Engaging youth in citizen science fulfills several objectives and enables youth to conduct "real" science in community settings. Adult volunteers play key roles and also benefit.

Citizen Science and Youth Audiences: Educational Outcomes of the Monarch Larva Monitoring Project

Dina L. Kountoupes and Karen S. Oberhauser

Abstract

Citizen science projects in which members of the public participate in large scale science research programs are excellent ways for universities to engage the broader community in authentic science research. The Monarch Larva Monitoring Project (MLMP) is such a project. It involves hundreds of individuals throughout the United States and southern Canada in a study of monarch butterfly distribution and abundance. This program, run by faculty, graduate students, and staff at the University of Minnesota, provides research opportunities for volunteer monitors. We used mixed methods to understand contexts, outcomes, and promising practices for engaging youth in this project. Slightly over a third of our adult volunteers engaged youth in monitoring activities. They reported that the youth were successful at and enjoyed project activities, with the exception of data entry. Adults innovations increased the success and educational value of the project for children without compromising data integrity. Many adults engaged in extension activities, including independent research that built on their monitoring observations. This project provides an excellent forum for science and environmental education through investigation, direct and long-term interactions with natural settings, and data analysis.

Introduction

A growing number of citizen science projects engage the public in observing nature using defined protocols that range from monitoring species abundance to more detailed observations of organisms and their environments (Citizen Science Central, 2008). Most citizen science projects involve networks of volunteers, many of whom participate in scientific research despite little or no scientific training. These programs provide benefits for both the participants and project managers at many levels. Because college and university scientists coordinate so many citizen science projects, they provide an excellent example of community engagement by higher education institutions. They fulfill an important mission of these institutions by offering the opportunity to work collaboratively with the broader community on issues of common interest. Because many citizen science projects address environmental questions, the resulting community engagement often directly relates to environmental health and well-being. From a scientific perspective, public involvement has expanded scientific capabilities and applications, resulting in long-term data covering wide geographic areas (e.g. Swengel, 1995; Wells, Rosenbery, Dunn, Tessaglia-Hymes, and Dhondt, 1998; Goffredo, Piccinetti, and Zaccanti, 2004; Prysby and Oberhauser, 2004; McCaffrey, 2005; Pilz, Ballard, and Jones, 2006). From a science education perspective, citizen science projects provide venues in which non-scientists can engage in the processes of inquiry and discovery scientists use to understand natural phenomena. This engagement meets important science education goals (Ferry, 1995; National Conference on Student and Scientist Partnerships, 1997; NRC, 1996, 2000; Trumbull, Bonney, and Bascom, 2000), giving participants opportunities to ask and "determine answers to questions derived from curiosity about everyday experiences," and "describe, explain, and predict natural phenomena" (NRC, 1996, p. 22). However, there have been few detailed studies of the educational value of citizen science projects. An exception is Brossard, Lewenstein, and Bonney (2005), who showed that adult participants in The Birdhouse Network, a Cornell University Lab of Ornithology citizen science project, gained science knowledge.

Citizen science projects also address environmental education goals by providing opportunities to engage in outdoor activities that promote connections with nature and by fostering an understanding and appreciation of environmental concepts through hands-on engagement with natural systems. Kellert (2005) found that direct exposure to nature, specifically interactions with "largely self-sustaining features and processes of the natural environment" (p. 65), particularly during middle childhood, helps to develop capacities for creativity, problem-solving, and emotional and intellectual development.

The American Institutes for Research (2005) studied the impact of extensive outdoor education programs on at-risk youth. Students who engaged in these programs exhibited increased mastery of science concepts, enhanced cooperation and conflict resolution skills, and improved self-esteem, problem-solving ability, motivation to learn, and classroom behavior. Taylor, Kuo, and Sullivan (2001) showed that contact with nature helped to reduce the impact of attention deficit disorder in children (see also Louv, 2005).

MLMP is a University of Minnesota citizen science project with well-documented scientific outcomes (Prysby, 2004; Prysby and Oberhauser, 2004; Oberhauser, Gebhard, Cameron, and Oberhauser, 2007; Batalden, Oberhauser, and Peterson, 2007). The project began as part of a graduate thesis project in 1996. Volunteers are recruited via e-mail lists and websites, word-of-mouth, or a network of cooperating nature centers. They learn monitoring protocols from hardcopy or online instructions or in training workshops. Monitoring involves weekly measurements of monarch egg and larval abundance throughout late spring and summer.

