Citizen Science in the Classroom: Assessing the Impact of an Urban Field Ecology Program on Learning Gains and Attitudes toward Science

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ABSTRACT

This study examines the educational impact of a citizen-science based teaching unit in the formal classroom setting. Citizen science has traditionally involved amateur scientists and adult volunteers, however, an increasing number of projects are focusing on student participants and K-12 education. A six-week curriculum intervention based on a citizen-science project studying ant diversity in urban areas was implemented in a New York City middle school science classroom. Quantitative analysis of students' pre- and post-assessments indicate significant learning gains as compared to a similar reference group that did not receive the intervention. Students in the treatment group showed a 22% greater increase in content knowledge from pre- to post- assessments. Qualitative analysis of these assessments along with interview responses show a positive change in students' perceptions and attitudes toward science as well as an increased desire to contribute to ongoing research. Students expressed increased confidence in their ability to contribute to scientific research after participating in this educational program. The results from this study provide an analysis of the effectiveness of citizen-science based curriculum units and support their use in the formal classroom setting.

INTRODUCTION

Citizen science can act as a powerful tool for achieving both robust research outcomes and empowering educational objectives. Citizen science is included in the growing field of public participation in scientific research, in which members of the public actively engage in the process of scientific investigation by asking questions, collecting data, and/or interpreting results. By focusing on both research and educational goals, citizen science projects are able to improve scientific research outcomes while also expanding public understanding of science. Recently, citizen science has expanded to include K-12 education and student participants (Mueller and Tippins 2012). This movement has coincided with a reform in the way science curricula are designed and presented to students and therefore, has allowed scientists to better align citizen science research goals with student learning and school curriculum objectives.

Science Education Reform

Current reforms in science education focus on developing effective inquiry and place-based learning curricula for formal classroom education (Keys and Lynn 2001, Mehalik et al. 2008). Traditional teaching methods often isolate classroom environments from relevant local science topics, separating students' learning from actual processes and patterns occurring in nature (Akerson et al. 2000). Teachers and students are choosing increasingly to work with real data and scientific problems, particularly those that have a connection to their local community and environment (Berkowitz 1997, Moss et al. 1998).

Projects that focus on local environmental issues and include outside learning are at the forefront of science education reform. By allowing students the opportunity to perform experiments in a field setting, place-based curricula can build students' awareness and understanding of biological diversity, ecology, and conservation (Dillon et. al 2006). Providing opportunities for students to connect to local species and ecosystems through hands-on experiential learning activities can positively affect students' attitudes towards preservation and sustainability (Wilderman et al. 2004, Wyner et al. 2010). As science education continues to move towards more practical and engaging teaching methods, the integration of science research can both improve environmental stewardship and promote scientifically informed decision-making (Jordan et al. 2012).

Learning outside the classroom can also improve student engagement in research and science learning outcomes. Place-based curricula allow students the opportunity to connect to their local environment and community in ways that promote authentic scientific reasoning and questioning (Wee et al. 2004, Pyle 2008). Through place-based investigations students are able to access the scientific inquiry process as a whole – from generating questions to planning and conducting investigations, and explaining and reporting findings.

Inquiry-based educational approaches allow students the opportunity to build both science skills and content knowledge through the use of hands-on learning activities. By encouraging students to explore, design and analyze science questions, they become active participants in the scientific inquiry process rather than passive learners. This approach to teaching can directly improve both students' perceptions and attitudes towards science (Gibson et al. 2002, Wee et al. 2004). Student learning outcomes are also greater in terms of knowledge gain and retention of core science concepts when inquiry based teaching methods are applied (Mehalik et al. 2008).

Citizen Science & Education

As an emerging discipline based on connecting authentic scientific research with public education, citizen science is focused on achieving similar learning outcomes as those seen in current science education reform. Like inquiry and place-based educational approaches, citizen science research projects have been shown to significantly improve participants' scientific knowledge, skills, and attitudes toward science and the environment (Brossard et al. 2005). These results highlight the potential for citizen science to be integrated within current K-12 science curricula and in formal classroom education (Bonney et al. 2009a). Students can also act as a valuable source of research support, in terms of data collection and analysis. More importantly, student engagement in science fosters the next generation of scientists whose contributions will help address the most pressing global environmental issues.

