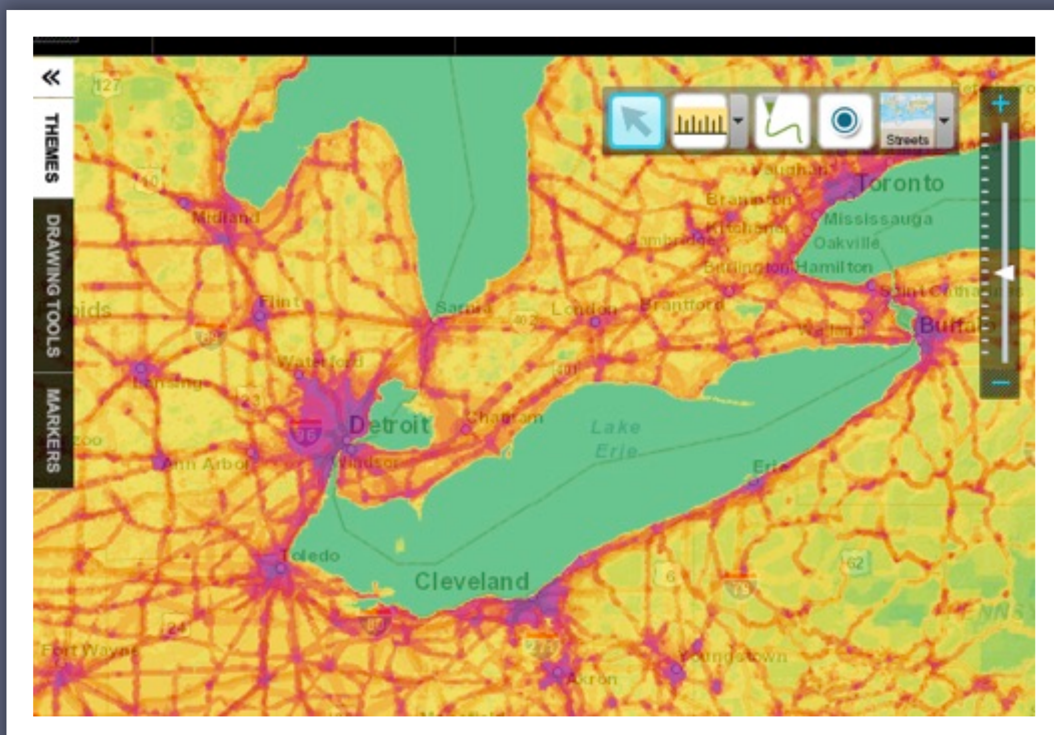
Evaluation of FieldScope



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Evaluation of FieldScope: A Geospatial Collaboratory for Informal Science Education

Over the last decade, the National Geographic Society (NGS) has been developing and supporting FieldScope, a web-based science information portal. Through an interactive mapping platform, citizen scientists have access to a wide range of tools that enable them to document and understand the world around them—both in the classroom and in outdoor settings. Through FieldScope, data can be shared broadly, and FieldScope also includes tools for analyzing and interpreting data. The uniqueness of the ability to overlay data on a geographic mapping tool such as FieldScope helps to identify larger trends and answer important research questions. By 2008, two major citizen science projects were using FieldScope, but the range of tools and the flexibility of projects were limited. NGS sought additional funding to expand the capabilities of FieldScope.

In September 2010, NGS received a award from the National Science Foundation (NSF) under the Informal Science Education (ISE) program. The purpose of this award was to expand the functions and applications of FieldScope. The goal was to create a single, powerful infrastructure for citizen science research projects that any organization could use to create their own project and support their own community of participants. FieldScope enables users to contribute volunteered geographic data collection efforts and share information among both professional and non-professional users. The NSF-funded project was designed to develop and test an enhanced version of the pre-2010 FieldScope application. The project goals included supporting major programming development for a fully functional web-based application that would significantly enhance the usability of the current application. Along with programming new features and capabilities, the project also involved extensive evaluation of the new capabilities and of the impact on three citizen-based organizations that joined as testbed sites.

This paper reports on the findings of those evaluation efforts. It combines data from three different evaluation efforts: that of The Research Group at The Lawrence Hall of Science, University of California, Berkeley, which conducted the evaluation from June 2013 to the project end; PEER Associates, which conducted the evaluation from the beginning to June 2013; and the New Media Consortium, which oversaw the usability components of the evaluation throughout the project.

Introduction

FieldScope was designed to have a major impact on the capabilities and transparencies in the world of citizen science. But what exactly is “citizen science”? Citizen science refers to engaging general public (i.e. non-professionals) in authentic scientific research to generate new scientific knowledge. Citizen science has been around for centuries.

This material is based upon work supported by the National Science Foundation under Grant No. DRL-1010749. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

For example, in feudal Japan (circa 1185-1600 CE), residents recorded the burst of cherry blossoms every spring, and the data were collected and collated by a central authority that used the data to predict not only the growth of cherry blossoms but also the times to plant and reap the harvest.

Recently, technological changes in personal computing, access to the Internet, and smart devices have led to a massive growth in the number of citizen science programs. In the past 20 years, thousands of citizen science projects ranging from astronomy to zoology have sprung up, engaging millions of participants in collecting and /or processing data around world (Bonney, Phillips, Ballard, & Enck, 2015, p.2). There are many new options for individuals to participate in citizen science. Individuals can be trained in person or virtually—through webinars and online courses—in how to collect data. They can use their mobile phones and tablets to collect and organize that data, and they can go online to data collection websites, adding their observations. Crowdsourcing has not only allowed more data points to be collected but has also allowed for a greater geographic distribution of those data. In addition, the ability of mobile devices to geo-locate, so that data can be pin-pointed to precise coordinates, has created a need for a mechanism by which geographical information can be retained and analyzed. This is one of the reasons for the development of the FieldScope project, which will be explored in more detail later.

Many citizen science projects were (and still are) designed for information to be a one-way street—that is, citizens collected data, which were then sent to scientists. In other words, the only practice of science in which non-scientists are involved is data collection. This has led to the criticism of non-transparency, that "scientists control the citizen-collected data" (Bonney et al., 2009; Druschke, & Seltzer, 2012, p.179). In response to this criticism, in recent years increasing numbers of citizen science projects that involve participants in the aspects of data interpretation, data processing, and data analysis have been developed (Raddick et al., 2010; Bonney, Phillips, Ballard, & Enck, 2015). FieldScope aims to provide a platform for engaging non-scientists in all aspects of the practices of science.

There are several reasons to engage non-scientists in more than data collection. First, engaging in the process makes science more real and more accessible. Rather than something that needs to occur in a laboratory, or requires cyclotrons, microscopes, telescopes, spectrometers, or other expensive equipment, science becomes seen as something that happens every day, which is relevant to the local community, and which is connected with the visible world. This is true whether the research is place-based—such as the observations of local frogs and toads—or space-based, such as projects that identify asteroids or seek intelligent life and new civilizations.

Participation in the processes of science also impact people's understanding of and interest in science. From an educational perspective, being part of a geographically dispersed community is part of the motivation to participate in citizen science, and it directly contributes to the achievement of critical learning outcomes about the importance of place and the connectedness of places. The majority of citizen science projects aim to achieve scientific research outcomes while also improving participants' scientific literacy and/or achieving knowledge, attitudinal, and behavioral changes on these participants (Cronje, Rohlinger, Crall, & Newman, 2011; Druschke, & Seltzer, 2012). This was one of the drivers for National Geographic as they designed and implemented the FieldScope project.

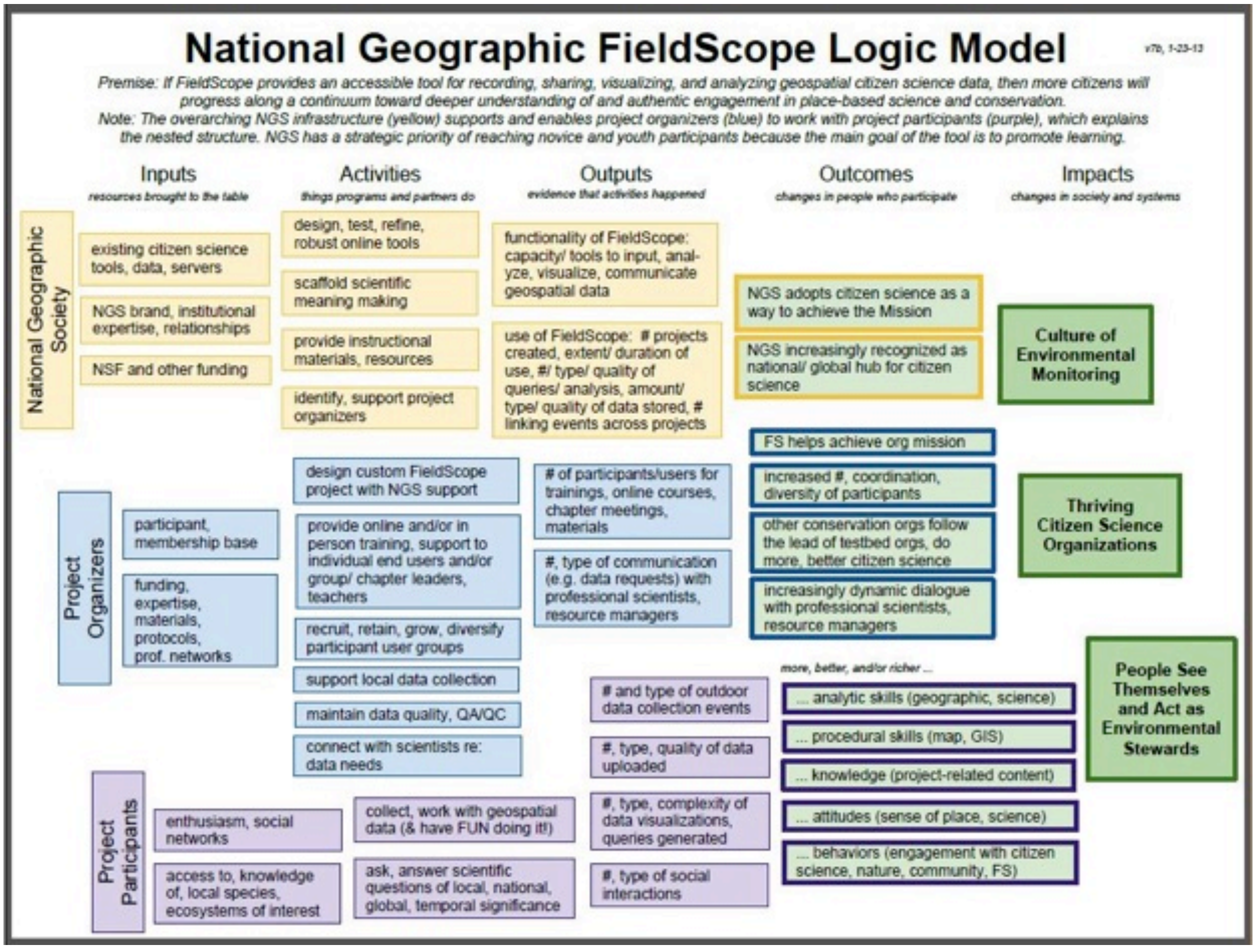
In recent years, compelling arguments have been made for the educational benefits of engaging the public in scientific research through citizen science projects. For example, Bonney et al. (2009) argue that citizen science projects can contribute to four critical science learning outcomes: awareness, knowledge, and/or understanding; engagement or interest; skills; and attitudes and behaviors. Scientific, educational, social, and psychological benefits of citizen science projects are becoming increasingly well documented. However, there has been little published literature that explores the benefits of the public participating in volunteered geographic information projects.

From the perspective of scientific educational benefits, citizen science projects can achieve participant gains in science-based knowledge, practical scientific skills, understanding of scientific methodology, scientific reasoning and scientific process, and awareness of biodiversity and the diversity of scientific research (Cronje, Rohlinger, Crall, & Newman, 2011; Druschke, & Seltzer, 2012; Riesch, Potter, & Davies, 2013; Leong, & Kyle, 2014; Bonney, Phillips, Ballard, & Enck, 2015). Past research also shows that changes are more likely to be detected on participants' ability to act or navigate using scientific or technical methods within real, specific contexts—such as those they encounter in citizen science projects—than those within decontextualized perspectives or situations that are not directly related to their lives or the citizen science projects in which they have participated (Cronje, Rohlinger, Crall, & Newman, 2011).

From the perspective of social and psychological benefits, citizen science projects can contribute positively to participants' social well-being by making an impact on the questions that they are addressing, and through the positive effects of being recognized and appreciated for contributions that might further influence scientific decision-making (Rotman et al., 2012; Bonney, Phillips, Ballard, & Enck, 2015). In addition, research indicates that participants in some environmental-related citizen science projects also report stronger stewardship ethic and a greater desire to contribute to the betterment of society and the environment after the projects (Leong & Kyle, 2014).

Nevertheless, citizen science projects also face many challenges. For example, prioritization, participant retention, and sustainability (particularly maintaining funding and project leadership) are often issues that citizen science projects confront (Dickinson et al., 2012; Sickler, Cherry, Allee, Smyth, & Losey, 2014). In addition, in order to achieve citizen scientists' knowledge, attitudinal and behavior changes, project planners and organizers have to implement a plan by which citizen scientists would actually achieve these goals, and offer citizen scientists opportunities to identify the aims of the research and to inform them why their research matters (Druschke, & Seltzer, 2012).