From 2001-2005 we conducted train-the-trainer workshops at nature centers throughout the eastern United States. Naturalists and other professional educators who took part in these workshops continue to train new volunteers. Faculty, staff, and graduate students in the University of Minnesota's Department of Fisheries, Wildlife, and Conservation Biology coordinate the program. They answer questions posed by volunteers and produce an annual newsletter that summarizes findings and spotlights volunteer work. They also publish findings and maintain a project website. University personnel monitor several sites and continue to conduct training for volunteers.

Volunteers choose and describe their own monitoring sites. These include backyard gardens, abandoned fields, pastures, and restored prairies throughout the monarchs' eastern breeding range (the eastern half of the United States and southeastern Canada). The only requirement is that these sites contain milkweed (species *Asclepias*), the monarch's larval host plant. Volunteers examine milkweed plants and record the number of eggs and larvae observed and the number of milkweeds, from which they make weekly estimates of monarch densities. They identify larvae instars (or life cycle stages; monarchs go through five larval instars). Optional activities include comparing characteristics of milkweed occupied by monarchs to randomly selected plants, collecting larvae to rear in captivity for estimates of parasitism rates, and collecting weather data. They enter their data into an online Microsoft Access relational database. Volunteers have contributed to scientific understanding of monarch butterfly population dynamics, predation, and potential responses to global science change.

Here, we focus on the educational values of MLMP, particularly when adults engage youth in informal educational settings in which participants pursue voluntary, self-directed activities not part of a school curriculum (see Falk, 2001). This free-choice learning is self-motivated and guided by the needs and interests of the learner (Institute for Learning Innovation, 2008). While some adults were teachers, they participated voluntarily during the summer, and student participants did not receive credit. Some adults in our study were professional naturalists, but the youth and adults with whom they worked did so on a voluntary basis. Thus, all learning was free-choice. The goals of this study were to determine the degree to which adults engaged youth in MLMP, what their goals were, and what outcomes they perceived for youth participants.

Methods

Evaluation Context and Methods

We conducted this research in coordination with a utilization-focused program evaluation (Patton, 1997) that would help to inform this and other citizen science projects that engage youth. An additional assessment was to understand the value of the program, and by extension other similar programs, in promoting educational goals that the adult leaders had for youth. Research questions addressed the contexts in which adults involve youth in this program, how adults implemented monitoring activities with youth, and the value of engaging youth in the project as perceived by the adults.

We used a mixture of quantitative (survey) and qualitative (purposive interviews) methods. All evaluation participants were adult volunteers; we observed, but did not survey or interview, the youth.

We initially conducted a short survey of participants monitoring with children as an addendum to our yearly evaluation questionnaire in 2004. Most participants filled out the survey online; participants without Internet access received questionnaires by mail. The addendum included multiple choice questions that addressed demographics, youth interest in activities, and the context of their participation in the project. As an incentive to fill out and send in the survey, we offered a free book on monarch biology.

We used the survey results to identify a purposive (Miles and Huberman, 1984) sample of volunteers whose answers indicated that they had the most experience monitoring with children. While the group represented a variety of monitoring contexts, our smaller interview group did not proportionally represent all of the contexts identified by the initial survey. Interviewees included teachers monitoring with children from their classes or their community and nature center educators. They were from North Carolina, Minnesota, Texas, and Vermont.

Interviews consisted of a series of open-ended questions designed to elicit data about participant goals and experiences monitoring with children, the context in which these experiences occurred, stories that illustrated their points, what they wanted from the program, and what materials they used. The interviewer used a format that allowed interviewees to speak from their own perspectives during 30 to 60 minute interviews conducted by phone (n = 7), in person (n = 1), and by e-mail due to a hearing impairment (n = 1).

