Designing Citizen Science for Both Science and Education: A Workshop Report

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A report of
the *Designing Citizen Science for Science and Education Project* at
BSCS Science Learning.

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The *Designing Citizen Science for Science and Education Project* at BSCS Science Learning

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1 Introduction

In January 2017, BSCS convened a group of scientists, educators, and technologists with significant experience in citizen science to consider the challenges of designing citizen science projects to achieve ambitious objectives in the areas of both science and education. The workshop was based on the following premise:

> *Achieving both scientific and educational benefits in a citizen science initiative requires not just a commitment to both, but the expertise and resources to design for both.*

The goals of the workshop were to (1) gather the insights of experienced citizen science project organizers about how to design citizen science projects and platforms for both scientific and educational outcomes and to (2) organize these insights into a set of recommendations for software developers on how to design online citizen science platforms for *both* scientific *and* educational outcomes.

Over the course of the workshop, attendees participated in a set of activities designed to help them articulate and organize their insights about what is required or helpful to achieve scientific and educational objectives in citizen science initiatives. To keep the conversation focused, we asked participants to focus on the category of scientific and monitoring projects that we call ***networked field studies***—projects in which participants collect and/or analyze geographically distributed data, for example, watershed studies, species distribution studies, and phenological studies. All the participants had experience with networked field studies. Participants were also asked to "represent" a networked field study or a platform supporting networked field studies at the workshop. These projects and platforms (listed in Appendix I) served as examples in the discussions throughout the workshop.

The workshop was structured to encourage the articulation of design principles grounded in examples. To initiate the process, participants enumerated objectives for both scientific and educational outcomes and challenges to achieving them. These were used to structure the work that followed. That work was conducted in two phases. First, participants generated examples of design approaches from specific projects or platforms for each of the scientific and educational objectives. Then, they clustered design features together and extracted general design strategies from the examples in each cluster.

The organization of this report reflects the structure of the workshop. In the next section, we present the key premises behind this work. In the third section, we describe the design objectives that were identified by participants. In the fourth and fifth sections, we describe specific design strategies identified to achieve the design objectives for scientific and educational outcomes respectively, together with examples showing how projects and platforms have implemented those strategies. In the final section, we discuss implications and future directions for this work.

2 Premises of This Work

While both scientific[1] and educational outcomes are touted as important benefits of implementing citizen science, there are two widespread misconceptions about the relationship between scientific and educational objectives in citizen science. The first is that if you design a project to achieve one of these objectives, you get the other automatically. That is, if you set up a citizen science project to contribute to scientific understanding, it will naturally lead to valuable learning for the participants. Or, if you set up an educational citizen science project, it will also contribute to science. The second misconception is at the opposite extreme. It holds that scientific and educational objectives are incompatible—that a project must choose between focusing on either scientific outcomes or educational outcomes, because it is not possible to achieve one without compromising the other. This work is premised on the belief that both of these views are wrong and, furthermore, that we can provide guidance to designers of citizen science initiators on how to pursue both outcomes simultaneously.

So, the first premise of this work is that it is possible and practical to implement citizen science initiatives that simultaneously achieve scientific and educational objectives. That is because the scientific and educational goals that most designers hold for citizen science are not incompatible with each other. They may be in tension because they are in competition for resources, but being in tension is very different from being incompatible. Scientific and educational objectives can be in tension in the implementation of citizen science initiatives because they can be different enough that they require separate design strategies (Zoellick, Nelson, and Schauffler, 2012), which means that pursuing both requires more effort and resources than pursuing one. Therefore, a goal of this work is to help designers of citizen science initiatives to see science and education as competing priorities, rather than conflicting goals, and to help them navigate design tradeoffs between them on that basis. We believe that when designers know more about how to design for each outcome, they will be able to identify better options and weigh the tradeoffs among them more effectively. Our hope is that we will reach a point where the expertise and resources available to designers will make it possible for many more designers to create initiatives that have both scientific and educational benefits.

It is worth noting that just because one can design a program for both science learning and scientific outcomes, addressing both is not always appropriate or desirable. There are times and places to select one and focus. Participants in projects that are focused on learning may move on to projects focused on scientific outcomes and vice versa. Every citizen science project need not be all things to all people and, arguably, shouldn't try. The collective output of our workshop participants will be of value in any case.

The second premise of this work is that software platforms can contribute to the practicality of simultaneously achieving scientific and educational objectives through citizen science initiatives. While the idea of software platforms is relatively new to the citizen science landscape, they have an important role to play in improving many aspects of citizen science and broadening access to its benefits. Historically, citizen science projects have had to develop their own software, making

[1] We use *scientific outcomes* to refer to both scientific research outcomes and applied science outcomes. Thus, monitoring the environment for practical purposes, while not scientific research as conventionally defined, falls under the category of a scientific outcome for the purposes of this report.

organizational resources and technical know-how limiting factors in citizen science initiatives (Newman, Graham, Crall, & Laituri, 2011). Large, well-funded organizations with substantial technical capacity have been able to develop sophisticated, purpose-built software for their projects (e.g., Cornell Lab of Ornithology, GLOBE program, Smithsonian Institution). However, most citizen science projects are started by individuals or small organizations with minimal capacity for software development (Newman et al., 2011). They typically settle for adapting or customizing free or inexpensive, general-purpose software.

More recently, though, organizations with software development capacity have developed a first generation of platforms designed to support citizen science (e.g., CitSci.org, FieldScope, MyObservatory, Vital Signs, Zooniverse). These platforms provide tools that enable project organizers to launch and maintain their citizen science projects with little or no specialized technical expertise. Such citizen science platforms address important pragmatic needs. They make sophisticated features and functionality available to citizen science projects that do not have the resources or capacity to develop their own software. In doing so, they also enable funders to spread their investment in a platform over multiple projects.

However, financial and technological economies of scale are not the only payoffs of citizen science platforms. They also can make it possible to leverage solutions to design challenges across multiple projects simultaneously. In the context of this work, this means that platforms offer the opportunity to bring strategies for achieving both scientific and educational objectives to numerous projects simultaneously.

The third premise of this work is that sharing design ideas and design cases can be an effective strategy for advancing a field. The method behind this work has a long tradition in the field of design, dating back to design's origin as a craft, not a science. The method amounts to collecting insights and examples gleaned from practical experience and sharing them with a broader community to inform their practice. This approach may seem to be out of step in an era that prizes rigorous, evidence-based decision-making, but it reflects the fact that we are in the early days of citizen science design and that important design insights can be gained through individual experiences[2] (e.g., case studies on CSA blog). It is hard to argue that at this time in the development of knowledge about the design and implementation of citizen science projects that we can justify the time and expense of conducting experiments around specific design decisions. Rather, it is more appropriate for the rapid advancement of knowledge that we develop a structured forum for designers to share their diverse experiences so that others can consider the lessons that they may hold for their goals and contexts and so that patterns may be revealed that would justify more systematic approaches to hypothesis testing in the future.

Thus, there are two audiences for this work. The primary audience is individuals and organizations who seek to create citizen science projects. The work is designed to make them aware of the opportunities and challenges for citizen science that might not be apparent to someone who lacks prior experience designing and implementing a citizen science project. In particular, our work is organized to make them aware of opportunities and challenges for achieving both scientific and educational goals through a citizen science initiative. In addition, the goal of this work is to provide

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[2] Case studies are available on the Citizen Science Association website at http://citizenscience.org/category/case-studies/.

citizen science project organizers with strategies for achieving the opportunities and overcoming the challenges presented here.

The second audience for this work is developers of platforms for citizen science projects. The information about opportunities, challenges, and strategies, together with the examples, that we provide in this report is intended to enable platform developers to build in supports for the design strategies. These supports will, in turn, enable project organizers to implement these strategies when building their citizen science projects on these platforms.