Figure 1. National Geographic FieldScope Logic Model



The National Geographic Society planned to undertake a large set of activities that, they hoped, would have measureable outcomes and impacts on participants. The initial evaluator helped NGS create this logic model to explore the ideal use of FieldScope in citizen science. The logic model asserted that the new, accessible tools would provide an opportunity for citizen scientists to engage more deeply and more authentically in data. This, in turn, would increase their understanding of the science and conservation. The theoretical assumptions of this approach is that citizen scientists have interest in engaging in data visualizations and analysis, but have not done so in the past primarily because of a dearth of tools. It assumes, too, that access to tools increases the amount and quality of time people spend engaging in citizen science. This report, as a summation of the evaluation efforts, explores the extent to which FieldScope was able to achieve the original goals. It also describes how and why the project goals changed over time as new information emerged, in response to partner needs, and because of the challenges associated with developing the technology.

Project Design

This project was designed to address the need for more systematic research on the educational and organizational impact of citizen science projects. In particular, it tried to address open questions about the design of citizen science projects posed by the National Research Council (NRC) review of informal science learning (Bell et al., 2009), such as "What specific program features are associated with learning outcomes? What kinds of programs or program features support the learning of concepts and facts? "(p.192). It also addressed some of the unanswered research questions posed by recent studies in citizen science, such as "How do people learn through participation in citizen science activities? What is the role that citizen science plays in fostering or supporting lifelong science engagement? How does participation in citizen science influence an individual's perception of their role in science?" (Bonney, Phillips, Ballard, & Enck, 2015, p.12).

The goals articulated in the proposal to the National Science Foundation in 2010 were to:

(1) Create a robust technology infrastructure to serve as a general resource for volunteered geographic information projects for informal science learning of all sizes and descriptions; and
(2) Incorporate tools to support data analysis, the communication of findings, and the social practices of scientific argumentation to enable participants to engage in the full cycle of scientific inquiry.

These goals were based on two assumptions; first, that citizen science projects—especially those with defined education objectives—would benefit from access to a technology infrastructure based in a geographical information system (GIS). The demand for geospatial skills in general, and for people who can use a GIS in particular, is growing worldwide (Gewin, 2004). Geospatial skills include "logic to infer implicit spatial relationships and knowledge from given geospatial facts" (Zhao et al, 2009).

The second assumption is that learning science through the full cycle of inquiry, with opportunities to engage in all the practices of science from asking questions to communicating findings, enables greater and deeper learning. First, FieldScope was envisioned as a repository for the collection, storage and sharing of geospatially-linked citizen science data. In addition, FieldScope was designed to help geospatially-oriented projects citizen science projects engage and support their participants in multiple ways, promoting more data collection and greater use of the data collected.

FieldScope was designed to fill a need to make data interpretation and analysis available to the participants in citizen science projects, which historically have rarely given participants the opportunity to do more than contribute data and view maps. By creating a shared infrastructure that is capable of hosting large numbers of citizen science projects, this project would also create the opportunity for different projects to benefit from each other's data. For example, a project that is monitoring animal species would be able to explore data from another project that is collecting data about habitat in the same geographic area over the same time period. The project was designed to create a shared technology infrastructure that would provide existing citizen science projects the ability to implement various data collection and data visualizations elements.

FieldScope is implemented in a citizen science project through the creation of a custom map that includes the project's required data fields and relevant map layers. The FieldScope development conducted under this award was done in conjunction with three testbed partners to support the needs of these organizations and their participants. Staff at each of the testbed sites worked regularly with NGS staff to ensure that the FieldScope project websites were useful and functioned well. The three testbed partners that participated in the project were:

- **FrogWatch USA** (https://www.aza.org/frogwatch/) is a citizen science program housed within the Association of Zoos and Aquariums (AZA), that, according to its website, "provides individuals, groups, and families with an opportunity to learn about wetlands in their communities and report data on the calls of local frogs and toads." The website reports that "volunteers collect data during evenings from February through August and have been submitting data for over 15 years." FrogWatch USA uses a model where volunteers are organized into chapters, which are run by a local AZA member organization, such as a zoo or park. Chapter coordinators provide training on frog monitoring as well as on use of FieldScope. FrogWatch USA volunteers have been able to view their data through FieldScope for the past three years. After a successful pilot program in six chapters in 2013-2014, all participants and/or their chapter coordinators now enter and access their data directly through FieldScope, which also provides mapping and analysis tools. Since the FrogWatch USA program moved to AZA approximately ten years ago, volunteers had recorded their data on paper forms, which were then transferred, at first to AZA headquarters and then, as the chapter model was implemented, to the chapter coordinators. FieldScope has provided FrogWatch USA with more timely data, greater quality control, and a platform for accessing and analyzing 18 years worth of data (1998 to 2015).
- **Project BudBurst** (http://budburst.org/), which is now housed at the National Ecological Observatory Network (NEON), was established in 2007 with the goal to "get you outside taking a moment to observe how plants in your community change with the seasons." Their mission statement captures outcomes of their citizen science program: "When you share your observations with us, they become part of an ecological record. Spending time outside with plants is calming, educational, and just plain fun." Project BudBurst participants enter their data on the Project BudBurst site, and these data are then duplicated to FieldScope. Data are available for download from Project BudBurst, and a variety of visualizations can be found on FieldScope. Although some data visualizations are available on the Project BudBurst website, the organization wanted a robust mapping tool where data could be accessed and analyzed.
- **Trash Free Potomac** (http://fergusonfoundation.org/trash-free-potomac-watershed-initiative/). In 2005, the Alice Ferguson Foundation (AFF) started the Trash Free Potomac (TFP) Watershed Initiative as a solution to the ongoing

problem of trash in the Potomac watershed. The initiative was designed to provide a forum where leaders, businesses, organization, and citizens would come together to solve this problem. Per their website, the Initiative "includes annual Potomac River Watershed Cleanup and Potomac Watershed Trash Summit, as well as a strategic framework with five core components including public education, policy, regulation, enforcement, and market-based approaches." The individuals who lead different clean-up events upload their data to an AFF website, and these data are then duplicated in FieldScope, where they are available to other users and the general public. AFF adopted FieldScope because it allowed for easy data visualization and could be used for data quality assessment, advocacy, and information sharing.

In addition to the national testbed partners, FieldScope is being used, or has been used, by a number of other citizen science projects including the Chesapeake and Delaware Bays and the Great Lakes water quality projects, Maryland Green Schools and NatureBridge in the Olympic National Park.

Given the number of citizen science projects that could benefit from FieldScope, seven currently-existing citizen science projects were asked to pilot test the "**Project Builder Tools**." These tools were designed to provide non-technical educators and scientists the ability to create customized projects through a visual interface, allowing community conveners to build FieldScope projects themselves.

More details about each of these programs are available on their websites or in the FieldScope Program final program report.

About the Evaluation

The main focus of this evaluation was on the impact of FieldScope on the testbed partner organizations and on the participants themselves. The main evaluation questions were divided into two main groups: 1) Impact on Organizations and 2) Impact on Individual Participants. The complete set of evaluation questions, along with a deeper description of the evaluation, is included in Appendix A. The main questions were:

1. *What are the impacts of FieldScope on the partner/testbed organizations*? Does FieldScope impact recruitment and retention? Improve quality and/or quantity of data collected? Engage participants more deeply in the mission of the organization?
2. *What are the impacts of FieldScope on individual participants*? Do they collect more data? Engage more in data analysis or sharing? What are their learning outcomes? How does using FieldScope impact their attitudes towards science or the environment?

In order to address these questions, the evaluators conducted a wide range of different data collection events, ranging from observation to interview. The main data collection methods included:

1. Engagement in Partner Meetings, with a focus on listening and recording the conversation as well as gathering feedback on the evaluation design.
2. Surveys of all participants, including:
    a. Project BudBurst users
    b. Project BudBurst Citizen Science Academy Course # 502 Participants
    c. Trash Free Potomac Event Leaders
    d. FrogWatch USA chapter coordinators and volunteers
3. Observations of FrogWatch USA chapter coordinator training programs
4. Interviews with:
    a. Project leads at testbed partners
    b. Project BudBurst Citizen Science Academy Course # 502 Participants
    c. Trash Free Potomac Event Leaders
    d. FrogWatch USA chapter leaders
    e. Project Builder Tool Users
5. Data analytics from FieldScope logs and Google Analytics

All of these data contributed to this analysis. The evaluation is described in more detail in Appendix A.

Findings

Impact on Organizations

The evaluation focused on the impact at the organizational level for the testbed sites. How did they benefit from being partners? Did they recruit more (and a more diverse) audience? Did the quality of their data improve? Were they able to better communicate with the public about geographically related matters? Through interviews and surveys (see Appendix A), the evaluation studied these matters in some detail.

Project BudBurst: Using Authentic Data in Educational Settings

For Project BudBurst (PBB), two products were the main outcomes that resulted from their participation in the FieldScope. First, through the NSF award, PBB was able to collaborate with National Geographic on the creation of two new data display web pages, one focusing on exploration (FS Data Discovery) and the other on learning about seasonality (FS Seasonality Tool). Through the data discovery page, individuals can explore and experiment with PBB data. Several videos were created to help guide people through this process. For example, one focuses on how to accomplish certain tasks (such adding base layers or seeing more data available for a particular observation).

Second, through the NSF award, PBB has been able to create a new course for their Citizen Science Academy focused on helping educators use PBB data and FieldScope in the classroom. Project BudBurst intends to continue to offer the course and materials to teachers after the expiration of the award. In addition, they plan to “deconstruct” the course, to put it in a more modular form, so that teachers can access stand-alone units. Project BudBurst recognizes the value of learning about the materials through a facilitated course, with access to a cohort of other teachers, but also realizes that there might be more widespread use if the materials can be understood and used as stand-alone content. While no timeline has yet been set for this work, information gathered from how teachers are using the materials from the course may provide insights to how the course can be deconstructed. Further information about the outcomes from using the Project BudBurst materials is described in greater detail in the section of this report entitled “Impact on Project BudBurst users.”

Frog Watch USA: A Platform for Engaging New Users

FrogWatch has been able to leverage its involvement in this award to expand its geographic reach and train additional coordinators. The number of FrogWatch USA chapters has grown steadily over the life of the award (31 prior to the award; 53 at the end of Year 2, 85 at the end of Year 3, and116 at the end of Year 4) and has now reached 130 chapters in 40 states and the District of Columbia (2015 Annual Report to NSF). From a recent survey of new chapter coordinators, who are, by design, usually professionals in a zoo or other institutional setting, we can see that most are well educated: of the 85 individuals who allowed their demographic data to be shared, most have completed four-year college degree as their highest level of education (49%) while 33% hold a Master’s and 11% hold a Doctorate. Seventy percent are female, and over 90% are white, non-Hispanic (FrogWatch, Coordinator Training Satisfaction Feedback Survey, 2015).

FrogWatch has reported increases in the number of observations. According to their 2014 annual report, by the end of 2014 monitoring season (August 31), there were more than 116 chapters that monitored almost 850 sites and reported more than 12,400 species observations through FieldScope. The number of sites monitored was almost double the number of sites monitored in 2013.

Another major impact on FrogWatch has been improved data quality. The parameters set by FieldScope ensure that participants are not entering out-of-range data. Participants also report paying closer attention to the data collection protocol (see Impact on Individuals below). Although not specifically attributable to FieldScope, FrogWatch reports, “the annual percentage of volunteer adherence to the FrogWatch USA monitoring protocol (e.g., listening for three minutes at least 30 minutes post sunset) had increased from an annual rate of 49%-74.8% between 1999 and 2009 to 92.3-96.8% since the chapter model was established in 2010.”

FrogWatch, prior to FieldScope, identified a lack of “negative data”—that is, participants were not reporting the times they visited their locations but did not hear any frogs. FrogWatch has seen an increase in the number of reports of “negative data,” which has improved the quality of data available.

Trash-Free Potomac: Transparency and Advocacy

Trash-Free Potomac has a separate data entry site, but the organization uses FieldScope to display and visualize data. While they encourage their event leaders and partners to learn to use the site themselves, staff at the Alice Ferguson Foundation will frequently generate the maps for partners. As one staff member says, “It used to take me three hours to show them how much trash was found at their site; now it takes me three minutes.”

TFP also uses FieldScope for policy monitoring and advocacy. The Environmental Protection Agency (EPA) has identified several watersheds that need rehabilitation, and have been working with the Department of the Environment in Washington, D.C. to use FieldScope to monitor the amount of trash in the identified watersheds. The Department can also monitor types of trash being removed and target interventions based on the data.

In addition to use by the Alice Ferguson Foundation, some of the Trash Free Potomac partner sites have begun to use FieldScope. One local water quality-monitoring site, which functions as an event leader/liaison for TFP, has begun to upload several years’ worth of data to the site. The coordinator for this organization explains, “We finally have this resource to visually show people the work that volunteers have been doing. We send out volunteers to monitor the health of streams throughout the country by looking at the invertebrates that live in the stream bottom. That data gets reported to the state at the end of each year, and it does have some effect on state regulation and enforcement of the clean water act, but again, it’s one of those things where it gets sent off but there’s very little visually evidence of it once it gets sent away. So, a lot of people who do the collection don’t really see the results of their work. FieldScope is really going to help us.”