Interviews were recorded and transcribed verbatim. Transcripts and written notes were then analyzed to derive coded categories from important themes and concepts, organizing the data in clusters for further analysis (Miles and Huberman, 1984). Coding, by co-author Kountoupes, entailed three stages: (1) initial exploration of the data to identify broad categories, or open codes; (2) axial coding, or coding to identify relationships between and among categories; (3) selective coding to identify a central story imbedded in the first two stages. This systematic analysis, rather than forcing themes into pre-existing categories, enabled development of themes grounded in data analysis and observation (Ezzy, 2002).

Results

Quantitative Results

Of 141 survey respondents, 52 (37%) identified themselves as participating in MLMP with children. Table 1 summarizes the contexts in which these respondents engaged youth. The three most common types of child participants were family members, neighbors, friends, or students of adult volunteers (Table 1a). Most adults monitored with five or fewer children, although some groups included more than 10 children (Table 1b). Groups tended to include relatively narrow age ranges, and few adults worked exclusively with children under the age of 7 (Table 1c).

Adults were asked to identify three favorite activities of the children. Finding monarch eggs and caterpillars was overwhelmingly the favorite

Table 1. Characteristics of Youth Monitors

a. Group Type*	%
Family of adult volunteers	60
Neighbors/community	30
School group	18
Home school group	10
Nature center program	6
Other summer program/camp	6
Day care	2
b. Group Size (number of children)	**%**
1-2	43
3-5	37
6-10	4
> 10	14
c. Youth Ages	**%**
5-6 years	4
7-9 years	20
10-12 years	22
worked with multiple ages	41

[*Respondents could give multiple answers]

Table 2. Responses to: Rate the Three Monitoring Activities that Children in your Project Enjoy Most.

Activity*	%
Finding caterpillars/eggs on plants	98
Rearing larvae	53
Being outside	42
Identifying eggs and caterpillar instars	40
Counting plants or monarchs	28
Data collection and entry	12
Taking egg home to watch metamorphosis	2

[*Percent of respondents who listed each activity as one of the top three]

activity (Table 2). We tested for correlations between age and the likelihood that activities were included in the top three, combining single age groups of elementary (ages 5-9) and secondary students (ages 10-16) to increase the sample sizes within each group. There was no age effect on the likelihood that any activities were or were not included among the top three.

Only one activity was rated difficult (identifying the correct instar of a caterpillar) by more than 25% of respondents (Table 3), although many groups did not do the three optional activities with children, and adults completed some required activities without involving the children (the milkweed density survey, filling out the data sheets, and inputting data into the online data base). The age of the children involved in the monitoring had no effect on the likelihood that they did any of the activities except inputting data; 80% of the children aged 5-9 and 43% of those aged 10-16 did not enter data ($X^2 = 3.77$, df $= 1$, $p = 0.05$).

Qualitative Results

Interviewees included four naturalists who monitored with children at nature centers and five teachers monitoring with children during the summer. One teacher's children were part of her group, and two teachers, both in Texas, continued monitoring into the school year with entire classes. Nature center groups included families who were trained at nature centers and then continued to monitor at that nature center, youth monitoring with home-school groups or other educational groups, and summer day camps for which monitoring was a focus activity. The sizes of the groups led by teachers in the summer ranged from 5 to 14 students, with up to 20 students working with the teachers who continued during the school year. These teacher-led groups included elementary students (one group), middle school students (three groups), and high school students (one group). Sizes of nature center groups ranged from 1 to 11 children and were often variable from week to week. The children at nature centers ranged from 6

Table 3. Responses (percentages) to: Please Rate the Success Children Experienced with Each of the Following Monitoring Activities.

MLP Activity	Easy	Moderate	Difficult	Did not do
Distinguishing milkweed from other plants	70	25	5	0
Identifying correct caterpillar instar	7	49	29	14
Finding eggs and larvae	36	50	9	4
Completing milkweed density survey	18	35	11	37
Filling out data sheets	35	31	7	28
Inputting data	19	17	5	59
Recording weather data*	31	36	2	30
Rearing larvae to estimate parasitism rates*	38	14	0	46
Comparing plants occupied by monarchs to random plants*	9	12	9	70

[*Optional activities]

Table 4. Adult Perceptions to Children's Response to MLMP Activities

Activities Children Enjoyed Most	%	Activities Children Enjoyed Least	%
Using research equipment	89	Collecting weather data with rain gauge	22
Being around monarchs	56	Children respond less to milkweed than monarchs	22
Finding eggs/larvae	22	Not finding eggs/larvae	33
Being outside	22	Mosquitoes and hot weather	33
Seeing field results online	22	Entering data	22
Finding other living things	56		
Socializing with other children	33		
Using field guides	22		

[Interviewees could give multiple responses. n = 9]

years old to high school students.