This work is intended to contribute to a line of existing work in citizen science with the goal of supporting citizen science project organizers with guidance on project design. This work includes a white paper by Shirk and Bonney (2015) that offers a high-level guide to thinking about and designing citizen science projects, particularly those that engage citizens in data collection. Shirk and Bonney follow the program design process from asking whether citizen science is the right method for the question the designers want to answer through considering how programs may be adaptively managed to address emergent opportunities and issues. Similarly, the Citizen Science Association's Education Working Group's *10 questions to prompt reflection on practice* (Kirn et al., 2016) advise citizen science practitioners on how to support both learning and science outcomes.

3 Design Objectives

The first key activity of the workshop was identifying what we decided to call ***design objectives.*** It is necessary to develop a vocabulary for characterizing the scientific and educational objectives that citizen science projects may be designed to achieve. We selected the phrase ***design objectives*** to describe the specific objectives that a citizen science project is being designed to achieve. Design objectives are specific scientific goals and educational goals. They reflect the challenges that must be addressed and opportunities that must be exploited in order to achieve these scientific or educational benefits. These design objectives play two important roles in this report. First, they provide a taxonomy of scientific and educational objectives that have been pursued by citizen science initiatives. Second, they provide an organizational framework for discussing ***design strategies.*** All the design strategies that are discussed in this report are associated with one or more of these objectives. These objectives are used to organize the discussion of the design strategies in Section 4.

Because we view this work as an initial step in a larger initiative, we have not set out to construct an exhaustive list of design objectives. Rather, we developed this list as a starting point. Our goal is to demonstrate the usefulness of this approach at the current time and lay the groundwork for a more comprehensive effort to follow.

3.1 Design Objectives for Scientific Outcomes

The design objectives for scientific outcomes reflect the opportunities that citizen science presents as a methodology for advancing scientific understanding. Some of them also reflect the challenges of implementing citizen science successfully to achieve those objectives. In this report, we discuss four core design objectives that apply to networked field studies, the subset of citizen science that was the focus of our workshop. They are

1. scale,
2. access,
3. community empowerment, and
4. data quality and credibility.

1. Scale. Scale is one of the most widely cited benefits of citizen science. It refers to the fact that by enlisting volunteer participants from the general public, a citizen science project can obtain a quantity of observations or analyses that would not be possible or affordable using a traditional scientific approach. In a networked field study, that scale may be measured in terms of numbers of observations, but it may also be measured in diversity of geography or some other attribute. The specific design objective associated with ***scale*** is

- *to achieve a larger number or broader diversity of observations or analyses than would otherwise be possible as a result of enlisting an appropriately large number of participants and/or getting each participant to conduct a large number of observations or analyses.*

2. Access. Access is another widely touted benefit of citizen science. The two categories of access are: access to locations and access to expertise. By enlisting participants from the general public, a citizen science project can gain access to locations or expertise that would not be possible using a traditional scientific approach. Access to specific locations is closely related to scale as measured by geographic distribution; but it is not about quantity of locations or magnitude of the area covered, it is about specific characteristics of those geographic locations. In many cases, networked field studies rely on recruitment of participants in specific locations (e.g., state parks) or who have access to locations with specific characteristics (e.g., high elevations, vernal pools, or private lands). Access to expertise refers to specific, rare expertise. One such form of expertise is familiarity with a specific area or phenomenon as a result of experience. Another is indigenous knowledge as a result of upbringing or education in an indigenous community. The specific design objective associated with ***access*** is

- *to obtain access to specific locations or expertise for data collection or analysis by engaging participants who have access to those locations or possess that expertise.*

3. Community empowerment. Community empowerment is a third potential benefit of citizen science. It is less widely cited or achieved than scale or access, but many advocates for citizen science view it as the most valuable from a societal perspective. Community empowerment refers to the benefit that can be obtained by a group (the "community") being able to influence or control a citizen science project to advance shared goals of the community. It contrasts with the model of science in which science is conducted by individuals who have an intellectual interest, but not a vested interest, in the outcome of the work. It aligns with movements to democratize science—to make science accessible to everyone as a tool and process for investigating and deepening knowledge of natural phenomena. The specific design objective associated with ***community empowerment*** is

- *to enable a community that may lack credentialed scientific experts to launch or shape a citizen science project that focuses on a phenomenon of concern or interest to the members of the community.*

4. Data quality and credibility. Data quality and credibility are recognized as challenges for citizen science, but studies of citizen science projects have shown that these challenges can be successfully managed (e.g., Bonney et al., 2009; Crall et al., 2011; Miller-Rushing, Primack, & Bonney, 2012; Newman et al., 2010; Shirk & Bonney, 2015; Wiggins, Stevenson, Newman, & Crowston, 2011). The large and growing number of publications in peer-reviewed scientific journals is testament to the validity of citizen-collected data[3]. The benefits associated with scale, access, and community ownership may be undermined if the quality of the data collected is not adequate for the purposes for which they were intended or if the data are not analyzed with sufficient rigor to address the research question. Therefore, the specific design objective associated with *data quality and credibility* is

- *to enable participants in a citizen science project to collect or analyze data of sufficient quality to serve the scientific purposes of the project.*

3.2 Design Objectives for Learning Outcomes

The design objectives for learning outcomes reflect the fact that citizen science offers an opportunity to engage participants in authentic science, which, under the right conditions, can lead to a wide variety of cognitive and noncognitive learning outcomes. Thus, two categories of design objectives for educational outcomes correspond to learning objectives and affective objectives. We have labeled a third category of design objectives *instrumental objectives.* This category captures intermediate goals that can be instrumental to achieving the objectives in the other two categories.

The educational design objectives identified by our group of experts are:

Cognitive objectives

- Mastery of scientific practices
- Understanding of nature of science
- Understanding of science concepts

Affective objectives

- Self-efficacy
- Stewardship attitude and behavior
- Interest in pursuing science

Instrumental objectives

- Structuring participant activity to support learning
- Supporting facilitation by teachers or other educators

Because we did not want to be constrained by prior work, these objectives were identified through a brainstorming session at the workshop. Interestingly, though, they have considerable overlap with the outcomes identified by the Cornell Lab of Ornithology's DEVISE project (Phillips, Ferguson, Minarcheck, Porticella, & Bonney, 2014) for use in evaluating citizen science projects.

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[3] For example, a search of the Web of Science for the keywords citizen science, public participation in scientific research, participatory action research, and volunteer monitoring found 280 publications published in 2010 alone.

DEVISE Learning Objectives		Workshop-identified Objectives	
Cognitive		Cognitive	
	Skills of science inquiry		Mastery of scientific practices
	Knowledge of the nature of science		Understanding of nature of science
			Understanding of science concepts
Affective		Affective	
	Motivation		Self-efficacy
	Self-efficacy		Stewardship attitude and behavior
	Interest in science & the environment		Interest in pursuing science
Behavioral		Instrumental	
	Behavior & stewardship		Structuring participant activity to support learning
			Supporting facilitation by teachers or other educators

Cognitive objectives. Cognitive objectives include the development of new understanding, skills, and abilities. Citizen science presents opportunities to achieve three kinds of cognitive objectives:

- Mastery of scientific practices: *to enable participants to develop enhanced abilities to plan and carry out investigations, analyze and interpret data, and use mathematics and think computationally by engaging in these practices as part of an authentic investigation* (National Research Council, 2012).
- Understanding of the nature of science: *to enable participants to learn about the nature of science through firsthand experience.*
- Understanding of science concepts: *to enable participants to develop conceptual understanding in the context of legitimate scientific activities that draw on or build such an understanding.*

Affective objectives. Affective objectives are changes in attitudes and dispositions. Citizen science presents the opportunity to achieve three important kinds of affective objective:

- Self-efficacy: *to help participants develop a greater sense of their ability to act effectively in the world.*
- Stewardship attitude and behavior: *to foster a feeling of responsibility in participants to care for their community and environment and an inclination to act on that feeling.*
- Interest in pursuing science: *to cultivate a desire to engage in scientific activities in the future.*

Instrumental objectives. In contrast to cognitive and affective objectives, instrumental objectives do not lead to learning outcomes themselves. Instead, they represent important intermediate objectives that, once achieved, support the achievement of the other two categories of learning objectives. They include:

- Structuring participant activity to support learning: *to structure the activities of participants in a way that creates opportunities for achieving cognitive and affective outcomes for participants.*
- Supporting facilitation by teachers or other educators: *to provide support for an educator to guide and monitor the activities of participants toward the educator's learning and affective objectives.*

4 Design Strategies

Design strategies are specific techniques that citizen science project organizers can use to achieve ***design objectives.*** The design strategies included in this report were identified by the workshop participants as approaches they have observed being used to effectively achieve design objectives in the context of one or more project. The rationale for identifying these design strategies is to encourage developers of citizen science platforms to provide support in their software to enable project organizers to implement them in their projects.