FieldScope and the Practices of Geography

Impact On Participants

Goals of this project including helping participants learn more about the science behind their selected citizen science project, increasing their environmental awareness, and engaging them more deeply in the practices of science. FieldScope provided the tools for data entry but also for data visualization and analysis. This section explores, for each of the partner organizations, how access to FieldScope changed the ways in which participants engaged in citizen science and how this changed engagement influenced their cognitive, behavioral, and attitudinal outcomes.

FrogWatch Participants

As described above, FrogWatch USA uses a model where volunteers are organized into chapters. The chapters are coordinator by one volunteer, who is often housed at an Association of Zoos and Aquariums member location. In general, these coordinators received training in FieldScope from FrogWatch USA. The chapter coordinators conduct trainings for their local volunteers in identifying frog calls and using the FrogWatch USA protocol. These trainings also include information about how to use FieldScope. Surveys were administered to both volunteers and chapter coordinators. In addition, a small number of chapter coordinators who participated in a pilot of FieldScope were interviewed in 2013 and 2014.

Volunteers

FrogWatch has also used the award to extend its reach to more volunteers. Over 150 training sessions were offered, reaching potential volunteers of all ages and varying backgrounds. Several chapters offered sessions geared specifically to school-aged audiences and families, as well as group field trips (2015 Annual Report to NSF).

Increased use of data

FieldScope has simplified the data entry process for FrogWatch volunteers. According to one volunteer, "The program has greatly simplified data entry and is accessible to volunteers with little computer experience." Another volunteer shared praise for the system and ideas for future implementation: "FieldScope makes it much easier to enter data. Before FieldScope, I filled out a data sheet with a pen in the field, then I had to scan and email that sheet to my chapter coordinator. Now, I can enter it myself, though I still have to transcribe data from the field to an online platform. Ideally, I would like to fill out a data sheet online as I collect data, in one step. "

This simplified data entry process also resulted in increased use of data. On the survey, volunteers were asked about whether they have engaged in five different FrogWatch-related activities, and how frequently they have engaged in these five activities before and after using FieldScope (Figure 2). After using FieldScope, the volunteers reported higher engagement in data collection in the field, entering data in any computer or online system, data analysis, and mapping data, although there is a drop of engagement in sharing data or findings with others. (One possible reason for this decrease in the number who "shared data" is that volunteers are counting the times they provided data—through email or written documents—with chapter coordinators as "sharing", which they no longer do since the advent of FieldScope.)

Figure 2. Volunteers' Engagement in FrogWatch Activities Before and After Using FieldScope

	% engaged with activity		**Average score**[1]	
	Before	After	Before	After
a. Collected data in the field (n=132)	77%	98%	2.35	2.98
b. Entered data into any computer or online system (n=128)	62%	91%	1.78	2.61
c. Analyzed data (n=113)	25%	43%	0.56	0.78
d. Shared data or findings with others (n=115)	48%	30%	1.15	0.69
e. Mapped data (n=114)	29%	47%	0.68	0.97

[1] Measured by a scale of 0-4, where 0="I have never done this", 1= "Once a field season or less", 2="Once every few months", 3="1-3 times a month", and 4="At least once a week"

Figure 3. FrogWatch training

Many volunteers reported that FieldScope has also made it easier for them to access and download data for purposes such as exploring, teaching, and preparing reports and presentations. For instance, volunteers mentioned, "FieldScope is an excellent teaching resource (secondary research data)," and "I used FieldScope to download data from my sites in the Gateway National Recreation Area and provided this data in a report, [and] also used the mapping."

Volunteers also reported that FieldScope has helped them to conduct data analysis and to map data. Some volunteers mentioned that these data analyses allowed them to study more about the frogs in their areas. For example, in open-ended survey responses, a volunteer shared that "I have mapped data for my state to see where volunteers are monitoring, and which species they have found," and "I have used filters to look at temporal and spatial trends among frog/toad species in my area." Other volunteers mentioned that the analysis and mapping functions in FieldScope allowed them to compare their findings in different regions across the U.S. One volunteer shared "FieldScope provides an easy access view of frog populations across the nation," and "I have used FieldScope to explore frog findings in other parts of the country out of personal interest and curiosity."

While the volunteers overall liked to map data and use or create visualizations, they also mentioned they hope to receive more training on how to use maps and graphs, and conduct data analysis. For example, one shared, "I would like to have a more involved tutorial with the other functions of FieldScope besides just data at the AZA trainings. Maybe after the introductory training, another more in-depth training in use of FieldScope mapping and graphing could be offered." Another said, "Now that I see there are so many more possibilities on my end to use the data for community education then I would like more information on a Webinar or class specific to FieldScope." Another stated, "I'd like to be able to sort/filter/map/graph the data all sorts of ways—just for my education and interest—but it's very difficult to figure out how to do this." In addition, some of the volunteers expressed that they hoped FieldScope could be more user-friendly for data analysis. According to one volunteer, "FieldScope is relatively easy to use to enter data, but is confusing to review data and very difficult to analyze data." Another volunteer indicated that "FieldScope has a lot of good uses, but is not easy to use."

More connected to FrogWatch

In addition to the increased use of data, the volunteers surveyed felt more connected to FrogWatch after using FieldScope. Volunteers generally agreed that FieldScope increased their program involvement by providing them the big picture. They felt like they were actually contributing to FrogWatch because they were able to see their data entered

Figure 4. Learning about frogs

in the system immediately (immediacy seems to be a key). For example, one volunteer shared that "The entry method is reliable and gives more confidence that the data has been received and logged. It's greatly improved over the old method."

Volunteers also increased their sense of belonging to FrogWatch through knowing that their data will be further processed and analyzed by scientists, and being able to see the data entered by other volunteers. According to one volunteer, "it does make you feel more involved when you can see everyone else's data." Another volunteer mentioned, "It gives a bigger picture to the program I am contributing to. In turn makes me feel I'm part of a big program that will and can make a difference in the science field."

Increased content knowledge about frogs and science

Some volunteers reported that they learned about frogs and science through their participation in FrogWatch, but it is difficult to parse how FieldScope has contributed to this learning. A few volunteers, however, were able to identify ways in which FieldScope contributed to their learning. For example, one volunteer shared that, by being able to see —visually—how frog populations are distributed, "It [FieldScope] has allowed me to get a broader knowledge of frog populations, user participation, and keep informed on what's happening in the frog world."

Attitudes toward environment and stewardship change

In addition, FieldScope has made a positive impact on participants' attitudes towards the environment and stewardship. Over 29% of participants indicated that their interest in stewardship or protecting the environment has been increased after they used FieldScope (with the other respondents indicating "no change"). While the survey didn't specifically ask more about volunteers' attitudes toward environment and stewardship change, one respondent reflected that "It has made me aware that if there are issues with frogs in the community that there may be issues with our local environment: soil, water, etc." when answering the survey question "How have you used FieldScope to ask questions and explore answers related to frogs and toads in the U.S.?"

Chapter Coordinators

Chapter coordinators usually used FieldScope for the purposes of rechecking the data that volunteers have entered, conducting data analysis to figure out the trend behind the data, and developing calling calendars (an important aspect of frog observations) for future training and presentations. Of those who have been engaged in FrogWatch USA since before the advent of FieldScope, chapter coordinators report more frequent data collection, data entry, data analysis, and mapping of data. In addition, a greater percentage of chapter coordinators engage in these activities after the implementation of FieldScope than before (see Figure 5). Interestingly, chapter coordinators also report a decrease in "sharing data" with others. As with volunteers, we believe that coordinators are counting the times they provided data – through email or written documents—with FrogWatch USA national offices as sharing data. As they no longer need to send the data to the national offices, they no longer report "sharing data."

Figure 5. Chapter Coordinators' Engagement in FrogWatch Activities Before and After Using FieldScope

	% engaged in this activity		Average score[2]	
	Before FS	After FS	Before	After
a. Collected data in the field	76%	91%	2.18	2.39
b. Entered data into any computer or online system (n=32)	69%	91%	1.63	2.09
c. Analyzed data (n=34)	53%	79%	1.21	1.44
d. Shared data or findings with others (n=33)	73%	58%	1.49	0.94
e. Mapped data (n=34)	38%	85%	0.68	1.50

FieldScope has made it more convenient and efficient for chapter coordinators to recheck volunteers' data entries. According to one chapter coordinator, "FieldScope is very easy to input data and analyze the data new volunteers/citizen scientists input. It's easier for me, as a chapter coordinator, to catch mistakes and help guide the volunteers." Other coordinators shared that "We are extremely time-limited at my site, and try to find ways to streamline our data entry. FieldScope is easy to use and it prevents mistakes" and "FieldScope creates less work for chapter coordinator to recheck volunteer's entries."

Chapter coordinators also mentioned they enjoy using FieldScope for analyzing data, especially to create graphs and charts, determining the trends of the data based on a certain period of time, and comparing the data to other sites in the region. For example, chapter coordinators shared that "FieldScope offered a great way to visualize data and compare to other sites in [the] region" and "It has been a very user-friendly system for recording and analyzing the data. The first season I entered all of the data myself but this season I have trained the volunteers on how to do it. I love having all of the data in one place and being able to determine trends, if any, over the course of our two years' worth of data."

Additionally, FieldScope is a handy tool for chapter coordinators to develop calendars recording frog calls ("calling calendars"), and to prepare other materials for training sessions and presentations. Chapter coordinators mentioned "I have looked at historic call data in FieldScope to develop a more localized 'call calendar' for both volunteer trainings and for outside presentations," and "FieldScope gives me a quick way to enter data and has become a great educational tool during training sessions." Another chapter coordinator also mentioned that "I have used it in my training sessions, show frog distribution in our area and how it can change seasonally."

Impact on Project BudBurst Users

[2] Measured by a scale of 0-4, where 0="I have never done this", 1= "Once a field season or less", 2="Once every few months", 3="1-3 times a month", and 4="At least once a week"

Project BudBurst (PBB) reaches a wide range of users, not all of whom are also users of FieldScope. Through Project BudBurst's Citizen Science Academy, the organization reaches a large number of educators—in both formal and informal settings—who engage in science learning experiences for learners of all ages. This section describes benefits for educators as well as for Project BudBurst users in general.

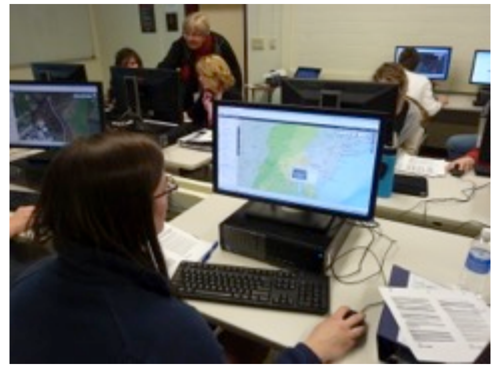


Figure 6. Using FieldScope in the classroom

Project BudBurst Educators

As part of their involvement with FieldScope, Project BudBurst developed a course for their "Citizen Science Academy"—an online series of professional learning experiences for both formal and informal educators. The course, ("Using Project BudBurst Data for Advanced Analysis and Visualization") was, according to BudBurst materials, "designed for both K-12 educators and informal educators. It provides educators with both the tools needed to use Project BudBurst data in an educational setting and also with more detailed background with respect to plant phenology, physiology and the influences of climate change on plants." Unit 3 of the course focused on using FieldScope in the classroom. In this unit, participants learned "how to create a basic map for your area, highlighting Project BudBurst observations, how to add different data layers to their map, and how to export and share their map with others."

Project BudBurst began to develop the course materials in 2012, while FieldScope was in Version 4. The final materials support both Version 4 and Version 5. The course materials include three units in a self-study session, which is monitored by an instructor. Five different videos are also available online, which explain how to use FieldScope in general, and several tools in particular, in more detail. The course was launched in 2013, and the current set of materials was published in April 2014. To date (September 2015), 85 educators have completed the course. The course materials have been downloaded 1,878 times, and the FieldScope pages on PBB have received over 5,000 views since January 2013.

Figure 7. Students recording data for FrogWatch

Using FieldScope in an educational setting

FieldScope provides the opportunity for educators to use project-based learning tools, incorporating authentic data and real issues. In order to learn more about how educators use FieldScope, we conducted a series of interviews, and educators were surveyed at the end of the project. (See Appendix A for more details about the evaluation plan.) Because of the timing of when FieldScope came online and when educators obtained training, few had begun to use FieldScope with their students at the time they were surveyed. Of the educators who were interviewed, all intended to use FieldScope with students—and they provided a wide range of ways in which they intended to use it. Educators also tended to believe that, if they could find the time within their curriculum, it would not require extensive effort on their part to incorporate the materials. Teachers indicated that FieldScope "has many classroom applications, and is very user-friendly, so is something that can be incorporated into my classroom without a huge time investment."

Educators also believe that the design of FieldScope will help students engage in the practices of science and geography. One educator said, "The FieldScope activities are interactive, which allows a good bit of inquiry." Another felt that the combination of ease of use and mapping would benefit students, saying, "I'm excited to try and use this technology with my students. I think they will find it easy to use and that it will lead to a lot of great human impact on the environment questions."