Our interviews revealed monitoring logistics and practices to which children responded positively and negatively. When the qualitative data gleaned from interviews allowed, we compared positive and negative reactions to correlated thematic activities (Table 4). For example, children enjoyed carrying and using their equipment appropriately. Responsibility for the equipment generated pride in their work even though it was very simple, consisting of clipboards, field journals, meter sticks, data sheets, hand lenses, and rain gauges.

"[The children] love walking around with their butterfly nets; they love looking with their hand lenses. This is very cool business." – MLMP volunteer

However, this positive feeling did not apply to all equipment. Two adults remarked that children were not very interested in using the rain gauge. Additionally, most noted that children responded positively to being around and finding monarchs, but the activities that involved milkweed did not engage them as effectively, and they were discouraged when they did not find monarchs.

Adults made modifications to improve the experience for the children with whom they were working, but eight interviewees emphasized the care they took not to veer from the prescribed protocol. They emphasized the importance of teaching children that a key part of scientific research is following the methods exactly to ensure scientific accuracy and validity. Three groups collected data from small sub-sites of 50 or fewer plants and monitored every plant, rather than following the random sampling methodology outlined in the protocol. Two groups only counted eggs and larvae with the children, noting that time constraints did not allow them to do the milkweed counting or the optional weather or milkweed condition data collection.

One naturalist conducted a training for youth only. She found that children could not keep up with adult learning speeds when adults and youth were trained together, and adults lost interest when she took the time needed to practice and teach children the protocol properly. The modified training involved more hands-on learning; they "went out in the field and practiced the monitoring rather than talking about it."

Five interviewees made changes to the data collection sheets to cater them to their groups' ability and interest. These changes included simplification (such as using a separate page for each day), adding columns to allow children to write down additional observations, color-coding data sheets, and making multiple data sheets to allow comparisons between sections of a single site.

Six interviewees had children pair up to collect data in the field with one observer and one recorder. Newer monitors were paired with experienced individuals when possible, providing leadership opportunities as well as a way to quickly teach data collection. In three cases, inexperienced children monitored with an adult until they felt confident doing it on their own or with another partner. Many adults separated nonstructured play, or "hang-out" time, from data collection time, resulting in less distraction and playing around when children needed to concentrate on accurate data collection.

Most interviewees added extension activities to MLMP protocol. Depending on the children's ages, additional activities ranged from reading story books about insects to designing and carrying out independent research. Activities mentioned by at least two interviewees included raising and tagging monarchs, observing and identifying organisms in the field, implementing other outdoor educational activities, and taking science-related field trips. Five groups conducted additional outdoor field research. Three of these five groups designed and implemented independent research projects – coming up with the question, designing methods to answer it, and collecting their own data – in addition to collecting MLMP data. They presented their findings at local, regional, state, and international science fairs and to community groups. The other two groups chose a site-level question, working together to design methods to answer these questions. For example, one group of children monitored two different sites, a restored prairie section and an agricultural field with milkweed, and compared their data to learn if there were any differences in monarch population characteristics between the sites.

Interviewees identified a number of challenges to involving children in MLMP. Online data entry, the biggest challenge, was resolved in a variety of ways. Five adults entered the data weekly without involving the youth. Two groups entered data every week, and two had a data entry party at the end of the season. Three interviewees said that the children simply did not like being inside in front of a computer. Access to computers was noted as a problem by three interviewees and time constraints by two. Adults with access to multiple computers had the most success entering data with groups of children. Because of concern for accuracy, two adults entered all the data themselves.