It is important to note that there is not a one-to-one correspondence between design strategies and design objectives. One design strategy may serve more than one design objective (see table in Appendix III). Likewise, one design objective can be supported by more than one design strategy (see table in Appendix III). In the sections that follow, the design strategies are organized by objective. However, they are cross-referenced to indicate when strategies support multiple objectives.

Workshop participants developed a standard template for describing design strategies. In the sections that follow, design strategies are presented using this standard template. The template consists of the following fields:

- Strategy name and description
- Activity phase
- Technology support
- Examples
- Other objectives

The ***strategy name and description*** fields need no explanation. The ***activity phase*** field is used to describe when the strategy is employed in the course of designing and implementing a citizen science project. The ***activity phases*** used in this report are detailed in the following table:

Preparation	Protocol development
	Participant recruitment
	Participant preparation
Field Study	Participant retention
	Data collection
	Data entry
Data Work	Participant retention
	Coding
	Analysis
	Dissemination

The *technology support* field is used to describe the role that technology can play in the implementation of the strategy. The *examples* field describes how the strategy has been implemented in citizen science projects and platforms.

The *other objectives* field highlights additional scientific and learning objectives that may also be supported by the strategy.

Within the section for each design objective, the strategies are sequenced according to the activity phase where they apply.

4.1 Design Strategies for Scientific Outcomes

In this section, we present design strategies identified by participants in the workshop for achieving valued scientific outcomes.

4.1.1 Scale

The objective for *scale* is to achieve a larger number or broader diversity of observations or analyses than would otherwise be possible as a result of enlisting an appropriately large number of participants and/or getting each participant to conduct a large number of observations or analyses. Workshop participants identified six design strategies for this objective:

Minimize barriers to entry
Standardize protocols across projects
Promote participation through publicity
Support social interaction among participants
Use and incorporate existing data sets
Hold community events to reduce discomfort in nature

Strategy	**Minimize barriers to entry**
Description	Make the data collection protocol as easy to understand and implement as possible.
Activity phase	Protocol development
Technology support	NA
Examples	• In *iNaturalist*, the protocol only requires that the participant take a photo of an organism using the smart phone app. The app automatically uploads the image with location and time information to the *iNaturalist* database. • *Snap-a-Striper* asks participants to fill out a simple data card and include it in pictures of striped bass they catch. • In *Project BudBu*rst, participants identify a tree or shrub using provided resources; record its location on a map; and describe its current state of budding, leafing, or flowering using a taxonomy of states and transitions that the project provides.
Other objectives	Successful participation can also contribute to *self-efficacy.*

Strategy	**Standardize protocols across projects**
Description	Enable aggregation of data across projects and enable participants to contribute to multiple projects by adopting shared data protocols.
Activity phase	Protocol development
Technology support	Centralized databases of measurement protocols for project designers
Examples	• *CitSci.org* has a page with information about protocols being used on existing projects to encourage projects to use common protocols. • The *iNaturalis*t database uses standards that enable the platform to share research-grade data with the Global Biological Information Facility (GBIF).

Strategy	**Promote participation through publicity**
Description	Seek publicity through traditional and social media in order to recruit more participants.
Activity phase	Participant recruitment
Technology support	Provide media kit (logo files, descriptions, contact name, etc.) on-site
Examples	• *Project BudBurst* received national coverage through NPR and had a big growth in interest immediately following. • *eBird* is actively promoted through the traditional and social media outreach mechanisms of Audubon and Cornell Lab of Ornithology.

Strategy	**Support social interaction among participants**
Description	Encourage retention by providing social interaction with other participants, scientists, and organizers.
Activity phase	Participant retention
Technology support	Online platform that supports social interaction around contributions.
Examples	• In *Vital Signs,* participants give and receive comments, and species experts confirm or question identifications. • In *iNaturalist,* participants receive comments and species identifications from others, including experts. • *Zooniverse Ta*lk supports discussions and learning among project participants.
Other objectives	Since quality of data increases with experience, retaining participants also improves *data quality and credibility.*

Strategy	Use and incorporate existing data sets
Description	Identify preexisting data sets that can supplement participants' data.
Activity phase	Data analysis; protocol development
Technology support	NA
Examples	• *eBird* draws on historical data from the Christmas Bird Count. • The *Tamarisk Coalition* combines data from citizen science projects with data collected by scientists. • *Vital Sign*s integrates data sets from other investigations.

Strategy	**Hold community events to reduce discomfort in nature**
Description	Overcome the anxiety that certain populations have in nature by holding an event where they can be with others.
Activity phase	Data collection
Technology support	NA
Example	• *National Park Service BioBlitzes* are held as events where people can participate as part of a group led by a scientific expert.
Other objectives	Reducing discomfort can also support *community empowerment.*

4.1.2 Access

The objective for ***access*** is to obtain access to specific locations or expertise for data collection or analysis by engaging participants who have access to those locations or possess that expertise. Workshop participants identified two strategies:

Gain access to locations through partnerships
Gain access to expertise

Strategy	**Gain access to locations through partnerships**
Description	To gain access to key locations, work with partners who can connect to participants in those locations.
Activity phase	Participant recruitment
Technology support	NA
Examples	• *GLOBE Program* works with partner organizations around the world who recruit, train, and support schools in their parts of the world. • *FrogWatch USA* works with a network of zoos, aquariums, and nature centers that train and oversee participants who are identified as members of their chapters. • *Snap-a-Stripe*r recruits fishing guides in areas of particular interest.
Other objectives	Partnering with organizations and their members can increase project *scale.*

Strategy	Gain access to expertise
Description	Recruit those with expertise to complete desired tasks.
Activity phase	Participant recruitment
Technology support	NA
Examples	• *Vital Signs* works with educators who have the expertise and access to youth to engage them in science activities. • *Snap-a-Striper* recruits fishermen and fishing guides who have expertise and interest in catching striped bass. • *Front Range Pika Projec*t recruits hikers and mountaineers with expertise to safely reach pika habitat and trains them in science skills required to make and report observations.