When designing citizen science projects for classroom education, aligning the goals of scientists and students involves may unique factors. In balancing the achievement of both learning and research outcomes, scientists must consider the role of citizen science participants and their level of involvement with each aspect of the research process. Research most often associated with citizen science, including the analysis of water quality and weather data, and observations of species distributions and other natural phenomena, has taken place within the realm of informal science education (Bonney et al. 2009b, Zoellick et al. 2012). In this learning environment, the range of educational outcomes is broader and less rigorously assessed than those in a traditional school setting. Citizen science projects designed for formal science education can be constrained by their requirements to achieve a set of specific learning outcomes, often prescribed by state or national standards. This trade-off between scientist-benefit and student-benefit in then becomes much more apparent and expresses itself in a variety of ways when citizen science projects are placed in a formal science education setting (Rosner 2013, Zoellick et al. 2012).

In order to addresses both the needs of scientists and students, citizen science projects must be designed with inputs and desired outcomes that are tailored to each party. Projects that recognize different investment abilities, requirements and envisioned goals can effectively achieve both scientific outcomes and educational objectives (Jordan et al. 2012). This method of design can avoid a major pitfall of citizen science in formal education – when a project focuses on science goals to the exclusion of education goals and uses students as passive participants rather than active contributors in the entire research process.

Scientists can also improve the broader impacts of their own research and better communicate their findings by including adults, young students, and other members of the public in the scientific inquiry process. Citizen science is able to go beyond traditional science outreach efforts because it offers members of the public the opportunity to participate in science, rather than simply receive scientific information (Pandya 2012). Improved transparency of science research can also lead to more effective application of this research to management, particularly with projects that include community members in monitoring and protection of local ecosystems. This innovative 'management matrix' catalyzed by citizen science projects has had both cumulative and measurable impacts on biodiversity and ecosystem conservation (Cooper et al. 2007). These multi-faceted approaches to performing research include a diverse set of stakeholders that have traditionally been isolated from the field of science.

A growing number of citizen science projects, particularly those that incorporate social and economic goals, focus on urban ecology and biodiversity in cities. There are many benefits, both for research and education, associated with these projects: urban habitats are accessible to large numbers of people, species in cities often more familiar to the general public, and urban ecosystems tend to be diverse (Pandya 2012). In terms of educational outcomes, urban ecology projects can engage traditionally underrepresented citizen science participants and respond to the priorities of urban communities. Despite efforts to increase equity and close achievement gaps, the science education reform movement has failed to reach the most at need students, particularly minority and inner city children with less access to nature (Lynch et al. 2005). Conservation outcomes, particularly those in the urban setting, are improved by increased geographic awareness and ecological literacy as well as the cultivation of students' scientific knowledge and skills (Mueller and Tippins 2012).

Study Purpose, Design, and Research Questions

This study uses the School of Ants project, a citizen-science driven study of ants in urban areas, as a model for designing and implementing a curriculum unit for use in the formal classroom setting. Many citizen science projects have received funding because of their broader impacts related to science education (Dickinson et al. 2012). Yet like most student-oriented citizen science projects, School of Ants sampling activities have been performed more frequently in an informal education setting. This is in part due to the lack of educational materials and paired lessons available for teachers to use in classrooms. Citizen science projects that provide background information on the theory and ideas behind the research as well as a comprehensible description of the research questions are more effective in achieving both research and learning outcomes (Dickinson et al. 2012, Zoellick et al. 2012). In order to improve student participation and more importantly, to reach historically underrepresented populations based in inner-city public schools, it is important that learning resources for teachers and students be made available through the School of Ants program.

The curriculum unit developed as a part of this study includes eight lessons to be preformed over a six-week science unit (Appendix 3). These lessons focus on two core science content areas: scientific inquiry and ecology. Students were introduced to the process of designing and performing a research study, collecting, examining, and identifying biological specimens, ecosystems and habitat dynamics, interactions between species, and human impacts on urban ecosystems. These resources were developed in order to determine the effectiveness of a citizen science based curriculum in teaching both scientific inquiry skills and relevant science content.

METHODS

This study took place at MS 345 Collaborative Academy of Science, Technology, and Language-Arts Education in the Lower East Side of Manhattan. MS 345 is a Title 1 New York City public school (*i.e.*, a school with a high percentages of children from low-income families). Two separate groups of students were involved in this study: one sixth and one seventh grade general science class. All students were between 11 and 13 years old and were enrolled in the general education setting. Students in this study were introduced to a new unit on science inquiry and ecosystems, topics which they had no previous academic experience. Both classes in this study were taught by the same science teacher and did not receive any previous school instruction that would influence their knowledge of this material. Although comparing two sixth grade classes would have been preferred, enrollment at this school was not sufficient for that experimental design.