Perceived Value of MLMP to Children

A comparison of adults' goals for monitoring with children and their perception of what children gained shows that many of their goals were met (Table 5). All adult interviewees said their principal motivation was giving children an opportunity to make important scientific contributions by participating in "real" science. (Table 5a). Clearly, this goal was met; learning and understanding scientific research was the most commonly noted outcome of participating in MLMP (Table 5b):

> "To me there is nothing more exciting than seeing kids turned on to science and to be able to have them turned on doing 'real' science." – volunteer

> "It (MLMP) has truly changed the whole thought process of working with kids and giving them science that is real." – volunteer

Adults nurtured children's perceptions of themselves as scientists in many ways. For example, some of them recognized youth participants by placing signs at their monitoring sites that explained the project and identified the participants. One group wore "Jr. Lepidopterist" name tags while monitoring, and many showed the children their field data on MLMP's website, emphasizing the importance of their contributions.

Providing "fun" activities that nurtured a love of science were goals for the adults, and they reported that these social goals were realized (Tables 5a and 5b). Interviewees identified enjoyment of time outside and socializing and meeting friends as important outcomes of the project. They supported social outcomes by providing a social hour each monitoring day to eat, talk, debrief, and become closer (n = 6) and having an end-of-season party (n = 6).

"They (children) get to come to my house and we hang out afterwards and always have goodies on the porch. It's just kind of hanging out and it's good. There's tons of bonding, science bonding." – volunteer

Discussion

Many citizen science projects have an explicit educational focus, and when their target is

Table 5. Adults Goals for Monitoring with Children and Perception of Outcomes*

a. Goals	**%**
Make important science contributions	100
Inquiry-based learning experience	78
Do real science	78
Connect with nature	33
Inspire children to work in the sciences	22
Fun learning experience	22
Adult leader loves doing science	22
b. Perceived Outcomes	**%**
Understand real scientific research	67
Children feel like real scientists	44
Do something important	44
Discover, learn about living things outside	44
Time to socialize and meet new friends	44
Enjoy time outside	33
Children go on to study science	33
Leadership opportunity	33

[*Respondents could give multiple answers] a youth audience, many of them work through schools. For example, GLOBE (Global Learning and Observations to Benefit the Environment) promotes investigations of the environment in primary and secondary schools (GLOBE, 2008), and many classrooms participate in stream monitoring programs (Overholt and Mackenzie, 2005). The values of these programs in formal education settings have been well documented (Bouillion and Gomez, 2001; Juhl, Yearsley, and Silva, 1997; GLOBE, 2008). However, many citizen science projects take place in informal science education settings and youth engagement is primarily through adult volunteers; it is this context that we addressed in our study.

Because monarch butterfly eggs and larvae can be found in urban, rural, and suburban areas, MLMP is accessible to a diverse audience. Additionally, monarchs are familiar, fairly common organisms easy for children to observe and handle. While this project has the benefit of an accessible and familiar organism, our findings are applicable to a broad range of outdoor science research projects, including those that focus on birds, weather, other insects, and even earthworms. Engagement in these projects can increase youth involvement in hands-on science, providing opportunities for keen observations and immersion into natural settings.

Many adults (37% of the participants in our quantitative survey) were engaging youth in this citizen science project. They had clear educational and social goals and perceived that these goals were being met. The large range of ages of children suggests that citizen science projects can provide quality experiences for many ages. Additionally, this age range as well as the variety of group types, sizes, and contexts illustrated how this free-choice learning activity is guided by the varied needs and interests of participants.

Adults identified a number of challenges for children, elected to do some of the more difficult activities themselves, and chose not to do some of the optional activities when they monitored with children. They modified training procedures and activities to increase learning outcomes. Only one project activity was identified as difficult for children by over 25% of survey respondents (assigning an instar level to caterpillars that they found in the field), suggesting that youth are able to carry out most activities, at least with the help of adult mentors.

Both our survey and interview data identified online data entry with children as a barrier, with adults in over half of our survey (59%) and interviews (55%) doing this activity without involving the children. The data provides interesting reasons for and ways of coping with this challenge. In general, children didn't like being indoors in front of a computer, and access to computers was a barrier for some groups. Some adults were also concerned about the accuracy of data reporting if children entered the data. As we have said, some resolved this challenge by entering the data themselves while others made data entry into a party, illustrating adult creativity in addressing challenges.