4.1.3 Community empowerment

The objective for ***community empowerment*** is to enable a community that may lack individuals with scientific credentials to launch or shape a citizen science project focused on a phenomenon of concern or interest to the community. Workshop participants identified three strategies:

Support community creation of projects
Accept suggestions from participants
Offer examples of interesting research questions

Strategy	**Support community creation of projects**
Description	Provide technological tools that will allow anyone to create their own project.
Activity phase	Protocol development; Participant retention
Technology support	Project authoring tools.
Examples	• *CitSci.org* and *FieldScope* provide tools that enable people with minimal technical or scientific expertise to create a networked field study by specifying the observations to be recorded. These tools also help to manage the study. • *iNaturalist* provides tools to allow people to set up a focused species distribution study by specifying a geographic region, taxa of interest, and/or an interval of time. • *Vital Signs* invites anyone to define new Field Missions around specific research questions. • *Zooniver*se has a Project Builder tool to help anyone create a new Zooniverse project.
Other objectives	Enabling people to create projects can enhance their *self-efficacy.*

Strategy	**Accept suggestions from participants**
Description	Enable participants to influence the design of a study by providing them with functionality to suggest new protocols and data collection campaigns.
Activity phase	Protocol development; Data collection
Technology support	Suggestion functionality
Examples	• The *GLOBE Program*'s functionality for community generation of campaign ideas resulted in a mosquito larvae protocol and campaign and an El Niño/Southern Oscillation (ENSO) campaign. • *iNaturalist* expands functionality in response to user suggestions and has a "Feedback" link on the bottom of every page. • *CitSci.org* offers project forum pages and customizable feedback forms where project participants can offer suggestions to their project manager(s).
Other objectives	Allowing participants to shape a project can enhance their *self-efficacy.*

Strategy	**Offer examples of interesting research questions**
Description	To encourage students to conduct their own investigations, provide them with examples of interesting questions they can pursue.
Activity phase	Participant recruitment; Participant preparation; Participant retention; Data collection; Coding; Analysis; Dissemination
Technology support	Extensible, searchable library of research projects
Examples	• *Project Budburst* provides instructional materials with example questions for investigation. • *FrogWatch USA* annotates maps that users can browse through with questions that can be investigated and instructions on how to conduct those investigations. • *Vital Signs* has 32 Field Missions for participants to choose from, or they can create their own. • *iNaturalist* has a wide variety of projects on local to global scales; participants can also create their own.

4.1.4 Data Quality and Credibility

The objective for *data quality and credibility* is to enable participants in a citizen science project to collect or analyze data of sufficient quality to achieve the scientific goals of the project. Workshop participants identified six strategies:

- Train and/or test participants on data collection protocol
- Monitor protocol adherence
- Require documentation in support of an observation
- Constrain data entry
- Verify data or classification
- Employ reputation- or contribution-based data verification

Strategy	**Train and/or test participants on data collection protocol**
Description	Offer training for participants on how to implement the data collection in accordance with the protocol and/or require them to succeed on an assessment of their ability to implement the protocol.
Activity phase	Participant preparation; Participant retention
Technology support	Online training tools, tasks, or other resources

Examples	• *FrogWatch USA* offers both in-person and online training for volunteers. • The Citizen Science Academy is an online, asynchronous course for educators on how to use citizen science in their classrooms, using *Project Budburst* as a case study. • *Front Range Pika Project* provides in-person training that prospective participants are required to complete in order to participate. • *Vital Signs* has online trainings for educators, curriculum for developing required fieldwork skills, and illustrated How-to Guides for new participants (educators, students, and others). • *Zooniverse* projects have a compulsory training module before users can participate; users are periodically given test tasks to calibrate their performance. • *GLOBE Progra*m requires teachers to complete training on each protocol before submitting data for that protocol.
Other objectives	Increasing participants' skill at implementing a data collection protocol can increase *mastery of scientific practices* and enhance *self-efficacy.*

Strategy	Monitor protocol adherence
Description	Ask participants to describe their data collection process to determine if it was consistent with established protocol.
Activity phase	Data collection
Technology support	NA
Examples	• *FrogWatch USA* asks participants to report how many minutes they listened—a key aspect of the protocol—as an indicator of adherence. • Various *CitSci.org* projects leverage this strategy. For example, the *Front Range Pika Project* asks volunteers to report search time for pika evidence of presence.
Other objectives	Asking participants to monitor protocol adherence can enhance their *understanding of the nature of science.*

Strategy	**Require documentation in support of an observation**
Description	For each observation, require the participant to provide an image or other recording that allows the participant's observation to be verified by others.
Activity phase	Protocol development; Data collection; Data entry
Technology support	Technology may be used to automatically capture an image or other recording at the time the observation is being made; require defined fields to be filled in before observations are accepted.
Examples	• The *Vital Signs* project requires users to upload images, descriptions, and location data before observations may be accepted. • The *iNaturalist* project asks participants to submit photos and sound recordings of the organisms they observe to enable other participants to review and verify species identifications. • The *CitSci.org* platform asks participants to submit photos for observations and allows multiple photos for species observations to support further review by experts.

Other objectives	Asking participants to provide documentation of observations can enhance their *understanding of the nature of science.*

Strategy	**Constrain data entry**
Description	The data entry mechanism constrains users to only entering data that conform to the protocol.
Activity phase	Data entry
Technology support	Allow definition of ranges for data fields
Examples	• The data entry forms for *CitSci.org* and *GLOBE* do not permit input of data that fall outside a prespecified allowable range for a given measurement. • *Vital Signs* data entry form has required and optional fields; acceptable ranges are defined for certain fields (e.g., temperature, pH, salinity in marine and freshwater environments). • *iNaturalist* project definition includes setting required and optional fields and setting input ranges if desired.

Strategy	**Verify data or classification**
Description	Verify data by having multiple, independent reviewers or by requiring that an initial classification be supported by other classifiers.
Activity phase	Coding
Technology support	Systems for presenting the same observation to multiple individuals for coding or for obtaining verification for all initial codes; alert systems to notify data classifiers of new submissions needing verification.
Examples	• In *iNaturalist* species identification must be confirmed by at least one other participant for that observation to be classified as "Research grade" and forwarded to the Global Biodiversity Information Facility (GBIF). • *Vital Signs* species identifications are confirmed or questioned by experts. • *Zooniverse* projects put the same task in front of multiple participants. • *Zooniverse* functionality intersperses test tasks to calibrate a participant's contributions.
Other objectives	Transparently engaging participants in verification of data and classifications can support participants' growing *mastery of scientific practices* and support their sense of *self-efficacy*.

Strategy	**Employ reputation- or contribution-based data verification**
Description	Assess quality of data based on a participant's credentials and history.
Activity phase	Data entry; data coding
Technology support	Track activities in order to weigh future contributions based on the history of a participant's data being used and/or verification by respected users; algorithm to apply calibration factor to individual participants' data contributions
Examples	• *Zooniverse* checks a participant's performance on test tasks and uses the results to weight participants' contributions. • *iNaturalist* tracks participants' performance at identifying species as measured by how often their identifications are confirmed or challenged.

4.2 Design Strategies for Educational Outcomes

In this section, we present the design strategies that can enable networked field studies to achieve valued educational outcomes.

4.2.1 Mastery of scientific practices

The objective of ***mastery of scientific practices*** is to enable students to develop enhanced abilities to plan and carry out investigations, analyze and interpret data, and use mathematics and think computationally. Workshop participants identified one strategy:

Data visualization and analysis

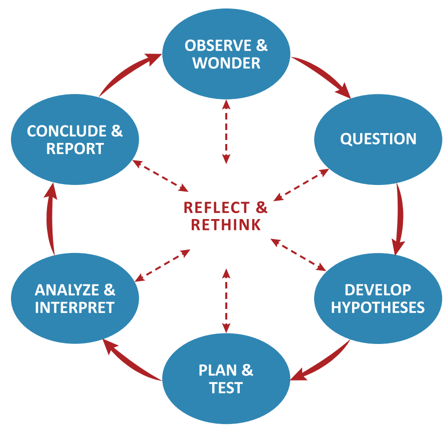
Strategy	**Data visualization and analysis**
Description	Provide participants with the ability to analyze and interpret data by creating visualizations and conducting analyses themselves.
Activity phase	Data analysis; Dissemination
Technology support	Visualization and analysis tools
Examples	• The *GLOBE Program* offers a sophisticated suite of tools for mapping, graphing, filtering, and exporting data. • The *FieldScope* platform includes a set of tools for creating maps and plots and for conducting geospatial analysis of data. • *Vital Signs* offers an interactive map and searchable, downloadable database. • *CitSci.org* offers dynamic real-time interactive charts that allow participants to make comparisons, visualize trends over time, and/or view relationships between variables being measured by a given project.
Other objectives	Creating data visuals and conducting analysis of data may increase participants' *interest in pursuing science*.