Citizen science projects will need to comply with new state science standards, which focus on building both core science concept knowledge and critical thinking and problem solving skills, in order to be used in the formal classroom setting (Nargund-Joshi et al. 2013). The teaching resources included within this curriculum intervention have been tailored to meet Next Generation Science Standards. These new K–12 state standards were developed National Research Council to provide an improved focus on both science content and practice (Quinn et al. 2012). New York City schools, along with many other states, have adopted the Next Generation Science Standards for implementation in the 2014-2015 school year.

This study uses a phenomenological qualitative framework and quantitative analysis methods to examine the impact of a citizen science based curriculum intervention. This mixed methods design is recommended for science education research, as it enhances the usefulness and understanding of results (Johnson and Onwuegbuize 2004, Newman and Benz 1998). Phenomenological analysis is able to show both the variety and individuality of responses while also generating themes that reveal the common shared experience in a group (Creswell 2012). The combination of these two methods allows for a greater evaluation of the educational impact of a citizen science based curriculum unit.

A standardized evaluation of changes in students' content knowledge before and after the intervention was achieved using pre- and post-intervention questionnaires. The pre- and post-assessments contained 12 short answer questions: five relating to scientific inquiry skills and attitudes toward science, four on ant-specific and insect sampling topics, and three on content knowledge relating to ecosystems and species interactions. The responses were coded using a rubric developed for these questions (Appendix 1). Out of the twelve questions on the pre-assessment, seven (two about scientific inquiry, two about ant-specific and insect sampling, and three about ecosystems and species interactions) were appropriate for a scoring system with a total of four possible points (zero, one, two, or three). These points were based on how closely the response matched content from the students' textbook. For several questions, responses were evaluated on their logic, reasoning, and complexity. Question eight was not analyzed for this study.

For questions nine through twelve, a Likert scale was used to determine students' level of interest in performing science research, inquiry and hands-on experiments, and outdoor, place-based learning. These questions also included an open response section, asking students to explain their Likert choice. The open response portion of the final question was coded to determine overall patterns of shared experience. This open coding process involved determining expected themes, reading through student responses, extracting significant statements, and determining shared codes within each theme (Creswell 2012).

Interviews were conducted after the curriculum intervention in order to determine changes in student perceptions and attitudes toward science as well as their desire to contribute to science research studies. Students were given the opportunity to reflect on their experience by answering four interview questions (Appendix 2). Eight students were selected at random from the intervention class for interviews. Students were separated into three different levels based on their pre-assessment scores: one (below average), two (average), and three (above average). Students' names were changed to pseudonyms to protect their privacy. All interviews were transcribed for analysis, responses were coded openly, and significant statements were extracted for the development of key themes.

Quantitative data for pre and post assessments was analyzed using R statistical software (R 2013). G-tests of the goodness of fit were also used to test if the significance of changes in the pre and post assessment. For the qualitative analysis, main themes were extracted from assessment's free response questions. These are grouped and reported on to reveal trends in the students' experiences as participants in the School of Ants citizen science project. Institutional Review Board approval was granted through both Columbia University and the New York City Department of Education for this study.

RESULTS

I successfully used this intervention in a treatment group of 25 students and used the a reference group of 37 students as a comparison. Both quantitative and qualitative analysis techniques were used to measure student-learning gains and evaluate changes in attitude and perceptions toward science. Student interviews were analyzed to determine students' experience participating in the School of Ants citizen-science based curriculum intervention.

Quantitative Analysis of Pre- and Post-Assessments

The first section of questions on the student assessment was designed to measure learning gains in terms of content knowledge and related science skills. Using the scoring rubric (Appendix 1), pre- and post-assessments were scored out of a total of 24 points.

The overall mean for the treatment group increased from 25% in the pre-assessments to 57% in the post-assessments (Figure 1). Mean post-assessment score is significantly greater than mean pre- assessment score [$t(45) = -7.23$, $p<0.05$] with a 95% confidence interval for learning gains on these assessments ranged from 127.4% to 129.4%. The overall mean for the reference group remained the same at 35% from pre-assessments to post-assessments. The mean post-assessment score was not significantly greater than mean pre- assessment score [$t(71) = .086$, $p>0.05$]. The 95% confidence interval for learning gains on these assessments ranged from -1.2% to 1.3%.