Educators also use FieldScope to encourage their students to get outdoors and into nature. For example, one alternative high school has developed a course called "Interacting with Nature" where the goal is to help students think about their natural environment, become aware of their surroundings, and grow more interested in what is happening in nature. The teacher believes that FieldScope benefits students because students can see the connection to previous lessons and their local environment. The teacher says, "It's hard to get them engaged with things. I can definitely integrate FieldScope activities into actual lessons that we're doing, and what it does is it makes the connections to the local environment, which I think has a potential to engage them a little bit more because they're more familiar with this area and they can say yeah, I've seen that tree before. I want to make them more aware of things in their own environment, in the world around them."

In the projects, students receive the opportunity to work with authentic data. It is one thing to ask students to review data that have been cleaned and polished—or invented—for the sake of a hypothetical problem. It is another thing entirely to ask students to use authentic data. Educators can address many standards and learning goals surrounding data use, such as quality of data, limitations based on data collection, analyzing and interpreting data using visualization tools. One educator believed that FieldScope can be useful for preparing students for both real-life activities as well as standardized tests, saying, "A lot of times on the test that the students have to take, they need to be able to read and interpret graphs, you know, it'd be cool to have some authentic data for them to look at."

When using FieldScope, students are also able to collect data themselves, and see that "their" data are available to others for analysis. The process is not only engaging for students, but it can help students think like scientists and understand the processes of science. One educator, who had not yet used FieldScope said, "I'm also hoping that the science process skills, that they will be thinking like scientists, and using this content, and models, and this process for a way for us to be scientists." Being engaged in the process of collecting data is useful for students to expand their concept of what scientists do. Another educator said, "We're trying to find more websites like that that kids can see scientists doing real data, because they don't realize that scientists are actually out in the field doing data like that, and then taking it and doing something with it. I think they think scientists just all sit in a lab and mix beakers all day long." As more states and districts adopt the *Next Generation Science Standards (*NRC 2011*)*, which include standards about understanding and engaging in the practices of science, the demand for access to authentic data should increase.

The fact that the authentic data are used to drive discussion of authentic problems is a major benefit. One educator said, “It’s really cool that I am able to look and compare what’s happening now versus looking back to what the plants were like in the past. I think that connection to real world issues is very interesting.” Students may have difficulty comprehending global climate change, but they can see or sense it at their local level, and they can use FieldScope to understand how the data reflect the changes they see around them, or how data may demonstrate long-term changes that students are too young or otherwise not able to sense. An educator said that FieldScope helps students “understand the impact that climate change might have on a local level with something that they’re familiar with, as opposed to speaking in general terms about global changes.”

Finally, the process of using FieldScope also helps students see the connection between maps and models and the real world. One educator plans to have students expand the maps while they are out in the community. She takes her students to a nearby park to complete their BudBurst observations. Along the way, she will have them add their own landmarks, such as their favorite ice cream shop, so that they can see how the map models reality. She says, “I see a combination of, ‘We’re doing our maps online, but we’re also just walking outside, we’re walking through that same place that we’re seeing on our map’. So that’s how we would be adding that information. And so you know, okay, let’s make these maps that are of this area that we are familiar with.”

Challenges and Concerns

Although all of the educators we interviewed, and those who returned the survey, intended to use FieldScope with students, some expressed their concerns about FieldScope.

Educators varied on their assessment of the **appropriate age** level of users. While many of those who responded did not feel that FieldScope was appropriate for elementary schools, others felt that, with the right scaffolding, the program could be used with young students. However, the examples of how educators intended to use FieldScope with elementary-aged students were very educator-centered. One educator, who works with second graders, planned to demonstrate use to students: “I was going to show them how maybe some friends down in Denver snap me some photos of plants and trees around their neighborhood, so we could compare them as well. So they can see them on the map, they could see what the plants are doing at that time of the year at lower elevation on the map, and they could actually see real photos.” That said, another elementary teacher, who had not yet used FieldScope with her students, identified ways to make the tool more student-centric: “I think that FieldScope is a really appropriate way to use technology as a tool, and to allow the kids to really interact with technology in a great way. It’s not like playing a game or something like that that I don’t value as much.” One educator felt that students might be more motivated to persevere through challenges when they were contributing to a larger project: “If there was a particular project, if [students] had ownership of being responsible for data or results at the end of the year, it would make it a big deal."

Teachers were more divided about whether FieldScope is developmentally appropriate for middle school students. Teachers appreciated the possibility to use FieldScope for project-based learning, but some questioned the extent to which students would be able to understand the scope and reach of the technology. One educator, who works with middle school students, said, "My kids are highly motivated by project-based learning and by being outdoors. Some of them are super computer savvy and could probably do this better than I could. But I think it is a little difficult at the middle school level. I think they can appreciate the output. I think they can appreciate the end result but asking them, even as a team, to manipulate some of this data and to assign different filters and to make decisions about how the data should be presented is expecting too much for them to do independently." Educators wondered if students should be given instructions about what steps to take, rather than explore the possibilities themselves. One said, "I think, even if you had step by step instructions, so like 'add this layer, now change this input,' I think it would make it a confusing, frustrating computer assignment." This connects to the larger question of what it takes to learn how to use a GIS—are there developmental stages? Is there a standard learning progression, and, if so, what is it? How can instruction help a learner gain the technological skills and the geographic skills simultaneously?

A few educators expressed concern about the limited data for some elements or fields. One said, "FieldScope was a little tricky, mostly because I was never able to get it to complete loading at home, or in school when the students were here. Also, while there was interesting data on that site it did not look as though it went back very far for some of the settings." Another said, "I do not know what I think of the data on the FieldScope tool yet. I think that is because it is newer and does not have enough data to compare and contrast with yet." Again, an educator felt, "Most frustrating was the FieldScope mapping. Hard to get to sort data and at times has limited data." Some educators explored the data first, to understand where sufficient data were available that would help meet their or their students' needs.

Educators were also divided about whether FieldScope seemed to be **anathema to the goal of getting students out of doors**. One said, FieldScope "also makes it one step removed from when we were observing trees." She stressed that her goal was to get students away from computers and screens and to enjoy the outdoors. If they felt that if the purpose of going out of doors was to later come back and sit at a computer, they might miss the joys of being in nature. Another teacher, who worked with a small set of students in an informal setting, said that her students joined her program to be outdoors, doing things with their hands. She felt that they were not interested in translating that to computer work.

Figure 8. Students collecting data outdoors for FrogWatch

On the other hand, another teacher felt that FieldScope was likely to increase the amount of time students spent out of doors. She said, “I can really see them spending more time with their family, contributing data and people do spend more time outdoors.”

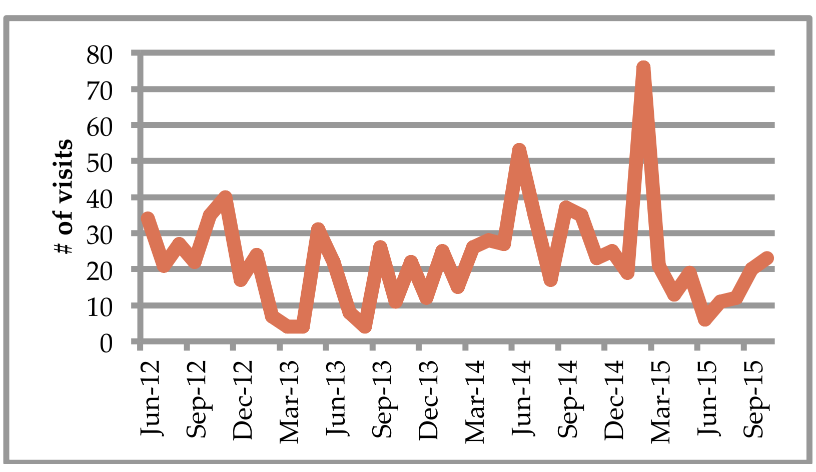
As is frequently the case (Dorph et al, 2011), teachers reported that **lack of time** was one of the biggest barriers they faced in terms of implementing FieldScope. This was particularly true of educators in a formal setting, but it applied to informal educators as well. Some of this lack of time is driven by curricular demands, and some of it by the structure of the school. For example, teachers often have to schedule time in a computer lab, and this might be the only opportunity for all of their students to work on FieldScope together. One teacher expressed the barrier thusly: “In our school district, the computer lab time is structured, and you could go there if there’s a curriculum that they’re going through. They don’t have free time to just work on projects like this.”

Related to the limited time, some teachers reported **limited access to technology**. In some cases teachers only have access to the Internet when in the computer lab at school, and that time is limited and often highly structured. One teacher exemplified this by explaining that even if they are allowed to work on outside projects, “any time in the classroom where a new technology piece is involved is… it’s kind of a stressful day. All 20 students ask questions at once, and if the technology isn’t working, and you press that button and it goes somewhere else… it’s always difficult.” This teacher tries to alleviate the stress by bringing in parents to help facilitate, but that requires training parents on FieldScope before they can help. Another teacher tries to resolve this problem by dividing her class into small groups, but this takes a lot of coordination and additional transition time.

Project BudBurst All Users

Project BudBurst (PBB) participants are not required to use FieldScope. They enter the data they collect on the PBB website, and then those data are synced with the FieldScope maps. Participants can view data (theirs and others) on either the PBB or the FieldScope websites. Because of this, it is difficult to track the number of individuals who have used the PBB FieldScope maps. Analytics indicate that the PBB FieldScope website has had at least 938 separate visits from 283 different cities from 38 counties around the world. In general, we see an upsurge of activity at the start of the school year and again in spring. This corresponds with the months (April and October) when the number of annual observations tends to peak (per Project BudBurst 2014 and 2013 data).

Figure 9. Number of visits per month to FS PBB websites



Note that peak activity in February 2015 came from 60+ different IP addresses on the same day from a university in Texas.

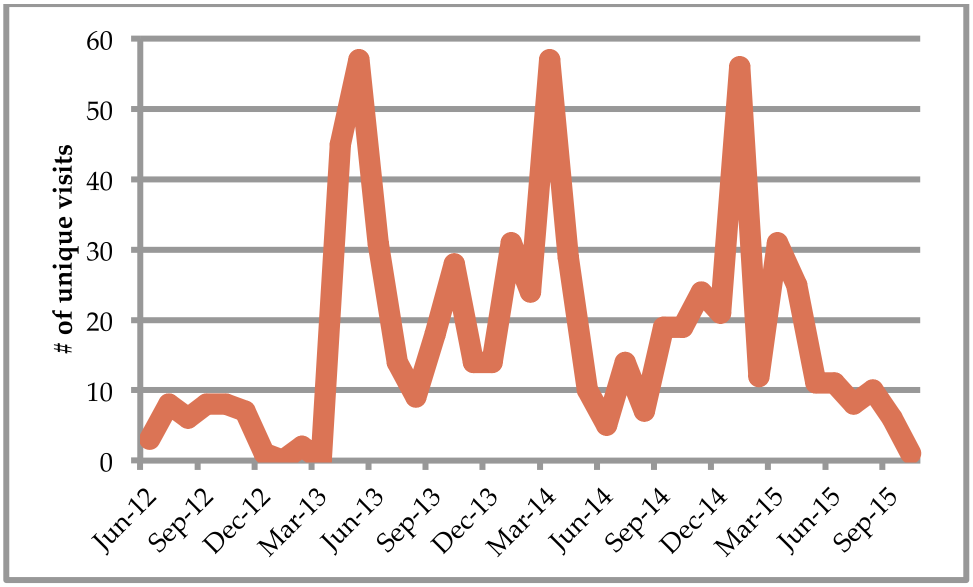
Figure 10. Testing water quality

The amount of data collected by Project BudBurst volunteers had increased during its time with FieldScope, although it would be difficult to attribute this change to FieldScope. In 2012, just over 3500 observations were recorded. In 2013, that number had risen to 6100 observations. In 2014, over 16,000 observations were recorded.

Impact on TFP Event Leaders

The Trash Free Potomac FieldScope site has seen activity since June 2012. Since that time, it has been visited by 276 different IP addresses. This tells us little about the number of individual users. We can also see that the viewers came from 107 different cities. By combining the unique dates and unique IP addresses, we can get an approximation of the number of “visits” to the TFP FieldScope site. We identified 704 separate visits, with most visitors visiting only one or two times. Not surprisingly, these visits peak around Trash Free Potomac’s April Clean-Up Event (see Figure 11).

Figure 11. Number of visits per month to TFP FieldScope site



Impact of Project Builder Tools

The Project Builder Tools were created to help sites build out their own FieldScope projects. As part of the NSF award, seven projects participated as pilot sites for the Project Builder Tools. Most of the sites had been involved in citizen science prior to joining with National Geographic. They began to participate because they were searching for new ways to display data collected by volunteers. Others were launching new citizen science projects and were looking for educational tools.

Several challenges were mentioned by multiple projects. One of the main ones was the **lack of flexibility** for data entry. As one partner said, "A lot of the data that we collected, we couldn't enter into FieldScope because there was no field for it. Even for some of the fields that existed, we had to have the ranges or units changed. It would be helpful if there was some process where you go like, 'Oh, okay I don't have this field' and just propose a category and get it approved or something like that. So, we have a lot of other metrics that we couldn't put into the system. It was too much of a hassle really to get that updated."

Many of the project builders took the opportunity to allow their students to problem-solve and understand that sometimes, in science, processes and technologies do not work as planned. One said, "I wanted to get the students involved in that process. Yes I know that a lot of them are interested in the sciences and a lot of them are going to go to undergrad and graduate school for something like this… and just getting used to this whole process, like you're going to have to get really used to documenting things."

