle as it happens to Internet viewers across the world. After 2000, participants received only a "welcome packet" in the mail; this contained posters, instructions, and information for contacting TBN staff. They also continued to receive *BirdScope*, CLO's quarterly newsletter in which results from all of its citizen science projects

The responsibility for reading materials created and provided by CLO scientists in order to learn about bird biology and the scientific process rests with the participants. Once they receive materials, they are electronically reminded of the importance of proper monitoring and the need for submitting their data in a timely manner. Unless participants request information or are involved with a special project, they do not receive individual attention from CLO staff. As CLO scientists analyze the accumulated data, findings are published in numerous places for the general public to view, including the Internet, *BirdScope*, technical journals, and popular publications. Another important aspect of the communication process is interchange among participants, who are strongly encouraged to sign up for electronic mail lists. Through the use of these semi-monitored lists, "veteran" nest box monitors have provided valuable expertise to people new to nest-box monitoring.

TBN also strives to communicate the conservation needs of lesser-known cavity-nesting birds, termed "Most Wanted Birds." After CLO scientists realized that nearly 70 percent of all nesting records in the TBN database belonged to just 3 of the 40 cavity-nesting species, they developed a proactive conservation initiative to: 1) communicate to participants that data on *all* cavity-nesting birds were important and needed; 2) encourage nest-box monitors to evaluate their habitats and provide nesting sites for birds; and 3) increase the diversity of nesting records in the database to allow for analyses of species that are less common and possibly in decline within their breeding ranges.

EVALUATION

Evaluation of TBN has included a mix of qualitative and quantitative research methods. In 1997, participants received a pre-test survey prior to receiving educational materials and a post-test survey at the end of the field season. The researchers used a modified version of an existing instrument—Attitude Toward Organized Science Scale (ATOSS)— in order to compare collected data with those of national norms. The ATOSS survey enlisted the Dillman (1978) method for designing and conducting pre and post surveys. The total study population was 798 individuals and the response rate was between 53% and 67% for pre and post surveys. One concern in using this survey instrument is that the results are not generalizeable outside of programs like TBN.

In 2005, a subset of the Views of Science, Technology, and Society (VSTOS) survey—developed in Canada, and used to assess beliefs about the nature of science (Aikenhead & Ryan 1992)—was used to conduct a pilot survey of active TBN members involved in a slightly more complex investigation entitled Incubation Rhythm Study. In this pilot study we acknowledge that the sample size was very small (12 TBN participants and 9 scientists). Also, a few scientists raised concerns about the survey instrument itself, commenting that the response choices were either too vague or too closely related to make a distinction. The scope of the qualitative research is too broad to describe fully in these pages, but it relies on collection of evidence from scientific reports, quotes and comments from the website and e-mails, reports of hits to TBN's website, examination of products produced by TBN participants and students, and interviews with citizen scientists.

Comparisons of pre- and post-project surveys have shown that TBN participants increase their knowledge of bird biology (Brossard et al. *in press*). This is due in part to the fact that participants were self-selected, and their motivation to learn about bird biology was probably quite high. Evidence is less clear that participants have increased their knowledge of science process as a result of participating in TBN. This finding is likely a result of participants joining TBN to learn about cavity-nesting birds rather than to learn about science; also, there was little information in the packets received by the early participants that would "teach" them that they were learning about science process, and not just about birds. Finally, participants seemed to change little in their attitudes toward the environment, but this was again probably because they were self-selected and their initial attitude towards the environment was already well established (Brossard et al. *in press*).

In developing the Incubation Rhythms Study, CLO scientists solicited feedback from TBN participants to refine the protocol. . Preliminary data are being evaluated to compare whether TBN participants who helped to develop scientific protocols have views related to the scientific process similar to those of CLO scientists. In comparing the two groups, scientists and participants had a majority of similar responses in 6 of the 15 questions. Interestingly, while a majority of scientists and participants agreed that the scientific method was "questioning, hypothesizing, collecting data and concluding," they differed in their beliefs about what the scientific method could accomplish. For example, when answering a question about best practices used by scientists, 44% of CLO scientists chose the response "The scientific method is useful in many instances, but it does not ensure results. Thus the best scientists will also use originality and creativity." In contrast, 75% of TBN participants chose the response: "The scientific method ensures valid, clear, logical, and accurate results. Thus, most scientists will follow the steps of the scientific method." These responses suggest that citizen scientists have a more absolutist view of the scientific method than do professional scientists.

Several forms of qualitative data suggest that TBN has effectively used its Internet presence, particularly through Nest Box Cams, to educate diverse and underserved audiences about the breeding biology of cavity-nesting birds. We believe that the daily commentary provided for each Nest Box Cam species has effectively engaged online viewers and provided an interactive online learning experience. Official "WebTrend" log reports estimate that each year nearly 250,000 people view the Nest Box Cam pages. During the 2004 breeding season, the cams received more than 40 million hits. Additionally, the average time spent viewing cam pages was over 3 minutes, a longer view time than for any other CLO web page.