4.2.2 Understanding of the nature of science

The objective of *understanding of the nature of science* is to enable students to learn about the nature of science through firsthand experience*.* Workshop participants identified two strategies:

Provide a visual representation of inquiry process
Require a peer review or self-check of work

Strategy	Provide a visual representation of inquiry process
Description	Help students understand the inquiry process by providing them with a visual representation of the process that they can use to guide and track their work.
Activity phase	Data collection; Data entry; Coding; Analysis; Dissemination
Technology support	NA
Example	• *Driven to Discover* offers a diagram of the process of science to help participants situate their participation within the process (University of Minnesota Extension, n.d.).



Strategy	**Require a peer review or self-check of work**
Description	Help students to understand how and why scientists review each other's work to identify errors, evidence of bias, and weaknesses in reasoning.
Activity phase	Data collection; Data entry; Coding; Analysis
Technology support	• Feedback system • Embedded prompts for peer review; fields to track reviews
Examples	• *Vital Signs* has a review system in which students check each other's identifications of organisms and review each other's arguments for the quality of evidence and reasoning; the reviewing team's name is added to the observation they review, making visible their responsibility for quality.
Other objectives	Asking for peer review or self-check can also enhance *data quality and credibility*. Since review is an important scientific practice, this also can enhance *mastery of scientific practices*.

4.2.3 Understanding of science concepts

The objective of *understanding of science concepts* is to enable students to develop conceptual understanding in the context of legitimate scientific activities that draw on or build that understanding. Workshop participants identified two strategies:

Support interaction among science experts and project participants
Overlay an educational task on protocol

Strategy	**Support interaction among science experts and project participants**
Description	Enable learners to ask questions or receive instruction on science content and otherwise interact with scientists and science experts.
Activity phase	Participant preparation through Dissemination
Technology support	• Libraries of text or media recordings of scientists • Real-time or asynchronous discussion and commenting functionality • Databases of scientists • Matchmaking services
Examples	• In *FrogWatch USA*, participants receive training from an expert in amphibians from a local zoo or informal science institution, and they have ongoing access to them via email or phone. • *iNaturalist* has a community of novice and expert naturalists and biological scientists who freely interact with one another. • *Vital Signs* serves a diverse community of scientists and resource managers with observational data on species of interest and concern; these experts can interact with youth contributing data via public comments, species identification verification, and Field Missions. • *CitSci.org* supports a role for experts, allowing them to make comments and/or review data submitted by project contributors.
Other objectives	Exposure to and interaction with experts can help participants learn and grow their *mastery of scientific practices* and *self-efficacy*.

Strategy	**Overlay an educational task on protocol**
Description	Provide educational users with tasks that ask them to apply a science concept as part of conducting the data collection protocol.
Activity phase	Data collection
Technology support	NA
Examples	• The *Great Nature Project* provided "learning missions" that asked young people to take pictures of multiple organisms that exemplify a relationship and describe the relationship (e.g., multiple organisms in a food chain and describe the food chain). • *Driven to Discover* builds curriculum around existing citizen science projects such as the *Monarch Larva Monitoring Project* and *eBird*.

4.2.4 Self-efficacy

The objective of *self-efficacy* is to help students develop a greater sense of their ability to act effectively in the world. Workshop participants identified three strategies:

Provide multiple entry points to participation, multiple ways to contribute
Publicly recognize participants' contributions

Strategy	Provide multiple entry points to participation, multiple ways to contribute
Description	Provide multiple ways that learners can participate so that they can begin from a place of confidence and grow from there.
Activity phase	Participant recruitment; Participant preparation; Data collection; Data entry; Coding; Analysis; Dissemination
Technology support	NA
Examples	• *Vital Signs* observations include text, images, sketches, field notes, and measurements and are typically made by teams of students; individual students can contribute by lending their peer leadership, organization, attention to detail, art, mathematics, writing, and observational skills. • Participants contribute to *iNaturalist* by sharing observations and/or by identifying species in posted observations.
Other objectives	Giving participants many ways to contribute can encourage participation and can increase motivation and interest, thereby increasing project *scale* and participants' *interest in pursuing science.*

Strategy	**Publicly recognize participants' contributions**
Description	Provide participants with positive feedback in the form of recognition for their work.
Activity phase	Participant retention; Coding; Analysis; Dissemination
Technology support	• The ability to associate contributions with individuals or groups • Visible profiles
Examples	• *iNaturalist* and *Vital Signs* have publicly visible profiles that link to an individual's contributions. • *iNaturalist* maintains leaderboards of top observers and top identifiers of each species. • *iNaturalist* selects interesting data contributions to present as an observation of the week to the community of participants. • *Vital Signs* has a Best Of section highlighting outstanding observations, images, sketches, etc. • *Zooniverse* cites all participants in relevant research publications. • The *GLOBE Program* displays the number of observations contributed by each school, as well as interesting extreme weather measurements. • *CitSci.org* maintains leaderboards of top observers.
Other objectives	Recognizing participants' contributions can contribute to retention, which also enhances *scale* and *data quality and credibility*.

Strategy	**Provide participants with a sense of ownership of their contributions**
Description	By providing participants with private recognition of their contributions and a way to access them, projects give participants a sense of ownership that can increase their sense of self-efficacy.

Activity phase	Data entry, Database design; Dissemination; Participant retention
Technology support	Provide participants with individual accounts that maintain connection to their contributions
Examples	• *CitSci.org* provides users with a My Profile page that shows statistics for their contributions. It also highlights recent observations by members on the home page. • *eBird* provides an environment that allows birdwatchers to maintain their personal lists of birds observed, while also sharing their observations as data with scientific researchers. • After submitting an observation to *eBird*, the participant gets an animation indicating success. • *CitSci.org* offers a My Observations tab on the My Profile page for each participant to help track their contributions. • *GLOBE* displays electronic badges on schools' MyPage for their efforts.
Other objectives	Providing a sense of ownership can also increase retention of participants, which can contribute to *scale* and *data quality and credibility.*

4.2.5 Stewardship attitude and behavior

The objective of *stewardship attitude and behavior* is to foster a feeling of responsibility in participants to care for their community and environment and an inclination to act on that feeling. **Workshop participants identified one strategy:**

Provide information about and/or connection to stewardship actions

Strategy	**Provide information about and/or connection to stewardship actions**
Description	Provide information to participants about the actions they can take in response to the environmental problems they are investigating.
Activity phase	Participant recruitment; Participant preparation; Participant retention
Technology support	Support/provide extensible library of resources that includes information about stewardship actions
Examples	• *Monarch Larva Monitoring Project* provides participants with information about planting milkweed to provide food and habitat for monarch larvae. • *Yard Map* provides participants with information about how to improve the habitat for birds in the location they are monitoring. • *Vital Signs* provides a Managing Invasive Species curriculum extension to enable participants to plan and implement management projects.
Other objectives	To the extent that the project helps learners to see a relationship between stewardship and science, providing information about stewardship actions can also enhance *interest in pursuing science.*

4.2.6 Interest in pursuing science

The objective of *interest in pursuing science* is to cultivate a desire to engage in scientific activities in the future*.* Workshop participants identified two strategies:

Show peers participating in citizen science

Connect to participants' existing interests

Strategy	**Show peers participating in citizen science**
Description	Show examples of people doing the required tasks with whom they can identify to participants.
Activity phase	Participant preparation; Participant retention
Technology support	NA
Examples	• A research study found that girls who watched episodes of *SciGirls* featuring girls like them engaged in citizen science got more out of participation in *FrogWatch USA* than their peers who did not watch *SciGirls* (Flagg, 2016). • *Vital Signs* has a data quality hunt activity that gets participants to look at and critically evaluate species observations posted by their peers. • *CitSci.org* maintains a blog that highlights peers in featured projects participating in citizen science. • *GLOBE* has an alumni network that encourages alumni to engage with K-12 students in the program.
Other objectives	By attracting additional participants, showing peers participating in science can increase *scale.*