As part of the interview, project builders were asked to rate the likelihood that they would recommend FieldScope to other citizen science projects. On a scale of 1 to 10, where 10 is "would definitely recommend," the ratings were: 10, 10, 8, 8, 7, 7, 6 (for a

Net Promoter Score of 14%[3]). The reasons respondents rated the likelihood as a 10 were based on a combination of potential and current workability. For example, one person said, “I think that once National Geographic works with these bugs like the browser bugs, the program has the potential for basically any service and science program, not just ours. And, because, so on the user end it’s very easy to use… so the feature works like you’re stepping through step one, step two, step three.” This individual also added that the data available were very useful—you can have hard data such as temperature correlated with pictures for verification. Such tools make FieldScope very useful for data collection.

The only detractor (who gave a rating of 6) said that FieldScope was “too buggy” and s/he was not able to set up the project him/herself. After trying twice, s/he sent the parameters to NGS, where staff were able to create the project. Even then, however, the project did not work properly. However, s/he rated it above a 5, as s/he felt it had great potential, and because of the prestige of NGS. Similarly, the person who rated it a 7 (not a detractor but neutral) said, “I think it’s a great platform, but I think it’s still being developed. I would like to see it be a little bit simpler to use. I think it’s hard to figure it out on your own. You can’t just play with it and figure it out, and I would like to see it there.”

Common Threads Across Projects: New Perspectives on Science and the Environment

There were commonalities of impacts reported by individuals, beyond learning more about a specific science topic (e.g., frogs, watersheds). Participants reported finding or reconnecting with a love of science as well as learning to see the environment around them in different ways, being more observant and more aware. One PBB participants said, “I think it got me excited again, and I discovered a thing to be involved in, to keep my love of science as well as my love of teaching alive, too. So I think to have me excited about something, it helps with that.” Participating in data collection also honed the senses. Another PBB participant reported, “When I was in a different environment, I was down in California in the desert, it really made me think about the environment in a different way. It was a totally new language for me, and I didn’t really know about the plants’ phenology, so suddenly, I could see the world through new eyes and that was really neat.” In addition, a FrogWatch volunteer indicated, “I notice the wildlife around me more often. I am always trying to identify toad species by their mating calls. I have learned a lot about my local environment.”

Moving Forward

This project has yielded significant information about the benefits to both organizations and participants about using an online GIS-based data repository for geographically-distributed data. Some of the information is relevant to the citizen science field more

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[3] In analysis of this item, we adopted groupings introduced by Frederick Reichheld (2003) in his development of the Net Promoter Score. Reichheld asks participants to indicate their likelihood of recommending a company on a 10-point scale. He then groups customers into “promoters” (rated 9 or 10), “passively satisfied” (rated 7 or 8), and “detractors” (rated 1-6). Scores range from -100% to 100%. Consensus in the field considers a positive net promoter score (i.e., above 0%) a good score; above 50% is considered excellent.

broadly, and in some cases, more research would improve our understanding. This section explores what we have learned and what else we would like to know and understand.

What the Field Needs to Know about Training

Overall we found little difference in how training affects individual's reported behavior. The key to this finding is that there may be no "right" way to train participants. Some users learn better via online trainings, where they can rewind and re-listen to instructions. Others learn better through in-person trainings, where they can ask questions or follow along on their own computer. Still others feel the need to "work it out for themselves"—trying different buttons, layers and approaches. The distribution of different learning modalities is one indication that people may find the modality that suits them best if they are presented with a range of options. Of those who reported their training modality (n=267), 41% said they trained themselves (e.g., through trial and error), 40% said they received in-person training, and the remaining 19% said they were trained through the use of online documentation.

Participants' data activities before using FieldScope vary by their GIS background. The participants who are GIS experts clearly have the highest ratings for each of the data activities. As participants' reported familiarity with GIS goes down, there is a pattern of decreasing frequency in each of the data activities.

Figure 12. Relationship between GIS background and data activities before using FieldScope on a scale of 1 to 5, with 5=at least once a week; 3=every few months; and 0=I have never done this.

GIS Background	I am a GIS expert (n=8)	I have good familiarity with GIS (n=56)	I am somewhat familiar with GIS (n=80)	I know little about GIS (n=91)	I have never heard of GIS before (n=37)
Collected data	3.00	2.24	2.61	2.13	2.00
Entered data	3.00	1.70	1.78	1.61	1.81
Analyzed data	1.67	1.00	0.75	0.73	0.38
Shared data	2.25	1.44	1.25	0.91	1.20
Mapped data	1.33	1.02	0.76	0.46	0.50

After the participants were introduced to FieldScope, participants who are more familiar with GIS were still more likely to analyze data using FieldScope. However, such a pattern does not exist for other activities. For example, participants who have never heard of GIS reported sharing data more frequently than those who are somewhat familiar with GIS, participants who know little about GIS reported that they collect data and enter data frequently, and participants who have good familiarity with GIS reported that they map data frequently. What is interesting to note is that some participants only reported "sharing" their data when they handed it on paper to someone and did not see inputting the data online as promoting even wider sharing.

Figure 13. Relationship between GIS background and data activities after using FieldScope

GIS Background	I am a GIS expert (n=8)	I have good familiarity with GIS (n=56)	I am somewhat familiar with GIS (n=80)	I know little about GIS (n=91)	I have never heard of GIS before (n=37)
Collected data	2.67	2.94	2.87	2.95	2.82
Entered data	2.50	2.65	2.41	2.70	2.56
Analyzed data	1.60	1.40	0.85	0.69	0.53
Shared data	1.40	1.00	0.45	0.59	0.80
Mapped data	1.33	1.43	0.95	0.88	0.69

Participants who have received online training reported analyzing data in FieldScope more frequently than those who received training from other modalities (including "figuring it out for themselves"). Participants who have received in-person training tended to use FieldScope more frequently to map data than participants who did not receive in-person training. We suspect that this might be because the in-person training showed the data visualization capabilities of FieldScope more effectively and/or because the social experience encouraged people to explore more. Some of this was echoed in the New Media Consortium's report[4], which found that participants "appreciated working and learning in groups—the social experience of learning and engaging with the FrogWatch tools is important. … The group found the group activities much more helpful than the video tutorials, especially when less technologically savvy people are paired with more technologically advanced people."

Figure 14. Relationship between training modality and FieldScope use

Training Modality	Online documentation (n=47)	In-person training (n=97)	I have taught myself how to use FieldScope (n=103)
Collected data	2.87	2.92	2.90
Entered data	2.92	2.74	2.77
Analyzed data	1.05	0.78	0.92
Shared data	0.79	0.76	0.59
Mapped data	1.01	1.15	0.92

Engaging Students With Real Data – from a middle school honors program

On her morning walk from home to her middle school in rural Virginia, Amelia pauses with her mother to look more closely at weeds growing on a lawn. Five dandelions are her target, clustered together on the southwest corner. In a small notebook, she records the size of the bloom and the number of leaves. She smiles and says, "This one has changed so much since last week." She shows her notebook to her mother, where last week's entry shows a small dandelion with just two small leaves. When she gets to school, she goes to her classroom and logs in on the computer to the Project BudBurst site. She records her findings then returns to the FieldScope web page. Once here, she clicks on buttons to create a map of the United States. On the map are many small leaves, showing where others have found dandelions during the same week.

[4] New Media Consortium conducted the usability study, focusing on h
Their report was submitted separately to the National Geographic Soci

Amelia is one of five middle school students in an honors science program who are members of Project BudBurst. Their teacher, Ms. Williams, discovered Project BudBurst from the county office of education. She and a few colleagues were searching for a program that would allow honors students in a biology course to use authentic data to understand major concepts and ideas, some of which are not covered by the school's standard science curriculum.

Ms. Williams encouraged students to select a plant that they were interested in, and one for which give specimens could be found near their home or school. The teacher then helped the students ensure that sufficient data were collected about those plants by other people around the United States. Students then pursued a series of research questions about the plants – when did they usually bud? How does the timing change by latitude? By altitude? How has it changed over time?

Ms. Williams believes students were very successful in using FieldScope. She says, "My kids struggled at first, but after only a half hour of struggling with the website, they figured it out. They would say, 'Oooh! I found a flower!' They'd figure out what they need to do, and it worked. Students really liked it." Ms. Williams believes that seeing what "real scientists are doing" is one of the key elements. She and the biology department at their school look for websites like FieldScope that allow students to access real data. Students can use those data to analyze and write reports, create projects. FieldScope helps students realize that real scientists are out in the field, collecting data instead of sitting "in a lab and mix beakers all day long." Through FieldScope, students "make that connection that they are out in the field doing observations and stuff like that, and understanding, looking at real data, not looking at 1800s charts and graphs or something, but looking at something that pertains to them in their area or is alive currently."

The school hopes to expand the number of students who use FieldScope. Ms. Williams says, "We've changed our curriculum a little bit and, for next year, the push is for kids to be looking at data and really running data. My colleagues and I will spend some time on the FieldScope website and really look at it. I think the project that I had developed could be all-year long. Students will watch their plants go through fall phases, winter, dormancy, and into spring. Students go outside every month for thirty minutes and just sit in the same spot and record what they see, what's going on with their plants. They get some natural observations. Then they can compare what they found with what other find around the country. It's real data."

What the Field Needs to Know about Classroom Use

The use of GIS software and data in teaching brings many advantages to K-12 classrooms. One of the most popular advantages is that GIS software and data supplements traditional classroom with more hands-on learning, and therefore helps close the gap between understanding a GIS relevant concept and real-world problem solving, as teachers could offer students more concrete examples with the software and data when illustrating a concept (Deadman, Hall, Bain, Elliot, & Dudycha, 2000). More specifically, collaborative, internet-based mapping software supports K-12 education in that such software often focuses on a particular curricular topic or a specific project, and therefore allows students to learn in a richer context with data collection, analysis, and interpretation, as well as extends students' capability to practice problem-driven inquiries (Baker, 2005). In addition, the free, internet-based feature of GIS software also encourages classroom use and help address the biggest barrier of GIS use in K-12 classrooms—lack of time (Baker, 2005), as teachers could use it both in the classroom and before the classroom when preparing teaching, and students could to use it after the classroom as part of the more time-consuming homework (Höhnle, Fögele, Mehren, & Schubert, 2016).

As a free, interactive, internet-based mapping and data collection software (available on Windows, Macintosh, iOS and Andriod platforms), FieldScope has been used in schools for project-based learning, for advanced students, for challenged students, and as supplemental learning. Although finding time and adequate technology might remain to be a challenge, there are good reasons to consider how to engage with FieldScope in the classroom. National Geographic's use of FieldScope with teachers is best described through their work with teachers in a professional development program funded by NOAA.

In 2012, the National Geographic Society received a two-year award from the National Oceanic and Atmospheric Administration (NOAA) that overlapped the 3rd and 4th years of this NSF award. The NOAA award funded professional development for teachers about the Chesapeake Bay and nearby watersheds, how to teach about watersheds, how to conduct stream monitoring; it also provided them with activities to use on fieldtrips with their own students. FieldScope was an integral part of this project with the goal that classes would input their water quality and weather data into FieldScope and use FieldScope for data analysis and visualization. Teachers received 1 to 3 hours of FieldScope training on average.

Approximately half of the teachers who completed feedback surveys used FieldScope in their classrooms by having students work directly with FieldScope, or driving FieldScope for their students. The teachers who successfully used FieldScope with their students reported that it helped their students understand the environmental connections about watersheds, and was a helpful way to incorporate technology. Here are a few examples of how FieldScope was used by these teachers (quotes below come from the feedback surveys of the NOAA work):

- Students searched for their house, and traced the flow of our local creeks to the Susquehanna River and then to the Chesapeake Bay watershed. We also examined the boundaries of the watersheds in our local area.
- We used many layers in FieldScope to look at the history, geography, pollution, population, and major threats to the Chesapeake Bay as well as to look at our area and its contribution to the Bay.
- We completed a number of activities using FieldScope: basic overview of layers; a mapping activity to connect two students (their homes) by water; land use maps and excursion maps of field experience sites; identifying, locating, and labeling the major tributaries, posting water quality data; exploring CBIBS [Chesapeake Bay Interactive Buoy System] in connection with a unit on *What is a Buoy*?
- The FieldScope maps really helped to enhance my students learning and understanding of geo-literacy from both a Social Studies standpoint as well as a Science standpoint."
- I will be able to use that [FieldScope] in many of my courses and it gave me a greater understanding of human interaction with the environment.

While the majority of teachers in this program grasped the GIS concepts and could see the value in it for their students, a significant number did not develop the confidence needed to be willing to use FieldScope with their students. For a GIS novice, a couple of hours of training were not sufficient to build skills and enable them to describe its use to students. We identified several findings about teaching GIS to teachers, although the award period did not allow us to build on the findings to fully understand how to teach about FieldScope:

- Many teachers are not comfortable with technology.
- GIS is not an intuitive set of concepts and teachers need to better understand what a GIS is before they can learn how to use one, even one as user-friendly as FieldScope.
- As with any skill, practice is key. Since many of the workshops were in the late spring, there was too long a gap between training and use in the classroom.
- Online learning of FieldScope was a good starting point but not sufficient to build skills. Guided hands-on training in a workshop setting was more effective.