New in 2005, Nest Box Cam viewers are able to post comments directly to the website and have their questions answered by fellow Internet viewers. While a small percentage of the comments lack substance, a large number (over 80%) are valid questions related to breeding biology that are answered accurately by other members of the general public. A recent visitor to the cam site writes “What a marvelous opportunity for kids! My wife and I have managed bluebird trails for 15 years (over 14,000 fledglings), and, with these nest cams, we are seeing bluebird behaviors that we've never had the opportunity to actually witness. It's the next best thing to being there.” This quote demonstrates that even “veteran” nest-box monitors can gain new knowledge and benefit from viewing the nesting cycle in this way. Another recent cam visitor writes: “Thanks to watching your bluebird cams via the internet all last summer I got interested in helping bluebirds. I put up my first bluebird box last fall. The box attracted a nesting pair of Eastern Bluebirds this spring.” These kinds of quotes demonstrate that viewers are not only learning about nesting birds, but also becoming motivated to provide nest boxes for birds in their yards. Similarly, as a result of TBN’s “Most Wanted” initiative, many participants have provided nesting boxes for under-represented species and entered their observations online. As a result, the number of nesting records for 14 of the 16 "Most Wanted" species has increased significantly in TBN’s database. Moreover, many participants have documented their efforts to create “wildlife sanctuaries” in their backyards as a result of learning about the conservation needs of birds.

In addition, youth have demonstrated understanding of breeding biology and have used innovative technologies to demonstrate the cycle of life. As a result of participating in TBN and hosting a Nest Box Cam at their school, a fourth grade class from Kentucky created a two-minute video claymation of the Eastern Bluebird’s nesting cycle. The claymation included original music and lyrics and correctly illustrated the entire nesting cycle from nest building to young birds fledging. Another classroom that also was involved in TBN led a successful school-wide conservation agenda to increase the number of local nesting Ospreys along a nearby watershed. Still other classrooms have created original artwork, hosted nest-box building workshops, and entered their birdhouse projects into science fairs. One particularly ambitious student involved his community in a native species re-introduction program and, as a result of his efforts, was one of nine national winners to receive a Presidential Youth Award from the U.S. Environmental Protection Agency in 2005.

CLO staff routinely monitor (and sometimes moderate) the electronic mail discussions. Many of these involve participants asking questions related to specific biological question and in some cases, the scientific process. In some instances the questions raised by participants have been refined and developed into studies that TBN is currently investigating. In other cases, participants have set up their own experiments and shared their results with the e-mail discussion group. At least eight participant-initiated studies (which are written as scientific reports at the request of TBN staff) are currently presented on TBN’s website. These examples illustrate the ways in which public communication can directly affect the production of new knowledge well beyond simply providing data.

DISCUSSION

Qualitative and quantitative data have been used to illustrate the ways in which participating in one citizen science project can successfully increase understanding of science literacy (in this case, knowledge pertaining to breeding biology) and the conservation needs of birds. This is particularly true if participants are self-selected. Evidence is lacking that “doing science” through TBN actually increases scientific literacy among participants or their understandings of the nature of science. Although TBN's project materials were comprehensive, they did not explicitly refer to the scientific methodology involved in the process of developing the program. Nor do the materials ask participants to reflect on the scientific process. Informal science educators are now recommending that the "science" behind inquiry science projects be both explicit *and* reflective (Akindehin 1988, Crawford et al., in press). Future ISE materials should make the nature of science explicit in order to help participants better understand that process and how they are involved in it, and other CLO citizen science projects are being developed with this thought in mind.

As noted above, a key claim of the "web" model of science communication is that the public can contribute directly to scientific findings–"public communication" is not simply "popularization" from scientists to public. The TBN project, as with other citizen science projects, has demonstrated that this model does operate in some cases. To date, TBN has collected more than 50,000 nesting records on 40 cavity-nesting birds across North America. These data have produced eight scientific papers that have been published in peer-reviewed journals (for example, Dhondt et al. 2002; Cooper et al. *in press*; Winkler et al. 2004; Cooper et al. 2005).

There is also little doubt that findings from citizen-science collected data are helping scientists to advance ornithological life history theory and adding to the general body of avian bird knowledge. Projects such as TBN are also helping scientists to increase their understanding of breeding biology selection pressures (such as the cost of migration and seasonal variation of food resources), which birds face each breeding season. In the future, data collected by citizens should allow CLO scientists to develop management guidelines for attracting these birds and maintaining their nesting habitats. Also, there is strong anecdotal evidence that engaging in citizen science projects may actually increase conservation-related behaviors among participants. Future research should aim to measure the kinds of environmentally-friendly behaviors that participants undertake as a result of citizen science engagement.

CONCLUSION

The relationship forged between citizens and CLO scientists has proven to benefit both parties. These benefits have significant implications for increasing science literacy and environmental awareness in the general public, while also providing scientists with valuable data that have been used to study bird populations and which have been published in a variety of peer-reviewed journals. Furthermore, the citizen science model can be exported to other taxa and used by researchers to monitor environmental variables across large scales in a way not possible by any other means. Evidence is not as clear about the influence of citizen science in increasing scientific literacy. Given the complexity of these projects, however, and the inherent errors of measurement to quantify their effectiveness, a mixed methods approach that incorporates new measurement instruments and in-depth interviews of scientists and participant is needed in order to obtain more robust interpretation of data.

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