Nature of Science

Our interview data identified several aspects of engaging youth in the citizen science project applicable to their understanding of the nature of science (AAAS, 1993). A basic premise of science is that the world is understandable, that through careful and systematic study we can discover patterns in nature. Adults accurately perceived that youth were conducting "real" science. They were engaged in finding patterns during their systematic monitoring with the aid of scientific equipment. In fact, it bears repeating that adults perceived that the proper use and care of this equipment was a source of pride and helped children identify themselves as scientists.

Another key finding was the importance to adult volunteers of maintaining the scientific validity of the research, even as they modified procedures to make them more appropriate to their youth audience. The validity of all scientific claims must be determined by accurate observation and measurements, and adults clearly understood this. They took the science seriously and communicated this seriousness to the children. This attention to detail is key to the success of scientific research and clearly connects this audience to research done in more traditional settings. The adults ensured that the methods were repeatable and the findings meaningful.

A key feature of the scientific process is that answers to one question lead to more questions as we refine our understanding of natural systems (AAAS, 1993; NRC, 2000). In general, citizen scientists follow protocols that they have not designed and submit their data to project organizers. If this were all that they did, they might better be called "citizen technicians" than "citizen scientists." Interestingly, Brossard et al. (2005) found that participation in The Birdhouse Network did not increase adult understanding of the process of science; the experiential context of the project did not stress this process. Although participants were involved in one part of the scientific process, they were not involved in asking the questions or analyzing the data, and were probably motivated more by their interest in birds than their interest in science (Brossard et al. 2005). However, most adults in our qualitative study took steps to ensure that the youth were engaging in the entire process of science, from asking their own questions to analyzing and presenting their own data. The prescribed protocol focused their observations in a way that coming up with testable questions based on their own interests was a natural next step. This finding suggests that engagement in citizen science is a perfect opportunity to encourage youth to ask meaningful questions.

Interesting comparisons can be made between the science conducted by citizen science volunteers working with children and science conducted in traditional research settings. The focus on the educational value of the research may at first seem different from science done in more traditional settings. However, adult interviewees modified the program carefully, ensuring that the youth had a positive learning experience while preserving their data validity. In many ways, this is not very different from what occurs in research labs. Training the next generation of scientists is a goal in many university and private sector science labs, and protocols must often be modified to meet the practical requirements of available equipment, money, time, and expertise. The connection of this citizen science program to an active university science research program emphasizes the authentic science research aspects of the project findings.

Program Value

The interview data highlighted both the scientific and social value of MLMP to children. A dominant theme centered on participants' feelings about doing real scientific research; adults perceived that the children felt like real scientists and were proud of their contributions. Another theme centered on giving children the opportunity to connect to nature. When the adults were asked to identify what children enjoyed most about MLMP, many of their answers involved being outside. The children loved to find and discover plants and animals outside, as well as simply spend time outdoors with other children. The value of providing this time for outdoor discovery is well documented in recent literature (e.g. Louv, 2005; Kellert, 2005).

Additionally, interviewees noted the importance of the social aspects of the program. The shared experience allowed children to meet new friends with like interests while enjoying time together outdoors. One interviewee summed it up well when she described the experience for her group of children as "science bonding." Another emphasized a need for alternatives to just sports and recreation during the summer, giving testimony to the children's thirst for learning about nature.

Recommendations

Adults in this citizen science project engaged youth in creative and effective ways, clearly recognizing a variety of values in their participation. Our research suggests the following ways to promote more youth involvement in science, increase the quality of this experience, and future venues for this research:

Engaging youth and children. We interviewed individuals identified via our quantitative survey as being particularly successful at engaging youth in MLMP. These adults helped us identify practices for monitoring successfully with children, and it is likely that adults involved in other citizen science projects could make similar recommendations or form volunteer networks, sharing their experiences and resources as well as giving ongoing support. Project organizers could help identify youth-friendly training and enrichment activities that could be produced in print and accessed on the Internet. Our evaluation shows that many adults have developed such activities on their own; project managers could collect, suggest and otherwise facilitate such activities. One way to involve more children in monitoring is to promote partnerships among volunteers, nature centers, summer schools, and summer camps. Several of our volunteers have initiated successful partnerships that are centered on training and promotion, and programs could support these partnerships in a variety of ways.