Another lens through which to evaluate the capabilities of FieldScope is to look at how FieldScope supports learning that is aligned with standards. We will discuss alignment with the Geographic and NGSS.

To address the concern that Americans lack the critical geographic understanding and reasoning skills that will be required for careers and civic life in the 21st century, NSF funded *The Road Map Project*. The goal of this project was to create a "Road Map" for large-scale improvement in K12 geography education. The Road Map defines six Geographic Practices, four of which are directly supported by FieldScope: Acquiring Geographic Information; Organizing Geographic Information; Analyzing Geographic Information; and Answering Questions and Designing Solutions. As a part of the FieldScope award, we developed a Geographic Reasoning Instrument (GRI) to measure change in students who participate in a citizen science-type field experience and then use FieldScope to record and work with their data. For more information about the GRI, please see APPENDIX B: The Geospatial Reasoning Instrument.

The following figure describes how the capabilities of FieldScope support learning the geographic practices within each partner's citizen science program by encouraging question-asking and data analysis and visualization.

Figure 15. How the Partners and Participants Engage with the Practices of Geography

Practice	FrogWatch	Trash Free Potomac	Project BudBurst
Posing Geographic Questions	Learn more about the frogs in their area; compare different regions; figure out the trend behind the data (e.g., population change)	How surface affects run off; where trash is collected; what is the impact of trash bag policies?	How does timing of phenophase vary with altitude? When did brown-down happen ten years ago in different places?
Acquiring Geographic Data	Observations are linked to geographic coordinates	Observations are linked to specific locations, using either standardized location name or geographic coordinates	Observations are linked to geographic coordinates
Organizing Geographic Data	Using functions such as "select base map" and "add a map layer"		
Analyzing Geographic Data	Map data, use satellite image, create graphs and charts		
Answering Geographic Questions	How have species ranges changed over time?	How have policies, such as plastic bag bans, affected trash? How have clean up events impacted water quality?	How has the timing of the phenophases changed over time?
Communicating about Geography	Looking at others' data; sharing maps	Sharing information about impact of advocacy, clean up events	Looking at others' data; sharing maps; writing school reports

A second set of standards through which to look at the value of FieldScope is to align its capabilities with the practices of science as identified in the Next Generation Science Standards (NGSS). For example, the science standards include elements, such as modeling, that are part and parcel of geographic practices. Below is a description the capabilities of FieldScope of the science practices and the ways FieldScope support learning these practices.

Figure 16. How FieldScope Can Help Users Engage with the Practices of Science

Practice of Science	Related FieldScope activity
1. Asking questions (for science) and defining problems (for engineering)	Teachers went through exercises of asking questions about watersheds
2. Developing and using models	A map is a model of the world. By isolating certain characteristics of the model (e.g., layers), students gain better understanding of the purpose and function of a model, as well of the limitations of models
3. Planning and carrying out investigations	The nature of FieldScope allows students to design and carry out investigations, then to

	enter their own data. Limitations of entry parameters may mean that students can't do everything they're interested in, but there is a wide range of data currently available
4. Analyzing and interpreting data	Through maps, students can analyze data through pattern matching and recognition
5. Using mathematics and computational thinking	In addition to maps, FieldScope allows for tabular representation of data, which can be used for computational problem solving
6. Constructing explanations (for science) and designing solutions (for engineering)	Elements of causal relationships are inherent in FieldScope, such as the watershed feature, which can easily be used to construct explanations. Students can use changes over time and other features as well.
7. Engaging in argument from evidence	Abundant data in FieldScope provides the opportunity for students to engage in original argumentation using authentic data.
8. Obtaining, evaluating, and communicating information	FieldScope allows the creation of visual representations that can then be communicated to others. In addition, FieldScope provides the opportunity for students to compare explanations and learn to evaluate the quality of data.

Challenges Encountered During the Evaluation

The development of FieldScope required more time than initially planned. As with many other software development projects an iterative approach was used. Several versions of FieldScope were developed and piloted with selected users before a version with sufficient capability was available for broader audiences. The user interface was updated just prior to the last year of the award. This created delays in the development of end user documentation and training, which in turn created delays in the full implementation.

Working with Partners

Two key partners, FrogWatch and BudBurst, chose to implement FieldScope differently and these implementation decisions led to very different impacts on the organizations and their participants. While we learned from both experiences, additional work with other partners would be required to fully understand how to motivate citizen science participants to want to explore the citizen science data beyond simply entering their own data. This project did not gather sufficient information on what combination of usability features, training, pre-requisite knowledge and GIS capabilities, etc., would be needed to create a pool of citizen science participants willing and able to use FieldScope to delve into their project's data and gain the insights (science, sustainability, climate change, etc.) their projects desired.

It was also clear that different citizen science organizations "look at the world differently" and thus may require different capabilities of the GIS. Trying to meet the needs of different organizations looking for different ways to analyze, visualize and even enter data created an ever-increasing set of requirements that extended the software development phase.

FrogWatch pilot-tested FieldScope with several chapters in project Year 4 and, based on those results, rolled out FieldScope for data entry to all chapters in project Year 5, the final year of the award. As a result, there was a limited window for participants to become familiar with FieldScope and use it before we conducted the final impact evaluation. In Year 5, the program focus was on getting participants to enter their data using FieldScope. We were unable to gain insights into how the use of FieldScope for more than data entry, and over multiple data collection seasons, might have impacted the skills, knowledge, and attitudes of FrogWatch volunteers. The evidence we have from the pilot chapters does indicate that increased use of FieldScope increases the connection of participants to the FrogWatch citizen science project and other hoped for outcomes.

BudBurst made an early decision that participant observations would be sent directly to the BudBurst organization and the organization would do bulk uploads of the data to FieldScope. Since participants were not required to use FieldScope for data entry, their connection to FieldScope was indirect, through a link on the BudBurst website. While BudBurst described FieldScope in newsletters and on their website, this may not have been sufficient impetus to drive users to the FieldScope site, to “look around” at the other features and capabilities.

Project Builder Tools

In addition to creating the GIS capabilities, National Geographic attempted to create a development environment in which citizen science project owners could create their own customized project website using a set of ProjectBuilder Tools. A set of tools was developed in Year 4 and several organizations piloted them to create their own project websites. We found that the process to create a custom site required significantly more support than anticipated, so this capability was not rolled out for more general use. There is still a very big need in the citizen science world for organizations to be able to autonomously develop FieldScope projects, so further development of project builder tools should be considered.

User FieldScope Challenges

The most useful feedback we have about FieldScope use comes from FrogWatch participants and NOAA teachers. The biggest criticisms were that they did not find FieldScope a convenient method for data entry. For people who were accustomed to submitting data on paper or via email, FieldScope was a new method that would take time to become routine. FieldScope likely was more difficult to get used to for people who are less computer savvy. Other feedback included that data analysis could be more user-friendly. There were many other specific recommendations for further improvement, such as developing an app and removing the current Flash features on the website—most of these are software development-related and thus outside the scope of this evaluation.

Beyond using FieldScope for data entry, users need to have a purpose and an understanding of what they might learn, or a guiding question, to motivate them to use additional FieldScope features. This thought process came naturally to many but for other participants, there did not appear to be any question motivating them to look more deeply. This could be a lack of technical know-how or knowledge about what a GIS can provide, or it may be that many citizen science participants are satisfied with providing data and are not interested in a deeper experience with FieldScope and/or their organization's mission. The value to citizen scientists and to citizen science in general of enriching participants' experiences to accomplish more of the organization's goals needs further exploration.

Additional or Future Research Questions

This work has provided insights into how technology can support citizen science projects. We have seen opportunities for increased data quality, in data entry (through the use of embedded ranges and values) and in data review (through different visualization tools). We have seen opportunities to disseminate data more widely, through publicly available data presentation tools. We have begun to explore questions about how the mode of training might influence participants, and how and to what extent people use the technology. There remain, however, many questions yet to be addressed.

First, what does it take to teach someone how to use a Geospatial Information System? These systems are highly complex, and evolve rapidly. Many of the concepts used in a GIS, such as surface features or watersheds, are unfamiliar to the general public. Some of the features, such as data layers, are not tools commonly found in technologies people use on a regular basis. Self-training is difficult when one is not sure what questions to ask of the data, much less how to display the data in ways that will answer the question.

Future GIS-enabled projects, whether they are working with citizen science participants, teachers or students, start by better understanding 2 aspects of GIS—how to make the interface as intuitive as possible for participants who do not understand what a GIS is, and how to build their skills to bridge the gap between what they do know and what they need to know to use a GIS effectively. An analogy would be teaching someone who does not know what a spreadsheet does, how to use formulas—they may learn how to use formulas but they likely won't know when and why to use them. In the various projects that were funded by this award, the different approaches used to train users all yielded inconsistent results. While improvements were made to the user interface in the latest version of the software, to make it more intuitive and the functionality more logical, it is not clear from the results that citizen science users or teachers were willing to invest the time it would require them to become proficient FieldScope users. A deeper look at how people learn to use a GIS and to think geospatially is needed and this probably will require looking at differences for different populations, teachers, students, citizen scientists, etc.

Relatedly, we should learn more about how appropriate a GIS is for different age groups or age ranges—and learn more about what sorts of scaffolding can support different ages or types of users. What geographic concepts do users require before they can start to understand the tools available to them? Conversely, how can using a GIS support the learning of geographic concepts? In other words, what are the learning progressions for understanding a GIS?

Second, we should learn more about the relationship between participation in citizen science and the motivation to learn a new technology (in this case, a GIS). For example, does one's interest in frogs or protecting amphibian species provide the motivation to learn a new technology, so that one can learn more about frogs or so one's data can be better used for protecting amphibian species? What does it take to motivate someone to learn the technology? This may happen in reverse as well: an individual might be motivated to learn a GIS because it is a new technology and it provides unique data visualization capabilities but, through applying their new learning to specific data, becomes motivated to join a citizen science program. Can GIS, then, be used almost as a recruitment tool for citizen science programs?

Related to these questions, we know very little from this evaluation what how much *learning* itself motivates individuals to join a citizen science project. According to past studies, citizen science volunteers are mostly motivated by two factors to participate in scientific projects. The first factor is personal interest in the citizen science project and curiosity or thirst for new knowledge in related areas (Cronje, Rohlinger, Crall, & Newman, 2011; Rotman et al., 2012). The second factor is the desire to contribute to scientific research while being recognized (Raddick et al., 2010; Rotman et al., 2012). A person may be motivated to join FrogWatch USA because she loves frogs. Someone else may join Trash Free Potomac because she is concerned about the environment and wants see trash removed from her neighborhood. Another person may join Project BudBurst because she wants to participate in the experience of science and thinks it is important for scientists to have good data. For many individuals, these are the primary motivations for joining citizen science projects. We have little evidence from our project that individuals join citizen science projects because they are motivated by learning.

This does not mean that they do not take advantage of the opportunity to learn when it presents itself, and it does not mean that they do not appreciate whatever learning occurs. For example, the person who "loves frogs" may be excited to learn more about their habitats, their mating patterns, and how the health of the different species has changed over time—but this was not her primary reason for joining. This is an important distinction, because the extent to which people are persistent at a task or challenge—for example, how many times they are willing to redo a procedure because it is not working, or how long they are willing to spend reading about technology, watching videos—is related to their motivation to learn (Cooley, Ayres & Beaird, 1994; Feather, 1962; Maehr & Braskamp, 1986; Multon, Brown & Lent, 1991).

Finally, how can we measure Geospatial Reasoning? As citizen science projects, informal learning organizations, schools, and other educational programs incorporate geographic concepts and practices into their curricula, they will want to know if their work is having an impact. To understand the extent that people gain geospatial reasoning and awareness requires the capability to measure those skills. While there are measures of spatial awareness and aptitude such as the Spatial Thinking Abilities Test (STAT) (Lee and Bednarz 2009, 2014), we found no measures that focus on the practices of geography and how those change through use of a GIS, nor did we find a measure that is appropriate for children. As part of this award, a team from the Lawrence Hall of Science and National Geographic created and piloted a draft Geospatial Reasoning Instrument. National Geographic's *Road Map Project* provided the basic blueprint for the instrument, and we opted to focus on four of the six Geographic Practices: Acquiring Geographic Data; Organizing Geographic Data; Analyzing Geographic Data; and Answering Geographic Questions and Solving Problems. We felt that the others (Posing Geographic Questions and Communicating with Geographic Information) would be too difficult to assess in a multiple-choice instrument.

Multiple iterations of the instrument were developed. Staff from the Lawrence Hall of Science developed the first set of items. These first items were based on the geographic practices above and attempted to address low, medium, and high levels of skill. Approximately two to three items were generated for each practice. Next, Hall staff conducted cognitive labs with high school students to understand how respondents interpret questions and how they interact with the platform or administrative environment. Based on feedback from these cognitive labs, Hall staff revised the items and identified gaps where new or more items were needed.

After an initial pool of items was generated, Hall staff conducted a small pilot to investigate how these items worked as a scale. The instruments were pilot tested at middle schools (approximately 250 students) to determine poorly performing items and ensure adequate spread of difficulty level and coverage. Initial results indicated that items were needed that more deeply focused on the geospatial reasoning construct and relied less on other sets of knowledge and ability.