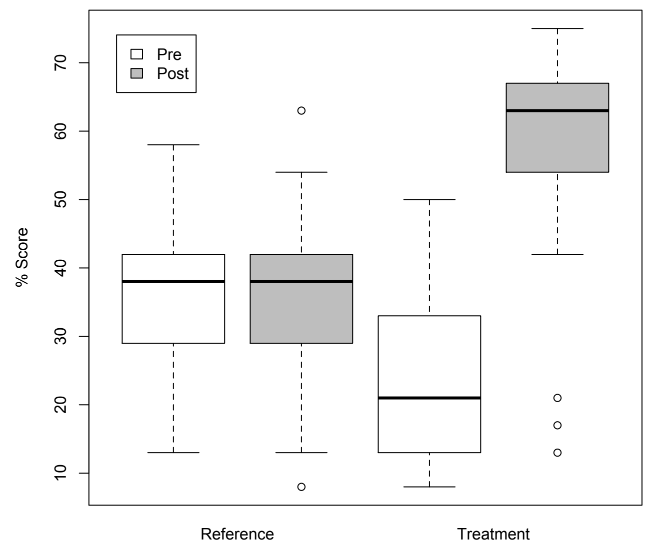

Figure 1. Paired box plots showing difference between pre and post assessment scores for the treatment and reference groups.

Analysis of Openly Coded Pre- and Post-Assessment Responses

The second section of the student assessment was designed to measure changes in students' perceptions and attitudes toward science as well as their interest in participating in authentic science research projects.

Students were asked for the strength of their agreement with the statement "I am excited to do experiments with ants that live around in our school's neighborhood." Students in the treatment group responded more positively to the statement in their post-assessment than students in the reference group (Figure 2). There was no significant change in responses for both the treatment [g (3) = 3.65, p>0.05] and reference group [g (3) = 5.09, p>0.05]. For agreement with the statement "I am more interested in science class when we do hands-on activities in class", students in both the treatment and reference group responded positively to the statement in both their pre and post-assessments – showing no significant difference between pre- and post-test in either the treatment or reference group [both p>0.05]. For agreement with the statement "I am more interested in science when we do experiments and learn outside of the classroom", students in the treatment group responded more positively (89% strongly agree) to the statement in their post-assessment than students in the reference group (62%), however, this difference was not significant for either the treatment [g (3) = 1.36, p>0.05] or reference group [g (3) = 4.35, p>0.05].

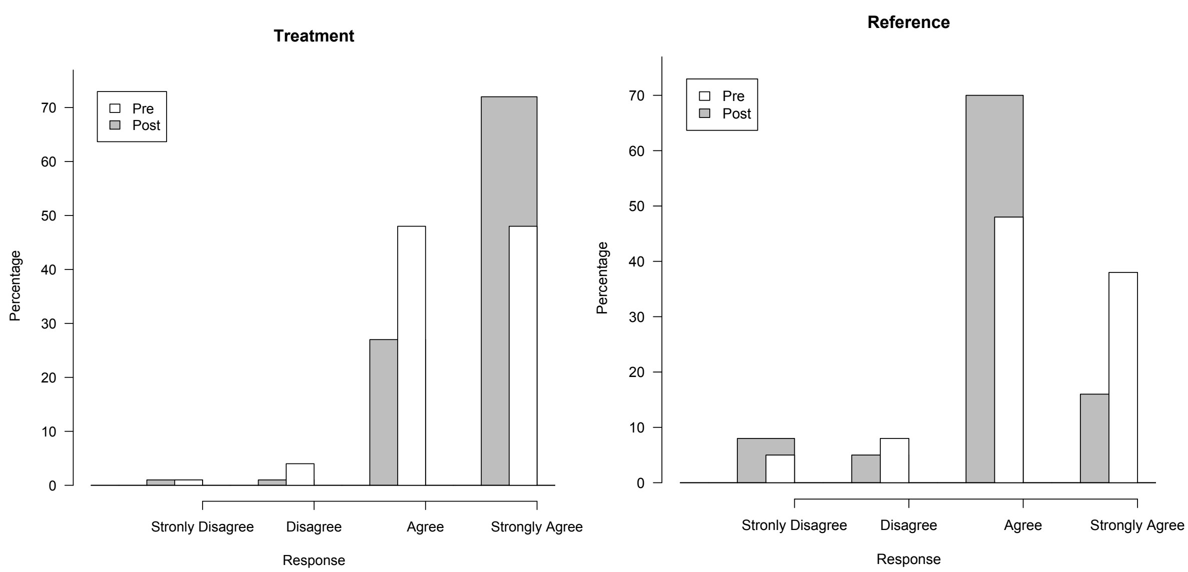

Figure 2. Paired histograms showing changes in student responses the question "I am excited to do experiments with ants that live in our school neighborhood" in both treatment and reference groups.