Future research. Additional research could better inform quality field research programs for children. First, we did not survey or interview youth participants. Triangulation using data from this audience would help us better understand their experiences. Long-term research on youth participants could identify how programs like this affect overall achievement in science, as well as changes in attitudes about the environment or science. We also recommend that future studies address socioeconomic and ethnic differences among children involved in field research projects, since these and many other factors affect the needs, interests, and experiences of youth audiences (e.g. Bennett, 1999). Our focus on teachers and naturalists helped us identify programs and strategies that could inform the smaller, less formal activities of families and friends. However, because a large proportion of children involved, and probably many others, monitor with family members or friends, more explicit focus on these groups would be beneficial. Previous researchers have identified a lack of informal science and environmental education programs that target adults (Ballantyne, Connell, and Fien, 1998), and citizen science programs address this lack. The motivation to engage their children in an educational program might encourage more adult participation. A fruitful next step will be to compare the different adult audiences that engage youth. For example, our interviewees engaged in a significant amount of practitioner innovation, using their experience in an ongoing assessment of what did and did not work. It would be interesting to find out how much of this innovation was based on their prior expertise with youth and science learning.

The Complete Experience. Many of our groups engaged in the entire process of science, from asking questions to analyzing data to sharing their findings. Participation in this process is unusual in most citizen science projects in informal education settings (see also Citizen Science Central, 2008). Perhaps interviewing adults with explicit educational goals for their youth participants made this degree of science participation more likely. The connection between engaging youth in the entire scientific process, and the research resulting from this kind of engagement, is a fruitful area for future research.

References

American Institutes for Research. (2005). Effects of outdoor education programs for children in California. Retrieved January 29, 2008, from http://www.cnaturenet.org/.

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for Science Literacy.* Washington, D.C.

Ballantyne, R., Connell, S., & Fien, J. (1998). Students as catalysts of environmental change: A framework for researching intergenerational influence through environmental education. *Environmental Education Research*, 4, 285-298.

Batalden, R., Oberhauser, K.S., & Peterson, A.T. (2007). Ecological niches in breeding generations of Eastern North American monarch butterflies. *Environmental Entomology, 36*, 1365-1373.

Bennett, C.I. (1999). *Comprehensive multicultural education: Theory and practice.* Boston: Allyn & Bacon.

Bouillion, L.M., & Gomez, L.M. (2001). Connecting school and community with science learning: Real world problems and school-community partnerships as contextual scaffolds. *The Journal of Research in Science Teaching, 38*, 878-898.

Brossard, D., Lewenstein, B., & Bonney, R. (2005). Scientific knowledge and attitude change: The impact of a citizen science project. *International Journal of Science Education, 27*, 1099–1121.

Christmas Bird Count. (2006). Retrieved January 10, 2007, from http://birdsource.cornell.edu/.

Citizen Science Central. (2008). Retrieved March 31, 2008, from http://www.birds.cornell.edu/.

Cooper, H., Nye, B., Charlton, K., Lindsay, J., & Greathouse, S. (1996). The effects of summer vacation on achievement test scores: A narrative and meta-analytic review. *Review of Educational Research, 66*, 227-68.

Ezzy, D. (2002). *Qualitative analysis: Practice and innovation.* London: Routledge.

Falk, J.H. (2001). *Free-choice science education: How we learn science outside of school.* New York: Teachers College Press.

Ferry, B. (1995). Enhancing environmental experiences through effective partnership among teacher educators, field study centers and schools. *Journal of Experiential Education, 18*, 133-137.

Global Learning and Observations to Benefit the Environment (GLOBE). 2008. Retrieved March 31, 2008, from http://www.globe.gov.

Goffredo, S., Piccinetti, C., & Zaccanti, F. (2004). Volunteers in marine conservation monitoring: A study of the distribution of seahorses carried out in collaboration with recreational scuba divers. *Conservation Biology, 18,* 1492-1503.