In order to generate new items, the Lawrence Hall of Science and National Geographic convened a meeting of geographers and geography professors to write new items for each of the identified constructs. The workshop lasted a full day, and participants also contributed additional items after the completion of the workshop. The new items were incorporated into the instrument, and then the entire instrument was administered in a second field trial (with 257 students in multiple classrooms). After a series of psychometric and statistical analyses, a second revision was made. While progress has been made in terms of developing and identifying items that can be used to measure geospatial reasoning, the instrument is not yet complete. The GRI would benefit from further iterations of the current items and the addition of more items including more difficult items. As the instrument improves it will become increasingly useful to create a description of intended uses of the instrument to clarify the appropriate inferences to draw from scores. Further, we suggest that moving away from classical test theory as a means to assess ability using this instrument to using more sensitive methods like item response theory to generate student scores.

A full description of the instrument, the development process, the current state of the instrument, and future development goals can be found in Appendix B.

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APPENDIX A: Evaluation Methods

The evaluation was conducted in Project Years 1-3 by Peer Associates and in Years 4-5 by the Research Group at the Lawrence Hall of Science, University of California, Berkeley. Data collected by PEER Associates were shared with the Lawrence Hall of Science. The main focus of the evaluations conducted by PEER and the Lawrence Hall of Science was on the impact of FieldScope on the testbed partner organizations and on the participants themselves. The New Media Consortium conducted the evaluation of the technology.

The evaluators were engaged in regular meetings with the program and partners. In addition to weekly meetings to ensure the alignment of the evaluation to the program work, evaluators participated in meetings designed to hone the evaluation questions.

Evaluation Questions

The evaluation questions were divided into two main groups: 1) Impact on Organizations and 2) Impact on Individual Participants. The questions morphed over time, as the technology and its use emerged over the course of the project. The complete set of evaluation questions were:

Questions about Impact on Organizations

- Does implementation of FieldScope (FS) help increase organizations' participation and retention rates?
- Do projects have a more diverse participant group at the completion of the FS implementation than they did at the start?
- How does staff capacity change within partner organizations? Do staff have more time for other (more analytic) work such as using data for actions or policies? OR, What is the benefit of using FS for organization staff? For data storage? For data use? For data "ownership"?
- Do projects that use a chapter or leader model find that chapter/event leaders are more involved with data collection, data input, data use at the completion of the FS implementation than they were at the start?
- What is the potential for FS to contribute to high-quality scientific data collection? To make contributions to scientific knowledge? Are data available and accessible to the scientific (professional and non-professional) community?
- How does an organization's implementation of a FieldScope-enhanced citizen science program affect its outcomes?
- How did the organization plan to use FieldScope (what changes to operations such as data collection, analysis, and volunteer interactions)?
- Did participating organizations make any changes to operations such as data collection, analysis, and volunteer interactions as a result of implementing FS? If so, what changes did they make and why?
- What are partner organization goals for participants/end-users? How does FieldScope help organizations help their participants meet those goals?

Questions about Impacts on Individual Participants

- What is the experience of public participation in science research (PPSR) organizations in using the Project Builder Tools to create their FS projects? Maybe their "data entry and analysis capabilities"? Their websites will likely exist with or without FieldScope. Information will be collected to examine:
  - How did the FieldScope implementation change the participants' experience with the *project*? (Entering own data, training)
  - How does the user experience using FS differ by organizational model?
  - What is the FieldScope user experience? How do they use it? When? Where? Why? How often? What difficulties do they encounter? What benefits do they see for themselves and their communities?
  - How does use of FS influence the user CS experience? Do they collect more data? Do they spend more time looking at organizational data?
  - How does participant/user content knowledge change after using FS for a field season?
  - How does participant/user attitude towards the environment and stewardship change after using FS for a field season?
  - How does participant/user perceived autonomy and competency beliefs change after using FS for a field season?
  - How does participant/user engagement with the project change after using FS for a field season?
- Is the way participants learn FieldScope related to how well or how likely they are to actually use FieldScope?

Data collection

In order to address these questions, the evaluators conducted a wide range of different data collection events, ranging from observations to interviews. This section summarizes the different data collection events.

Engagement in Partner Meetings. In June 2013 and October 2014, members of the evaluation team from the Lawrence Hall of Science participated in the annual meeting of the partner organizations. This participation included listening and recording the conversation as well as gathering feedback on the evaluation design. From listening, the evaluators learned much about the context of FieldScope implementation by different partners, gathered information about the challenges the partners had encountered, and were able to refine the interview protocol and understand critical questions to ask in the surveys of participants. Engaging the partners in the refinement of the evaluation design ensured that the questions being asked were highly relevant to the partners, that they were interested in the process, and that the data collection as planned would be effective, efficient, and meet their privacy and confidentiality needs.

Surveys. The main survey instruments were deployed in Summer 2015 after FieldScope had been "live" for all test-bed partners for one year. The goal of the surveys were to understand the participant perspective on the usefulness of FieldScope and to ask them to gauge the impact access to FieldScope had on their citizen science experience. Because FieldScope was implemented in different ways in different organizations, the specific audience that received the survey varied. Response rates were generally low, particularly for the two projects where users are not required to use FieldScope (Project BudBurst and Trash Free Potomac).

Project BudBurst (PBB) general users: PBB users are not required to interact with FieldScope. They enter their data into a website generated by PBB; data entered here are then synced with the FieldScope maps. Users are provided with the option of viewing data on either the PBB website or on the FieldScope website. In order to distribute the survey to users, PBB published a link to the survey in its newsletter and also included a link on its website. An unknown number of people saw the links in the newsletter and website. Only seven individuals responded to the survey, so numerical data are not reported.

Project BudBurst CSA 502Course Participants: Over 85 educators participated in the course “Using Project BudBurst Data for Advanced Analysis and Visualization” (CSA 502). PBB sent a link to all participants, asking them to complete the survey. The survey focused on how useful they found the course as well as whether and how they intend to use FieldScope with their students.

Trash Free Potomac Event Leaders: TFP Event Leaders are not required to use the FieldScope website. They enter their data into a different website or email their data to the Alice Ferguson Foundation (AFF). Data are then synced with the FieldScope map. AFF provided emails of Event Leaders to the evaluators, who then sent a link to the survey to all leaders. At the time, AFF noted that not all individuals in the database had participated in the last two years, so many were likely not familiar with FieldScope. The survey was emailed to 299 users; 12 email addresses were invalid. A total of 44 users responded to the survey, for a response rate of 15%.

FrogWatch USA (FW-USA): FW-USA participants are encouraged to use FieldScope. Because FW-USA participants needed to register with FieldScope in order to create and site and enter their data, we were able to email all registered users directly. In addition, FrogWatch USA emailed a survey link to other participants, in hopes that we could capture a few individuals who did not use FieldScope. Because, as we learned from interviews with and surveys of chapter coordinators, many of the non-users do not use email or computers, it is unlikely that many non-FieldScope users were contacted in this way. Overall, FW-USA response rate was approximately 26% (296 out of 1,100 users).

Observations. A member of the evaluation team observed one of the trainings conducted by the national office of FrogWatch, USA. This involved observation of the event as well as participation (and certification) in the training itself. The evaluator took extensive field notes and recorded questions and concerns about FieldScope as well as gauged the level of enthusiasm for using the tool. Members of the National Geographic team conducted further observations, and these data were shared with the evaluators.

Interviews. A member of the evaluation team conducted a series of interviews with many different user groups. Interviews were used to provide more detailed information about how FieldScope worked for the users—how they benefited and what challenges they encountered. Interviews provided the opportunity for the evaluator to ask clarifying and follow up questions and to allow users to raise and discuss issues that the evaluator might not have considered.

Testbed partners: At the onset of the project, PEER Associates conducted a series of interviews with members of the staff at the different testbed partners who would be working on or engaging with FieldScope. The main purposes of the initial interviews were to understand the reasons for participating in FieldScope and the partners' plans for using the tool. At the conclusion of the project, in spring and summer 2015, after the Lawrence Hall of Science conducted a series of interviews with testbed partners. The focus of these interviews was to understand if the tool had helped the partner meet its stated goals, and what unexpected benefits—or challenges—emerged during the course of the five-year project.

Project BudBurst CSA 502 Participants: Seven CSA 502 participants were interviewed after they completed the program. The purpose was to understand what they learned from the program and how they intended to implement their learning in an educational setting.

Trash Free Potomac Event Leaders: In Fall 2013, we interviewed three Trash Free Potomac Event Leaders. The purpose was to understand their goals for participating in the program, how they learned about FieldScope, how they used it in their program, and how they believe access to FieldScope impacted their organization.

FrogWatch USA chapter coordinators: There were six chapters that piloted the FieldScope tool for FrogWatch USA. In Fall 2013, we interviewed five of the six chapter coordinators; the sixth was out on medical leave. The purpose of the interviews was to understand how they were trained on FieldScope, how they trained or intended to train their volunteers, how they hoped FieldScope would benefit their chapter and their volunteers, and any challenges they had using the program.

Project Builder Tool Users: In Spring 2015, we interviewed seven Project Builder Tool users. The purpose was to understand their experience working with NGS to build out a project of FieldScope. They were also asked about if and how their program would continue to use FieldScope. Much of the conversation focused on challenges, potential for scale, and sustainability.

Data Analytics. Usage data were available from the FieldScope logs and from Google Analytics. The logs included available data such as: date and time of visit, IP address, city and state, type of action (e.g., create layer), length of action, and organization. In general, multiple logs were downloaded and combined to create a single log. For example, data could be downloaded from different Project BudBurst pages; to create a more complete picture of how many people visited all the relevant pages of the website, multiple logs were downloaded, and duplicate entries (where relevant) were eliminated. The logs functioned as a good approximation of the number of visits to the different FieldScope sites.

Challenges of the evaluation

Although not exceptionally problematic, the evaluation encountered a few challenges that made it difficult to ensure highest rigor. Among the challenges faced:

Limited direct access to participants. The testbed partner organizations varied in their willingness to provide direct access to participants. Convincing the partners to contact and recruit participants was challenging in some cases, and there were minor issues regarding whether partners were willing to collect demographic data. To further complicate matters, the testbed partners often use other partner organizations themselves to recruit volunteers, so that they themselves may not have direct access to participants or volunteers.

Limited use of FieldScope by some organizations. While FieldScope is the primary user interface for FrogWatch USA, it is not for Project BudBurst or Trash Free Potomac. This means that many people who volunteer for PBB and TFP are not necessarily aware of nor, even if aware of, do they use FieldScope. This limited the number of participants who could be surveyed or interviewed about the project.

Delays in deployment. Because of delays in full implementation of the FieldScope software, we were able to conduct only one round of major data collection. This is particularly true of some Project Builder Tool partners, for whom the tools were not complete before their projects were complete.

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DEVELOPMENT OF A GEOSPATIAL REASONING INSTRUMENT

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NOVEMBER 2015

CONSTRUCT BACKGROUND

Every day, people make decisions in their personal and professional lives about the world around them. These decisions require the knowledge and geospatial reasoning skills to work across environmental, cultural and geographic boundaries.

The People's Guide to Spatial Thinking (Stinton et al, 2014) says "Spatial thinking is a form of learning how to learn, a practice that involves an ability to visualize and interpret locations, positions, distances, and movements. The National Science Board has identified spatial thinking skills as on par with quantitative and verbal reasoning skills in so far as success in STEM innovators can be identified."

Children and adults alike need to not only be geographically literate but also capable of geospatial reasoning. More and more, advocates for civic engagement stress the need for adults to have the skills needed to wrestle with globalization, community development, environmental threats, and the depletion of natural resources.

As more formal and informal programs seek to build geospatial reasoning skills, they need a way to determine to what extent learners are acquiring these skills. To meet this need, we are developing an instrument that measures geospatial reasoning skills in a way that is independent of content and context.

Potential audiences include any group collecting, analyzing, or interpreting geospatial data such as

1. Formal education students (K-12 settings)
2. Citizen science volunteers
3. Informal education participants

In the next section, we describe the underlying practices of geospatial reasoning that guided the construction of the instrument.

DEVELOPMENT OF INSTRUMENT

The development of the geospatial reasoning instrument has been an iterative process. We began with identifying constructs, then developed items. Those items were tested on middle school students, then revised. The revised instrument was again tested with a larger number of students. This process is described in detail below.

Identification of main constructs. We started with defining the constructs of interest, the behaviors that would be indicative of those constructs, and the proportion of the instrument devoted to measuring each construct of interest. We began the process with the National Geographic's "A Road Map for 21st Century Geography Education" which lists six geographic practices, four of which are most appropriate for this instrument. The practices we used to guide the development of the GRI were:

1. **Acquiring Geographic Data:** Geographic information is any information connected to a location that includes data about physical and human characteristics or phenomena at any place on the planet.
2. **Organizing Geographic Data:** Once collected, the geographic information should be organized and displayed in ways that assist with analysis and interpretation. Data need to be arranged systematically.
3. **Analyzing Geographic Data:** Analyzing geographic information involves seeking patterns, relationships, and connections. As students analyze and interpret information, meaningful patterns or processes emerge.
4. **Answering Geographic Questions:** The answers that derive the other geographic practices can be organized in graphic form (maps, tables, graphs, and other geo-visualizations) as well as oral and written narratives. Whatever the format, responses must be based on provable and relevant facts that inspire interpretation, analysis, reasoning, and, when appropriate, the subtleties of inference.

Initial item writing. Staff from the Lawrence Hall of Science developed the first set of items. These first items were based on the geographic practices above and attempted to address low, medium, and high levels of skill. Approximately two to three items were generated for each practice.