Strategy	Connect to participants' existing interests
Description	Meet participants in issues of concern or interest, design project to build from there.
Activity phase	Protocol development; Participant recruitment; Participant retention; Analysis; Dissemination
Technology support	NA
Examples	• *eBird* gives active birders who are already recording what birds they see where and when a place to record these lists digitally, and share them with scientists researching birds. • *iNaturalist* gives people who are already taking pictures of organisms a place to share them with peers and scientists. • *Monarch Larva Monitoring Project* explicitly recruits people with an existing interest in monarch butterflies. • *Front Range Pika Project* takes advantage of participants' passion for high elevation hiking and asks them to record observations of pika as they hike. • *Snap-a-Striper* takes advantage of the fact that people are already fishing and enjoy taking and sharing pictures of the fish they catch. • *Vital Signs* lets participants choose which habitats to explore and which species to investigate.
Other objectives	Tapping into potential participants' existing interests can motivate participation and contribute to *scale* and *access.*

4.2.7 Structuring participant activity to support learning

The objective of ***structuring participant activity to support learning*** is to structure the activities of participants in a way that creates opportunities for achieving cognitive and affective outcomes for participants. Workshop participants identified two strategies:

Scaffold inquiry steps

Offer student guides and learning resources

Strategy	**Scaffold inquiry steps**
Description	Provide participants with guides that step them through the inquiry process.
Activity phase	Participant preparation through Dissemination
Technology support	Online activity guides; educator professional development resources
Examples	• *Vital Signs* provides Field Missions with research questions, special protocols, and rationale for why the question is important to scientists and to Mainers. It also provides curriculum units that support educators in guiding youth through a round of scientific inquiry. • *Driven to Discover* provides curriculum that helps educators guide students to generate and pursue questions of their own through a step-by-step structure. • The *CitSci.org* platform provides a template for each project that offers tabs that guide participants through steps of research from submitting data to viewing data to performing analyses and visualizations, getting feedback for program evaluation, and sharing results
Other objectives	Providing an explicit guide through the inquiry process can also enhance *understanding of the nature of science.*

Strategy	**Offer student guides and learning resources**
Description	Provide materials that guide learners through participation in a way that creates opportunities for learning and learning resources that can support knowledge building during participation.
Activity phase	Participant preparation; Data collection; Data entry; Coding; Analysis
Technology support	Online libraries of student materials
Examples	• *Driven to Discover* offers student guides and materials (e.g., field journal). • *Vital Signs* offers student guides for the activities that participants conduct. • *GLOBE* has materials available to teachers and students that guide student research and offers opportunities for students to share their findings with other students.
Other objectives	By supporting learning, offering student guides can help to achieve the cognitive objectives of *mastery of science practices*, *understanding of the nature of science* and *understanding of science concepts*, and the affective objectives of *self-efficacy* and *interest in pursuing science*. Because teachers can use student guides and learning resources, they are also *supporting facilitation by teachers or other educators*.

4.2.8 Supporting facilitation by teachers or other educators

The objective of ***supporting facilitation*** is to enable an educator to guide and monitor the activities of learners toward the educator's learning and affective objectives*.* Workshop participants identified two strategies:

Provide teacher professional development

Provide facilitation guides to teachers and educators

Strategy	**Provide teacher professional development**
Description	Provide educators with professional development experience that prepares them for leading learners through participation in the project.
Activity phase	Participant recruitment; Participant preparation
Technology support	Discussion forums to support peer-to-peer educator learning; extensible library of professional development offerings
Examples	• *Vital Signs* offers an online train-yourself guide for educators' advanced training on special topics from data skills to biodiversity investigations. • Prior to the 2016 *National Park Service BioBlitz* series, teachers attended a weekend workshop in the park where the BioBlitz would take place. They receive instruction on how to prepare their students for the event, and they participate in a species inventory. • Through a network of partners, *GLOBE* offers professional development opportunities for teachers who want to be involved in the program.
Other objectives	Professional development for educators can positively impact project *scale* and *access*, improve *data quality and credibility*, and support deeper *understanding of the nature of science* and *understanding of scientific concepts*.

Strategy	**Provide facilitation guides to teachers and educators**
Description	Provide resources (e.g., teacher guides, lesson plans) to help educators facilitate learning around their students' participation in citizen science.
Activity phase	Participant preparation; Data collection; Data entry; Coding; Analysis; Dissemination
Technology support	NA
Examples	• *Driven to Discover* offers both a Facilitator's Guide and an Investigator's Field Journal for each citizen science project they support. • *Vital Signs* offers Educator Tools, curriculum units and individual lesson plans, and illustrated How-to Guides. • *iNaturalist* offers a Teacher's Guide with resources, advice, and examples. • *GLOBE* offers a Teacher's Guide in multiple languages*.*
Other objectives	Providing a guide to educators can greatly increase the likelihood that educators will implement projects, thus favorably impacting project *scale*.

Discussion

This report identifies valued outcomes of citizen science projects for science and education and presents strategies that existing projects have used to achieve them. While the report is intended to provide practical support for individuals or organizations who are setting out to design citizen science projects and platforms, it should be viewed as a framework for approaching design with some strategies to consider rather than a complete set of recommendations to be followed. While the strategies presented represent the experiences of the convened group of professionals working in citizen science and education, participants acknowledge that neither their effectiveness nor appropriateness across contexts has been systematically studied. Nevertheless, the participants believed that sharing these strategies would contribute to the field by promoting conversations about design objectives and strategies and might encourage researchers to begin developing an evidence base for the effectiveness of design strategies. Toward those ends, we make three suggestions to advance the agenda behind this work:

The citizen science community should develop a shared taxonomy for describing valued outcomes of citizen science projects. This taxonomy would provide a common vocabulary to facilitate dialogue about how to design for improved outcomes. It would also support the development of common metrics for evaluating project outcomes and the implementation of research that could build toward the accumulation of findings based on common terminology and metrics. This report is designed to be a step toward this goal, but the effort to develop this taxonomy could build on the work of the DEVISE project (Phillips et al., 2014) for learning outcomes and best science method practices for scientific outcomes. To maximize its impact, such a taxonomy should be vetted through a public review process and should be promulgated by a membership organization, such as the Citizen Science Association.

The citizen science community should develop and maintain a repository of strategies that have been identified for achieving valued outcomes of citizen science. This repository of design strategies would support citizen science project and platform developers in creating or improving projects. The repository should reference examples for each strategy that would enable designers to understand the strategies more completely and provide them with models they could follow in implementing the strategies. Again, the strategies and examples presented in this report could serve as a model or a starting point for a community-wide repository.

The citizen science community should cultivate a body of evidence describing which strategies achieve which valued outcomes. The effectiveness of design strategies in achieving specific outcomes in human systems is inevitably contingent on specific circumstances. The evidence should not be oriented at simple “what works” conclusions in these cases, but should be contextualized in terms of the conditions under which certain strategies are effective and for which populations.

The development of such a research base requires both collective and individual action. Collective action across a community is necessary to establish priorities, to advocate for resources to support the research, and to accumulate evidence centrally. Individual action is required to carry out the research, to maintain a healthy dialogue about the quality of evidence, and to apply the findings to project design and development.

In conclusion, the objective of this workshop and report will be achieved if it serves as a stepping stone to a community-wide, collaborative effort to inform the efforts of project organizers and project and platform designers. While citizen science has made enormous strides forward during the brief life of the internet, networked data collection and analysis are still in their infancy. To the extent that the citizen science community can join together to articulate common goals, develop and share design strategies, and accumulate research on the effectiveness of these strategies under different conditions with different populations, the progress of the citizen science initiative can be maintained and accelerated. The recent establishment of organizations such as the Citizen Science Association, the European Citizen Science Association, and the Australian Citizen Science Association are testament to the viability and value of collaborative efforts to support the evolution and improvement of citizen science research and practice. The work presented here is intended to serve as a step in that direction.