Gopnik, A., Meltzoff, A.N., & Kuhl, P.K. (1999). *The scientist in the crib: What early learning tells us about the mind.* Harper Perennial. New York.

Hungeford, H.R., Peyton, R.B., & Wilke, R. (1980). Goals for curriculum development in environmental education. *Journal of Environmental Education, 11*, 42-47.

Institute for Learning Innovation 2008. Retrieved March 31, 2008 from http://www.ilinet.org/display/ILI/Home.

Juhl, L., Yearsley, K., & Silva, A.J. (1997). Interdisciplinary project-based learning through an environmental water quality study. *Journal of Chemical Education, 74,* 1431-1433.

Kellert, S.R. (2005). *Building for life: Designing and understanding the human-nature connection.* Washington, D.C.: Island Press.

Louv, R. (2005). *The last child in the woods.* New York: Algonquin Books.

McCaffrey, R.E. (2005). *Using citizen science in urban bird studies. Urban Habitats, 3.* Retrieved June 1, 2006 from http://www.urbanhabitats.org.

Miles, M.B., & Huberman, M.A. (1984). *Qualitative data analysis: A sourcebook of new methods.* Beverly Hills, CA: Sage Publications.

Monarch Larva Monitoring Project (MLMP). 2008. Retrieved January 20, 2008 from www.mlmp.org.

Moore, R.C. (1986). *Childhood's Domain.* London: Croom Helm.

National Conference on Student and Scientist Partnerships. (1997). Conference report. Boston MA: TERC.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning.* Washington, DC: National Academy Press.

Neuman, L. (2000). *Social research methods: Qualitative and quantitative approaches*, 4th Ed. Needham Heights, MA: Allyn & Bacon.

Oberhauser, K.S., Gebhard, I., Cameron, C., & Oberhauser, S. (2007). Parasitism of monarch butterflies (Danaus plexippus) by Lespesia archippivora (Diptera: Tachinidae). *American Midland Naturalist, 157*, 312-328.

Overholt, E., & MacKenzie, A.H. (2005). Long-term stream monitoring programs in U.S. secondary schools. *Journal of Environmental Education, 35*, 51-56.

Patton, M.Q. (1997). *Utilization-focused evaluation: The new century text*, 3rd Ed. Sage Thousand Oaks, CA: Publications Inc.

Pilz, D., Ballard, H.L., & Jones, E.T. (2006). Broadening participation in biological monitoring: *Handbook for scientists and managers.* USDA report PNW-GTR-680. Portland OR: USDA.

Prysby, M. (2004). Natural enemies and survival of monarch eggs and larvae. In K.S. Oberhauser, & M.J. Solensky (Eds.), *Monarch butterfly biology and conservation.* (pp. 27-38). Ithaca, NY: Cornell University Press.

Prysby, M., & Oberhauser, K.S. (2004). Temporal and geographical variation in monarch densities: Citizen scientists document monarch population patterns. In K.S. Oberhauser, & M.J. Solensky (Eds.), *Monarch butterfly biology and conservation.* (pp. 9-20). Ithaca, NY: Cornell University Press.

Swengel, A.B. (1995). Population fluctuations of the monarch (Danaus plexippus) in the 4th of July Butterfly Count 1977-1994. *American Midland Naturalist, 134*, 205-214.

Taylor, A.F., Kuo, F.E., & Sullivan, W.C. (2001). Coping with ADD: The surprising connection to green play settings. *Environment and Behavior, 33*, 54-77.

Trumbull, D.J., Bonney, R., Bascom, D., & Cabral, A. (2000). Thinking scientifically during participation in a citizen-science project. *Science Education, 84*, 265-275.

Wells, J.V., Rosenberg, K.V., Dunn, E.H., Tessaglia-Hymes, D.L., & Dhondt, A.A. (1998). Feeder counts as indicators of spatial and temporal variation in winter abundance of resident birds. *Journal of Field Ornithology, 69*, 577-586.

About the Authors

Dina L. Kountoupes is Monarch Larva Monitoring Project Coordinator in the Department of Fisheries, Wildlife, and Conservation Biology at the University of Minnesota, where Karen Oberhauser is an associate professor. Kountoupes can be reached at kount002@umn.edu.

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