For the final question, agreement with the statement "I would like to add to real science research and help scientists discover new things", there was no significant difference in pre- and post- responses from students in treatment [g (3) = 2.61, p>0.05] or reference group [g (3) = 2.20, p>0.05]. In order to gather more information on interest in participating in active research projects and collaborating with scientists, the open response section to this question was analyzed. Significant statements were separated out and grouped according to shared codes. The percentages of each code out of the total number of significant coded statements are shown below. Although there was no significant change in Likert responses to this question, students' statements in the open response section revealed differences in desire and perceived ability to help scientists with research between the treatment and reference group (Table 1). Further analysis on the open response section for questions 9,10, and 11 was not performed because of low response rates (below 45% for each as compared to 100% for the final question).

Table 1. Percent change between pre- and post- test student responses for open section of the question "I am excited to do experiments with ants that live in our school neighborhood." Responses were coded and grouped by shared themes.

Why?	**Treatment**	**Reference**
Excited to help scientists with research	15%	-5%
Like to discover new things	0%	-4%
Want to learn more about science	-5%	2%
Not excited, interested in other subjects	-5%	3%
Don't believe they can help scientists, too hard	-5%	4%

Qualitative Themes and Analysis of Student Interviews

Student interviews were conducted to examine changes in students' responses to being involved in an inquiry, place-based citizen-science research project. Significant statements and quotes were extracted from the eight participant interview transcripts and compared together to illustrate the emergence of several themes. Students are referenced by their pseudonym and assigned level (1, 2, or 3) based on their pre-assessment scores.

Theme 1: Expressing curiosity, novel learning experiences

Students were asked about their experience learning about ecosystems and the scientific method by performing a research study on ants. Several students focused how these activities were new to them and exciting to perform:

> "when we tried to catch the ants, it was new […] cool and fun" – Austin (1).

Another student commented on how these activities improved her confidence in performing science research:

> "these activities have expanded my mind a little bit […] if we can suck up ants, why couldn't we do something else too!" Erin (3).

Theme 2: Benefited from an outside, place-based learning experience

Students were also asked specifically about their experience studying science and performing research outside of the classroom. Almost all students interviewed enjoyed their experience in the community and noted that it allowed for a different and more positive learning experience as compared to instruction in the classroom setting. One student spoke about how studying outside allowed him to experience science in a more visual and hands-on manner:

> "it's like a picture in your mind when you're outside […] you're really experiencing the science" – Youssef (2).

Two students noted how outside learning allowed them to explore their surroundings and gain knowledge from a more dynamic learning experience:

> "I think it's better to be outside because there's space to move and explore" – Selena (1).

> "I like to do outside activities, we get to explore and touch things, and this helps my learning, I get to experience things outside" – Lin (1).

Theme 3: Understands ecosystems and species diversity

Students also described what they learned about ecosystems and species diversity in urban areas:

> "I learned that there's more types of ants, different species living everywhere" – Celia (2).

> "I learned there are different species of ants in New York City, and they all live in different habitats here" – Jeff (1).

Theme 4: Believes students like themselves can make contributions to scientific research

Along with more general comments on their perception of science, students also explained how this learning experience improved their knowledge of and desire to contribute to authentic science research:

> "I think student can help scientists, they could collect all kinds of information" – Austin (3),

> "from this experience I learned a lot, I had never known how to use these tools or how to do real science research before" – Jeff (1).

> Another student commented on how he felt like a scientist and now believes he

can make contributions to science research projects:

> "you're having the time of your life outside collecting and doing science, not only are you helping scientists, its like you're real scientist" – Youssef (2).

DISCUSSION

This study was designed to provide data on the effectiveness of a citizen-science curriculum initiative and a model structure to implement these curriculum interventions in the formal education setting. Results of this study indicate that students' participation in a citizen science project expanded their scientific inquiry skills and understanding of ecological concepts, improved attitudes toward science, and established connections to the local community. This was confirmed from pre and post assessment scores and open-ended questions as well as one-on-one student interviews. Overall, the combined findings from this mixed method study indicate that a citizen-science based curriculum improves learning gains, increases inquiry, and creates positive connections to local ecosystems for a particular group of 6th grade students.