Acknowledgments

The design ideas presented in this report were generated by participants in the workshop. The objectives and strategies in this report, which was written by Daniel Edelson with assistance from Sarah Kirn, are largely a synthesis of those ideas.

Ben Loh and Aleigh Raffelson made other important contributions. Ben Loh helped develop the design framework and contributed to workshop planning and facilitation. Aleigh Raffelson managed the administrative aspects of the workshop and the project.

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Appendix I: Workshop Information

The workshop was held in Colorado Springs, CO in January 2017. It was facilitated by Daniel Edelson, Executive Director of BSCS, and Ben Loh, Director of Inquirium. The participants in the workshop were:

- Adam Baukus, Gulf of Maine Research Institute (GMRI)
- Rob Blair, University of Minnesota
- Mary Ford, National Geographic Society
- Shelly Grow, American Zoos and Aquariums
- Sarah Kirn, Gulf of Maine Research Institute (GMRI)
- Scott Loarie, California Academy of Sciences
- Ben Loh, Inquirium
- Tony Murphy, GLOBE Implementation Office
- Greg Newman, Colorado State University

Jason Morris, Senior Program Officer for Environmental Education at the Pisces Foundation, attended the workshop as an observer.

As described in the Introduction, each of the participants presented a citizen science project or platform during the first session of the workshop. These served as common reference points throughout the workshop. They were:

- *BioBlitz*, National Park Service and National Geographic Society
- *CitSci.org* (platform), Colorado State University
- *eBird*, National Audubon Society and Cornell Lab of Ornithology

- *FieldScope* (platform), BSCS
- *FrogWatch USA*, Association of Zoos and Aquariums
- *GLOBE Program*, NASA, implemented by the University Corporation for Atmospheric Research (UCAR)
- *iNaturalist* (platform), California Academy of Sciences
- *Snap-A-Striper*, Gulf of Maine Research Institute (GMRI**)**
- *Vital Signs*, Gulf of Maine Research Institute (GMRI**)**

Appendix II: Citizen Science Project and Platform Overviews

This appendix provides overviews and links to websites for each of the projects and platforms that appear as examples of Design Strategies.

Platform Overviews

Name	CitSci.org
Description	The CitSci.org platform provides tools and resources to allow people to define and operate field-based citizen science projects. Tools include project creation, project member management, data sheet builder, data analysis, and feedback solicitation.
Intended audience	Scientists, or the scientifically curious and savvy who are interested in creating citizen science projects
Organizer	Natural Resources Ecology Lab, Colorado State University
Website	http://www.citsci.org/

Name	FieldScope
Description	FieldScope enables project organizers to set up and manage networked field studies. Designed with educational goals in mind, FieldScope provides project participants with the ability to analyze data with tools designed for nonscientists.
Intended audience	Organizers of projects for the general public including students and other learners.
Organizer	BSCS
Website	http://www.fieldscope.org

Name	iNaturalist
Description	The iNaturalist platform provides infrastructure for naturalists to share observations of organisms, crowdsource identification of organisms, and collaboratively amass a record of global biodiversity. Features include mobile application, search by place or organism, community forums discussing platform, collaborative system of species identification, and sharing of confirmed data with the Global Biodiversity Information Facility.
Intended audience	Naturalists worldwide
Organizer	iNaturalist is an independent program housed at the California Academy of Sciences

Website	http://www.inaturalist.org

Name	Zooniverse
Description	The Zooniverse is the world's largest and most popular platform for people-powered research, with a focus on enabling research that would not be possible, or practical, without massive effort by volunteers. The Zooniverse platform supports a growing collection of research projects to which volunteers can contribute using their own computer, at their own convenience (no fieldwork required). Zooniverse research results in new discoveries, datasets useful to the wider research community, and many publications.
Intended audience	Anyone with a computer and internet connection
Organizer	The Zooniverse Team housed at Oxford University
Website	https://www.zooniverse.org/

Networked Field Study Project Overviews

Name	Driven to Discover
Description	The Driven to Discover citizen science program engages youth in authentic scientific inquiry by capitalizing on the rich learning opportunities provided by citizen science. The program provides tools, resources, and curricula for youth group leaders and program managers and classroom teachers to plan and carry out citizen science–based research with youth.
Intended audience	Middle and high school classroom teachers; leaders and managers of youth programs
Organizer	University of Minnesota Extension and collaborating citizen science projects, including Cornell Lab of Ornithology's eBird, the Monarch Larval Monitoring Project, and the Minnesota Bee Atlas
Website	https://www.extension.umn.edu/environment/citizen-science/driven-to-discover/

Name	eBird
Description	eBird allows birders worldwide to record and share bird observations and images and maintain lists. The data submitted, especially the complete lists of all birds seen at a given time and location, are used extensively in scientific research. It is amassing one of the largest and fastest growing biodiversity data resources in existence.
Intended audience	Birders, scientists
Organizer	Cornell Lab of Ornithology & National Audubon Society
Website	http://ebird.org

Name	FrogWatch USA
Description	FrogWatch USA is AZA's citizen science program and provides individuals, groups, and families opportunities to learn about wetlands in their communities by reporting on the calls of local frogs and toads.
Intended audience	Individuals, groups, and families
Organizer	Association of Zoos and Aquariums (AZA)

Website	https://www.aza.org/frogwatch

Name	Front Range Pika Project
Description	The Front Range Pika Project is a citizen science program that trains the mountaineering public to participate in conservation research on the American pika, an alpine animal that lives at elevations of 8,000–13,000 feet. The Pika Project is built on the CitSci.org platform.
Intended audience	Volunteers who meet the project criteria (e.g., able to safely navigate the remote terrain inhabited by pikas, able to participate in training, meet age requirement)
Organizer	Rocky Mountain Wild and Denver Zoo, pika researchers at the University of Colorado, the Colorado Division of Wildlife, with computer support from the Natural Resource Ecology Laboratory at Colorado State University
Website	http://www.pikapartners.org

Name	GLOBE Program
Description	The Global Learning and Observations to Benefit the Environment (GLOBE) Program is an international science and education program that provides students and the public worldwide with the opportunity to participate in data collection and the scientific process and to contribute meaningfully to our understanding of the Earth system and global environment.
Intended audience	A worldwide community of students, teachers, scientists, and citizens
Organizer	NASA implemented by the GLOBE Implementation Office (GIO)
Website	https://www.globe.gov

Name	Great Nature Project
Description	This project engaged people of all ages and all over the planet to gather and share images of plants, animals, and fungi. This project ran from 2013 to 2015. The idea and effort continues in collaboration with iNaturalist.
Intended audience	Anyone with a camera
Organizer	National Geographic
Website	https://www.nationalgeographic.org/projects/great-nature-project/

Name	Yard Map
Description	Yard Map is a citizen science project designed to cultivate a richer understanding of wildlife habitat, for both professional scientists and people concerned with their local environments. Volunteers literally draw maps of their backyards, parks, farms, favorite birding locations, schools, and gardens. Tools are provided to inform better decisions about how to manage landscapes sustainably.
Intended audience	Professional scientists and people concerned with their local environments
Organizer	The Nature Conservancy and Cornell Lab of Ornithology

Website	http://content.yardmap.org/

Name	Monarch Larva Monitoring Project
Description	The Monarch Larva Monitoring Project (MLMP) involves volunteers from across the United States and Canada in collecting long-term data on larval monarch populations and milkweed habitat. The project focuses on monarch distribution and abundance during the breeding season in North America.
Intended audience	Anyone (individuals or groups) in the US and Canada (*Driven to Discover* offers an MLMP educators guide and resources)
Organizer	University of Minnesota Extension, and in particular, staff and students University of Minnesota Monarch Lab
Website	https://monarchlab.org/mlmp