Quantitative analysis through pre and post assessments showed significant gains in content knowledge for the treatment versus reference group (Figure 1). The treatment group's score gains after participation in the curriculum intervention directly reflects their improvements in content knowledge as assessed by the pre and post-test. In analyzing the open-ended assessment questions, students in the treatment group showed greater agreement with the statement "I am excited to do experiments with ants that live in our school neighborhood" as compared to the reference group (Figure 2). While this result was expected, it is important result to note – specifically when considering the impact that the School of Ants project has on exciting students to participate in local research projects. Assessments showed also showed a change in students agreement with the statement "I would like to add to real science research and help scientists discover new things" for the treatment versus reference group. This result was particularly important in determining how students' attitudes changed toward participating in science research and their confidence in their ability to contribute to scientist's work. Although there was no significant difference between the treatment and reference group for the statements "I am more interested in science class when we do hands-on activities in class" and "I am more interested in science when we do experiments and learn outside of the classroom", this was expected due to the nature of the questions. These open-ended questions did not receive enough responses to be further analyzed. Other limitations to this study include only two months of in-depth time working with students, confinement of the study to one 6th grade class, and pairing with a single teacher to perform this curriculum intervention.

Participation in the School of Ants project acted as an integral part of the students' science inquiry and ecology curriculum unit. Students in the treatment class designed their own experiment to sample ants in the school's neighborhood, performed the sampling activity, and then examined their specimens to determine which species were collected. Results recorded on the School of Ants website and ant samples were mailed to their labs in Raleigh, North Carolina for further analysis.

Students in the treatment group responded more positively to the question "I am excited to do experiments with ants that live in our school neighborhood" after their exposure to this citizen science project. This student-driven, outdoor sampling activity influenced students' desire to perform experiments in their community. Students from both groups responded positively to the statement "I am more interested in science class when we do hands-on activities in class", mirroring similar studies that have shown students' increased desire to engage in inquiry based learning projects (Gibson et al. 2002, Wee et al. 2004). Treatment and reference group responses to the question "I would like to add to real science research and help scientists discover new things” showed no significant difference in the distribution of Likert responses, however, many students in the treatment group used language that showed increased agency and ability to contribute to real world research (Table 1). More specifically, students in the treatment group showed a greater desire (+20% net) to help scientists with research after participating in the project than students in the reference group who did not participate. Students in the reference group showed less interest in discovering new things and a greater feeling that they cannot contribute to scientists and their research.

Phenomenological analysis through interview coding showed improved attitudes towards the study of science and increased desire to participate in authentic scientific research. Student interviews revealed several important themes, from which conclusions on the changes in students’ perceptions and attitudes toward science were drawn. Many students spoke specifically about the “discovery” and “adventure” involved in performing scientific research, especially in the field setting. Students expressed how this unique experience of learning science, outside in a place-based manner, added a level of excitement not found in the classroom. In terms of participating in citizen science research, many students stated how this experience improved their confidence in being able to make contributions to scientific research.

This focus on learning outside, and the impact it had on students’ interest in participating in the citizen science research project, was a particularly important conclusion of this study. Experiencing science outdoors allowed students in the treatment group to interact with both the organism, various species of ants, and ecosystem, urban habitats, they were being presented with in classroom lessons. This trend in the interviews was also reflected in responses to the statement “I am more interested in science when we do experiments and learn outside of the classroom”, of which students in the treatment group responded more positively to after the curriculum intervention (+27% strongly agree) in their post-assessment than students in the reference group.

I expected to observe other shared themes, however, these did not appear in student interviews. Specifically, I expected students to focus more on the experience of developing individual research questions and following through with the sampling experiment. Students were introduced to the scientific inquiry process by practicing it first-hand in their ant research outdoors, yet this experience of collaboration with their team members was not highlighted in the interviews. On the other hand, I expected more students in the treatment group to express frustration and explain difficulties with their research; however, most students felt confident and were able to persist through obstacles that arose during their participation the School of Ants project.

It should be noted that my background as an educator and knowledge as a graduate student could have acted as a factor of influence on this study. As a former New York City public school teacher, I am familiar with the design of educational resources and the learning processes of middle school age students. While I only facilitated the teaching of these lessons within the classroom, my ability to communicate scientific concepts in a way that is digestible and engaging for young students may have influenced the students learning gains. The results of this study do show, however, that the curriculum itself (especially participation in the School of Ants project and learning outside) played a dominant role in the learning and increased interest in science for the treatment group.