Name	National Park Service BioBlitz
Description	A BioBlitz is an event that focuses on finding and identifying as many species as possible in a specific area over a short period of time. National Geographic and the National Park Service put on a series of BioBlitzes in national parks in 2016 to celebrate 100 years of stewardship and to document biodiversity.
Intended audience	Scientists, families, students, teachers, and other community members
Organizer	National Park Service & National Geographic Society
Website	https://www.nps.gov/subjects/biodiversity/national-parks-bioblitz.htm https://www.nationalgeographic.org/projects/bioblitz/

Name	Project Budburst
Description	Project BudBurst engages a broad audience in careful observation of the timing of leafing, flowering, and fruiting phases of plants. The collective body of observations is used to understand how climate change is impacting plant life. The information is freely available to anyone.
Intended audience	People of all ages and abilities
Organizer	Chicago Botanic Gardens with local and national organizations such as the US Fish and Wildlife Service, the National Park Service, National Geographic, the Arbor Day Foundation, the US Forest Service, and many others
Website	http://budburst.org

Name	Snap-a-Striper
Description	Snap-A-Striper is an ongoing collaborative effort between the Gulf of Maine Research Institute (GMRI) and CCA-Maine. Body shape data collected from photos of stripers caught in Maine waters with Snap-A-Striper data cards in place as well as data from the otoliths (ear bones) of legally harvested fish can help GMRI scientists determine the origin (locally spawned or migratory) of stripers in Maine, information that can improve management of the resource.
Intended audience	Striped bass fishermen and fishing guides
Organizer	Gulf of Maine Research Institute & Coastal Conservation Association of Maine

Website	http://gmri.org/our-work/research/projects/snap-striper-program and http://cca-maine.org/

Name	Tamarisk Coalition
Description	The Tamarisk Coalition (TC) helps people manage invasive plant species and restore riparian areas in habitats where tamarisk could become established. Working with an extensive network of partners, they provide technical assistance, education, and outreach. They run a citizen science data reporting project on the CitSci.org platform.
Intended audience	Volunteers
Organizer	Tamarisk Coalition
Website	http://www.tamariskcoalition.org/ and http://bit.ly/2hAoNtG

Name	Vital Signs
Description	The Vital Signs program provides technology infrastructure, curriculum, how-to guides, and educator professional development to support anyone, but particularly middle school–age youth, in investigating the changing presence and absence of invasive and native species in Maine. Some 60 scientist partners benefit from species observations reported from locations around the state.
Intended audience	Anyone in Maine, with a particular focus on and resources for 7th and 8th grade students and teachers
Organizer	Gulf of Maine Research Institute
Website	http://vitalsignsme.org/

Appendix III: Outcomes and Strategies Tables

This report narrative presents a large number of outcomes, each of which is served by a number of design strategies. The design strategies, in turn, may be used to achieve multiple outcomes. The tables on the following pages summarize the relationship between each outcome and each strategy. Table 1 is organized by outcomes, with an alphabetical list of all the strategies that may be leveraged to achieve each. Table 2 presents the list of strategies, organized alphabetically, with a list of all the outcomes that might be served by each strategy.

Table 1

OUTCOMES	STRATEGIES
Access	Connect to participants' existing interests Gain access to expertise Gain access to locations through partnerships Provide teacher professional development
Community activation	Accept suggestions from participants Offer examples of interesting research questions Support community creation of projects
Data quality and credibility	Constrain data entry Employ reputation- or contribution-based data verification Monitor protocol adherence Publicly recognize participants' contributions Require documentation in support of an observation Support social interaction among participants Train and/or test participants on data collection protocol Verify data or classification
Scale	Connect to participants' existing interests Gain access to locations through partnerships Hold community events to reduce discomfort in nature Minimize barriers to entry Promote participation through publicity Provide multiple entry points to participation, multiple ways to contribute Provide participants with a sense of ownership of their contributions Provide teacher professional development Publicly recognize participants' contributions Show peers participating in citizen science Standardize protocols across projects Support social interaction among participants Use and incorporate existing data sets
Interest in pursuing science	Connect to participants' existing interests Data visualization and analysis Offer student guides and learning resources Provide multiple entry points to participation, multiple ways to contribute Show peers participating in citizen science
Mastery of scientific practices	Data visualization and analysis Offer student guides and learning resources Require documentation in support of an observation Support interaction among science experts and project participants Train and/or test participants on data collection protocol Verify data or classification

OUTCOMES	STRATEGIES
Self-efficacy	Accept suggestions from participants Minimize barriers to entry Offer student guides and learning resources Provide multiple entry points to participation, multiple ways to contribute Provide participants with a sense of ownership of their contributions Publicly recognize participants' contributions Support community creation of projects Support interaction among science experts and project participants Train and/or test participants on data collection protocol Verify data or classification
Stewardship attitude and behavior	Provide information about and/or connection to stewardship actions
Structuring participant activity to support learning	Offer student guides and learning resources Scaffold inquiry steps
Supporting facilitation by teachers or other educators	Offer student guides and learning resources Provide facilitation guides to teachers and educators Provide teacher professional development
Understanding of nature of science	Monitor protocol adherence Offer student guides and learning resources Provide a visual representation of inquiry process Provide teacher professional development Require a peer review or self-check of work Require documentation in support of an observation Scaffold inquiry steps
Understanding of science concepts	Offer student guides and learning resources Overlay an educational task on protocol Provide teacher professional development Support interaction among science experts and project participants

Table 2

STRATEGIES	OUTCOMES
Accept suggestions from participants	Community empowerment Self-efficacy
Connect to participants' existing interests	Access Scale Interest in pursuing science
Constrain data entry	Data quality and credibility
Data visualization and analysis	Interest in pursuing science Mastery of scientific practices
Employ reputation- or contribution-based data verification	Data quality and credibility
Gain access to expertise	Access
Gain access to locations through partnerships	Access Scale
Hold community events to reduce discomfort in nature	Scale
Minimize barriers to entry	Scale Self-efficacy
Monitor protocol adherence	Data quality and credibility Understanding of nature of science
Offer examples of interesting research questions	Community empowerment
Offer student guides and learning resources	Interest in pursuing science Mastery of scientific practices Self-efficacy Structuring participant activity to support learning Supporting facilitation by teachers or other educators Understanding of nature of science Understanding of science concepts
Overlay an educational task on protocol	Understanding of science concepts
Promote participation through publicity	Scale
Provide a visual representation of inquiry process	Understanding of nature of science
Provide facilitation guides to teachers and educators	Supporting facilitation by teachers or other educators
Provide information about and/ or connection to stewardship actions	Stewardship attitude and behavior

STRATEGIES	OUTCOMES
Provide multiple entry points to participation, multiple ways to contribute	Scale Interest in pursuing science Self-efficacy
Provide participants with a sense of ownership of their contributions	Scale Self-efficacy
Provide teacher professional development	Access Scale Supporting facilitation by teachers or other educators Understanding of nature of science Understanding of science concepts
Publicly recognize participants' contributions	Data quality and credibility Scale Self-efficacy
Require a peer review or self-check of work	Understanding of nature of science
Require documentation in support of an observation	Data quality and credibility Mastery of scientific practices Understanding of nature of science
Scaffold inquiry steps	Structuring participant activity to support learning Understanding of nature of science
Show peers participating in citizen science	Scale Interest in pursuing science
Standardize protocols across projects	Scale
Support community creation of projects	Community empowerment Self-efficacy
Support interaction among science experts and project participants	Mastery of scientific practices Self-efficacy Understanding of science concepts
Support social interaction among participants	Data quality and credibility Scale
Train and/or test participants on data collection protocol	Data quality and credibility Mastery of scientific practices Self-efficacy
Use and incorporate existing data sets	Scale
Verify data or classification	Data quality and credibility Mastery of scientific practices Self-efficacy