Similar citizen science projects have shown mixed success in improving student learning gains and attitudes toward science. The Bird House Network (TBN), operated by the Cornell Lab of Ornithology from 1996 to 2007, involved participants placing birdhouses in their backyards or neighborhoods and collecting data about the birds that bred in them. TBN used a mix of qualitative and quantitative research methods, pre and post assessments as well as open-ended surveys. Comparisons of pre- and post-project assessments showed that TBN participants significantly increased their knowledge of bird biology, however, surveys showed that no change in attitude toward science as a result of participation in TBN (Brossard et al. 2005). The Monarch Larva Monitoring Project and Spotting the Weedy Invasives project also found improvements in associated science content knowledge, but participants' attitudes toward science did not shift as a result of project participation (Bonney et al. 2009b). As with many citizen science projects, participants in these projects entered with very positive attitudes toward science and the environment compared with the average public. This has an obvious effect on a project's ability improve perceptions of science and engagement in research, as compared with other citizen science projects such as School of Ants, which focus on recruiting participants without any previous science research experience.

Recent studies in science education have shown that unless large-scale projects offer inquiry-based curricula specifically designed for schools, then substantial inquiry is unlikely to take place along with associated gains in content knowledge (Trautmann et al. 2012). Contributory ecological monitoring projects, like School of Ants, must be encouraged to intentionally design curriculum for K-12 students in order to achieve improved research and educational outcomes.

Future of Citizen Science and Formal Education

As the scientific community works to improve science literacy and public engagement in science research, integrating relevant and authentic science research into K-12 education must be a primary objective. This goal has become more attainable due to recent changes in education curriculum through the Next Generation Science Standards. These new curriculum guidelines focus on the interconnected nature of science as it is practiced and experienced in the real world. This conceptual shift allows for a strong focus on learning content through practical experience, particularly as it applies to activities centered on relevant, community-based science issues. Citizen science projects like School of Ants allow students to improve their understanding of core science concepts (ecosystem functioning, species interactions, and human impacts) while experiencing science research as scientists in the real world practice it. It also provides a deep connection to community, allowing for students to achieve a sense of place that bolsters confidence in addressing environmental and social concerns (Dillon et. al 2006, Cooper et al. 2007).

By utilizing ecology curricula in secondary schools to present conservation biology research, scientists can also help bring science stories to the classroom and give them a context in which they can be better understood by students. Without this approach to teaching science, environmental issues become less relevant and important to the daily lives of students (Wyner and DeSalle 2010). When research is embedded within the science curriculum, students are able to better understand the connection between local environmental conditions and the health of their communities.

Citizen science projects that involve a diverse set of stakeholders and include community priorities are also able to effectively address local environmental issues and improve public engagement in science research. The formal education setting can act as an important area of focus for addressing environmental issues and promoting public participation in science. Through an increased focus on aligning citizen science goals to science curriculum and providing educational materials these outcomes can be achieved.

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APPENDIX 1

Question	Score:3	Score:2	Score:1	Score:0
1. What is an ant? Describe in your own words!	Answer very close to text definition: a small insect, with three body parts, lives in an organized social group	Answer includes one part of the definition (i.e., small insect, 3 body parts, social)	Definition is alluded to, but several elements are not included.	No part of definition is included.
2. Name two species of ants and explain where they live!	Includes the names of at least two ant species and their habitat or location.	Includes the name of at least one ant species and its habitat or location.	Includes the name of one or two ant species, but doesn't provide any information on their habitat or location.	No ant species named.
3. What tools do scientists use to collect and identify different types of ants?	Includes at least three measuring, sampling tools (microscope, vials, dichotomous key, etc.)	Includes at least two measuring, sampling tools.	Includes only one measuring, sampling tool	No tools or other logical materials identified.
4. What is an ecosystem? Describe in your own words!	Answer very close to text definition: a community of living organisms interacting with the nonliving components of their environment as a system.	Answer includes one part of the definition (i.e., community, living things, nonliving, system)	Definition is alluded to, but several elements are not included.	No part of definition is included.

5. What is a mutualistic relationship? Explain and give one example!	Answer includes at least one example and is very close to text definition: a relationship between two species that live together and benefit from each other.	Answer includes at least one example and one part of the definition (i.e., benefits, living together, relationship)	Definition is alluded to, but several elements are not included. No examples provided.	No part of definition is included.
6. What is an invasive species? How do they affect ecosystems?	Answer is very close to text definition: organisms that have been moved to a new habitat and have a negative impact on the ecosystem.	Answer includes at least one part of the definition (i.e., foreign habitat, movement, negative impact)	Definition is alluded to, but several elements are not included. No effect included.	Does not include any part of the definition or the effects.
7. In science experiments, what is a hypothesis? Why is it important to have one?	Answer includes at least one reason and is very close to text definition: an idea you can test based on prior knowledge and observation.	Answer includes at least one reason and one part of the definition (i.e., educated guess, testable, observations).	Definition is alluded to, but several elements are not included. No reasons provided.	Does not include any part of the definition or reasons.

Name ______________________________ Date ______________

Pre-Assessment

Help Mr. Collins by telling him what you learned!

1. What is an ant? Describe in your own words!

____

2. What is an ecosystem? Describe in your own words!

____

3. What is a mutualistic relationship? Explain and give one example!

____

____

4. What is an invasive species? How do they affect ecosystems?

____

____

5. Name two types (species) of ants and explain where they live!

____

____

6. What tools do scientsits use to collect & identify different types of ants?

____

____

7. In science experinments, what is a hypothesis? Why is it important to have one?

____

____

Name ________________________________ Date ______________
Pre-Assessment

8. What are two things that you learned about ants living in New York City?

____

____

For the following questions, please circle the answer that is closest to your opinion.

9. I am excited to do experiments with the ants that live in our school neighborhood.

Strongly agree Agree Disagree Strongly Disagree

Why?

____

____

10. I am more interested in Science class when we do hands-on activities in class.

Strongly agree Somewhat Agree Somewhat Disagree Strongly Disagree

11. I am more interested in Science when we do experiments AND learn outside of the classroom (on fieldtrips, outdoor activities, etc.).

Strongly agree Agree Disagree Strongly Disagree

Why?

____

____

12. I would like to add to real science research and help scientists discover new things.

Strongly agree Agree Disagree Strongly Disagree

Why?

____

____

APPENDIX 3

Overview of Curriculum Unit Plan

Phase One:
What are Ants? Investigating Ants Up Close

Lesson Learning Goals:
1) What makes an Ant? Discuss physiology & behavior
2) Be able to identify and explain four distinct species of ants

Steps:
1) Introduction / *10 min*
- What is an ant? Where do ants live?
- Highlight Ant Diversity: Army, Leaf Cutter, Turtle Ants
2) Any Body Parts / *25 min*
 - Use ant body sheet linked here
 http://www.calacademy.org/science/citizen_science/pdfs/Ant_Anatomy_Packet.pdf
- Students use a microscope to observe ant specimen
- Draw their own ant specifics on it, identify …
 • three body regions (head, thorax, abdomen),
 • six jointed legs,
 • a pair of antennae, and
 • an exoskeleton
 - Take IPhone pictures of each students ant through scope, project on screen to share and discuss findings

3) Wrap-up & Procedures for Day 2 Sampling / *10 min*
- Show students the "sampling kits"
- Brief procedures: where, when, how

Phase Two:
School of Ants Sampling Day

Lesson Learning Goals:
1) Learn proper ant sampling protocol
2) Learn and share three facts about physiology, behavior, evolution of ants
3) Collect Ants using School of Ants protocol
4) Use Ant Game to learn facts about ants

Making Kit Directions http://www.schoolofants.org/sites/default/files/soa-images/How%20to%20make%20your%20own%20ANT%20KIT_NC_FL.pdf

Steps:
1) Outside to set collecting kits on gray & green space / *15 min*
 -Two students per collecting vial, names on vial
 -Students take "observation notes" of place, time, setting, etc.

Name ______________________________________
Assessment

2) Ant Fact Box Activity & Game / *25 min*
   http://www.calacademy.org/science/citizen_science/pdfs/Ant_Fact_Box.pdf
- Two students get the same fact, have to find each other
- Timed … first 3 groups to find each other get a prize
- Discuss the fact & what it means for humans vs. ants

3) Return to check samples & walk back to classroom / *10 min*
   -Each student group collects & seals vial, teacher collects
   -Note set out samples beforehand if you have limited class time
   -Return to classroom

In-Between Phase 2 & Phase 3

Teachers: Create accounts on School of Ants website to submit results & write in their observation notes taken at site

Phase 3:
Ant Diversity & Ecosystems

Lesson Learning Goals:
1) Understand the different environments in which ants live worldwide
2) Use identification techniques to determine the species of their collected ants

Steps:
1) Ant Diversity Presentation / *5 min*
- A look back at some of the more exotic ant species, introduce three more
2) Where Ants Live & Ecosystem Basics / *10 min*
- Use school of ants map to see what species live in US
- What makes US ecosystems different or similar to the exotic ants we saw?
3) Observe Collected Ants with Microscopes / *25 min*
- Use the "Who ate my cookie?" Urban Ant Key

http://www.schoolofants.org/sites/default/files/soa-images/Common%20Ant%20ID%20Infograph_130225.pdf
- Try to ID our ants, make observations
4) Wrap-Up & Discuss – *10 min*
- Collect student ant samples, explain shipping to School of Ants Lab