Cognitive labs with high school students. The items were put through their paces in cognitive labs with high school students to understand how respondents interpret questions and how they interact with the platform or administrative environment.

Revision of items. Items were refined based on feedback from cognitive labs conducted with a set of students.

Initial pilot test with middle school students. Once an initial pool of items was generated, we conducted a small pilot to investigate how these items worked as a scale. The instruments were pilot tested at middle schools (approx. 250 students) to determine poorly performing items and ensure adequate spread of difficulty level and coverage. In order to enable disaggregated analyses of assessment results, participants' demographic data were also collected. This will ensure that we can consider issues of assessment bias and the appropriateness of the instruments for subjects from a wide range of backgrounds. Initial results indicated we needed items that were more deeply focused on the geospatial reasoning construct and relied less on other sets of knowledge and ability.

Item writing workshop. Staff from the Lawrence Hall of Science and National Geographic convened a meeting of geographers and geography professors to write new items for each of the identified constructs. The workshop lasted a full day, and participants also contributed additional items after the completion of the workshop.

Pilot test of assessment in middle schools. We then administered a larger field trial (n=257) across several classrooms across the United States and the United Kingdom. The results of this pilot test are presented in this report. A version of the survey is available for viewing in Attachment A.

Data analysis. We conducted psychometric and statistical analyses to ensure that the measure conforms to best practices in measurement and supports our efforts to develop multiple equated forms of the survey.

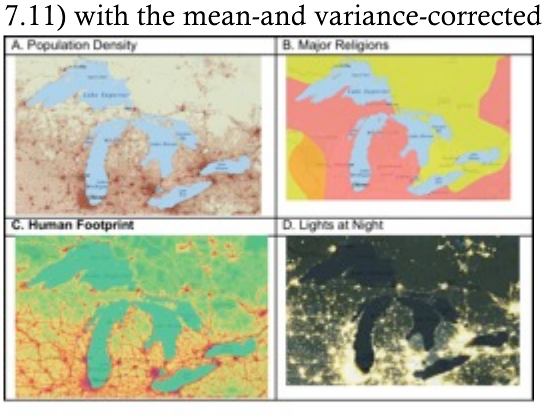
Final revision of instrument. Based on the data, we completed a final revision of the items, removing those that did not scale well with the other items. Our recommendations are included in Attachmen A, where the final instrument is presented.

PSYCHOMETRIC PROPERTIES

Reliability. Cronbach's alpha and the polychoric alpha are measures of internal consistency within a particular scale. The polychoric alpha accounts for the ordinal nature (e.g., Likert-scale) of the variables (Gadermann & Zumbo, 2012). A satisfactorily large alpha (i.e., >.80) implies that individuals responded similarly across the items.

As shown on Table 1, the raw scale reliability was not sufficiently large (α=.68) while the polychoric scale reliability was satisfactory (α=.81). Of the 23 items examined, three items (Q5, Q11, and Q23) were found to be negatively contributing to the scale reliability (i.e., the coefficient would be improved by deleting the item).

Exploratory Factor Analysis. Exploratory factor analysis (EFA) was used to identify the underlying latent factor among the measured items in the scale. All 23 GRI items were scored dichotomously (i.e., correct=1 and incorrect=0). Adequate fit to the model is determined by a satisfactory visual inspection of the scree plot, sufficiently large factor loadings on each item (>.30), and satisfactory fit statistics via the Root Mean Square Error of Approximation (RMSEA<.06), the Comparative Fit Index (CFI>.90), the Tucker-Lewis Index (TLI>.90) and the chi-square test of model fit (p>.05) (Costello & Osborne, 2005; Hu & Bentler, 1999; Byrne, 2010). EFA was conducted using *Mplus* (v. 7.11) with the mean-and variance-corrected weighted least squares estimator (WLSMV) with a moderate-sized sample (n=257). Subjects with missing data were included in the analysis via pair-wise (rather than list-wise) deletion.



The GRI scale was subject to exploratory factor analysis using forced one-factor, two-factor and three-factor solutions. As shown in Figure 1, the shape of the scree plot (i.e., an "L" shape) suggests a single dominant factor and a less dominant second factor. As shown in Table 1, the factor loadings were mixed for the one-factor solution. Two items (Q5 and Q23) were not significant, indicating that these loadings are essentially zero. Additionally, five items (Q2, Q11, Q13, Q14, and Q20) indicated significance, but were not sufficiently large (i.e., loadings were less than .30). In terms of fit statistics, the CFI and TLI resulting from the one-factor solution were below satisfactory (.868 and .855, respectively), but the RMSEA was satisfactory (.032). Additionally, the chi-square test of model fit was found to be significant (χ^2(230)=290.804, *p*<.01), thus indicating inadequate model fit. As a whole, these results indicate that the GRI (using all 23 items) is not unidimensional.

Alternatively, a two-factor solution showed satisfactory model fit statistics in regard to the RMSEA (.026), CFI (.924), and the TLI (.907), although not for the chi-square test of model fit (χ^2(208)=243.282, *p*<.05). Factor loadings for this model are shown in Table 1. When only considering items with loadings greater than .30, nine items indicated loadings to the first factor only (Q1, Q2, Q3, Q14, Q16, Q17, Q18, Q19, and Q22) and nine items indicated loadings to the second factor only (Q4, Q6, Q9, Q10, Q11, Q13, Q15, Q20, and Q21). The remaining five items (Q5, Q7, Q8, Q12, and Q23) showed factor loadings that were not sufficiently large for either factor.

Finally, a three-factor solution was utilized, which indicated satisfactory model fit on all set conventions (RMSEA=.023; CFI=.945; TLI=.925; χ^2(187)=212.463, *p*=.098). As shown on Table 1, eight items indicated loadings to the first factor only (Q1, Q3, Q6, Q7, Q12, Q14, Q15, and Q22). Five items indicated loadings for the second factor only (Q4, Q9, Q10, Q11, and Q20). Only three items indicated loadings for the third factor only (Q16, Q17, and Q18). Two items (Q19 and Q21) showed double loadings (factors 1 and 2 for Q21, and factors 2 and 3 for Q19). The remaining five items (Q2, Q5, Q8, Q13, and Q23) did not show sufficiently high loadings for any of the factors.

Figure 17: EFA Scree Plot

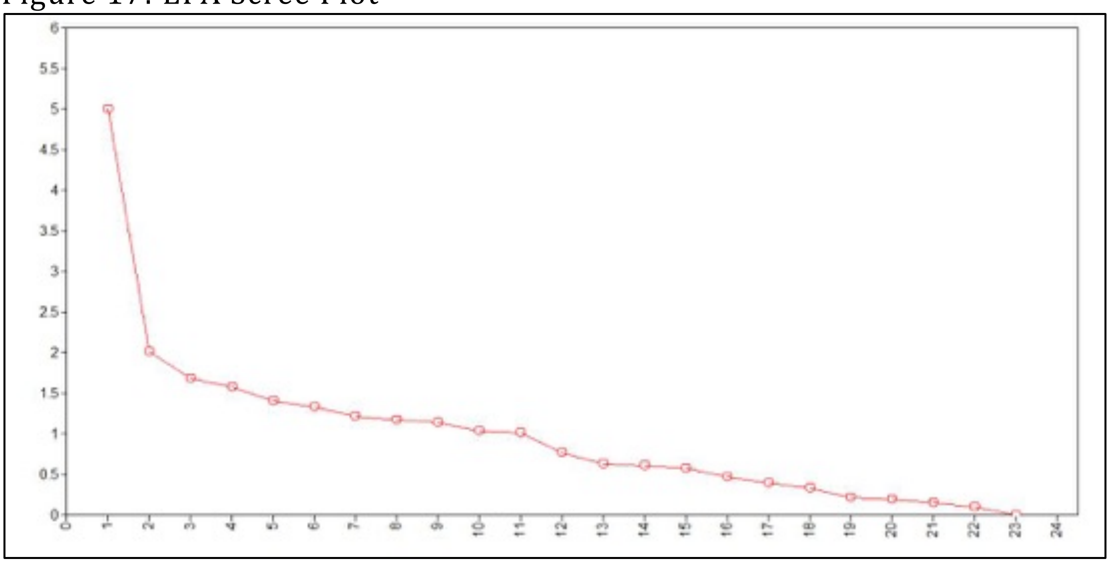


Table 1: Reliability and Factor Analysis Results for the Geospatial Reasoning Instrument

	Reliability		Exploratory Factor Analysis					
	Alpha if Deleted		1-Factor	2-Factor		3-Factor		
Items	Raw	Polych.	Factor 1	Factor 1	Factor 2	Factor 1	Factor 2	Factor 3
Q1	0.67	0.80	*0.615	*0.564	0.169	*0.635	-0.004	0.130
Q2	0.68	0.81	*0.266	*0.309	0.003	0.299	-0.071	0.089
Q3	0.67	0.80	*0.563	*0.699	-0.038	*0.589	-0.192	0.303
Q4	0.67	0.81	*0.428	0.157	*0.396	0.086	*0.386	0.187
Q5	0.69	0.82	0.144	0.228	-0.061	0.087	-0.066	0.177
Q6	0.67	0.80	*0.502	0.290	*0.342	*0.340	0.250	0.102
Q7	0.67	0.81	*0.389	*0.270	0.213	*0.422	0.084	-0.020
Q8	0.67	0.81	*0.342	0.152	*0.283	*0.297	0.187	-0.030
Q9	0.67	0.80	*0.443	-0.076	*0.695	0.038	*0.698	0.001
Q10	0.67	0.81	*0.324	0.005	*0.423	-0.002	*0.432	0.092
Q11	0.68	0.82	*0.199	-0.156	*0.439	-0.030	*0.424	-0.057
Q12	0.67	0.81	*0.343	0.203	0.226	*0.327	0.123	-0.009
Q13	0.68	0.81	*0.272	0.049	*0.303	0.190	0.240	-0.058
Q14	0.68	0.81	*0.247	*0.334	-0.040	*0.447	-0.175	-0.018
Q15	0.67	0.81	*0.341	0.075	*0.370	*0.422	0.236	-0.234
Q16	0.67	0.81	*0.420	*0.517	-0.025	0.142	-0.011	*0.471
Q17	0.67	0.80	*0.633	*0.742	-0.008	0.221	0.013	*0.651
Q18	0.67	0.80	*0.696	*0.652	0.172	0.058	0.255	*0.700
Q19	0.66	0.80	*0.680	*0.569	*0.255	-0.021	*0.367	*0.714
Q20	0.68	0.81	*0.272	-0.037	*0.396	-0.032	*0.414	0.061
Q21	0.66	0.80	*0.594	0.241	*0.527	*0.426	*0.392	0.006
Q22	0.66	0.80	*0.590	*0.456	*0.271	*0.598	0.088	0.067
Q23	0.69	0.82	0.130	-0.069	*0.247	0.209	0.159	-0.223
Scale	0.68	0.81						

*Statistically significant (p<.05) for null hypothesis that the factor loading equals zero.

SUMMARY.

In terms of model fit, a three-factor solution is suggested by the EFA when using all 23 items. However, the presence of double-loading items in the three-factor model is indicative that a modified two-factor model may be more appropriate. Given the appearance of the EFA scree plot, even a modified one-factor model may be sufficient.

It is notable that in all three EFA models (i.e., one-, two-, and three-factor), several items were present that were either non-significant or not sufficiently large in their factor loadings. Further, the polychoric reliability coefficient indicated several items that were negatively contributing to internal consistency. In general, these results indicate that these items are not useful to the scale, thus, modifications may be necessary.

One possible modification to the GRI is the removal of the problematic items that do not appear to be useful in the instrument (those with negative contributions to reliability or double factor loadings, i.e. Q5 and Q23). Another suggestion is a modification of items the items themselves or in how the items are scored (e.g., allowing for partial credit, i.e. Q2, Q11, Q13, Q14, Q20). Repeating the EFA with these modifications will yield changes in model fit and, consequently, the number of viable factors in the GRI. It is unclear what specific actions should be taken to improve the problematic items. In general, these items appear to be more difficult than other items on the scale, which may indicate that testing the tool with a more sophisticated population is warranted prior to making final conclusions regarding the utility of particular items. In general, we highly suggest a series of cognitive interviews with the target population for this instrument to determine sources for confusion and ways to improve the items to better align with the rest of the tool.

NEXT STEPS

The instrument has reached a stage in development where it is ready for further field-testing and revision. While this instrument appears to be a good measure of a single concept associated with geospatial reasoning, there are elements that should be considered and developed in more detail.

Multiple dimensions. The factor analysis we performed demonstrates one resulting factor, but we hypothesized that there were multiple dimensions or practices that are components of geospatial reasoning. The use of additional items may be able to detect that the different dimensions correspond with different cognitive skills or states of mind. The limited number of items developed as of this point are not able to detect the existence of multiple dimensions.

Appropriateness for multiple contexts. The current instrument was designed with middle school students in mind. We envision that it is developmentally appropriate for multiple audiences, but this needs to be demonstrated. The instrument should be tested with high school students and adults, including undergraduate students.

Application in research on geospatial reasoning. One main goal we have is to understand how individuals develop geospatial reasoning skills. It is hoped that this instrument, by being applied in multiple contexts with multiple audiences, will enable us to understand more about how people learn and apply geospatial reasoning skills.

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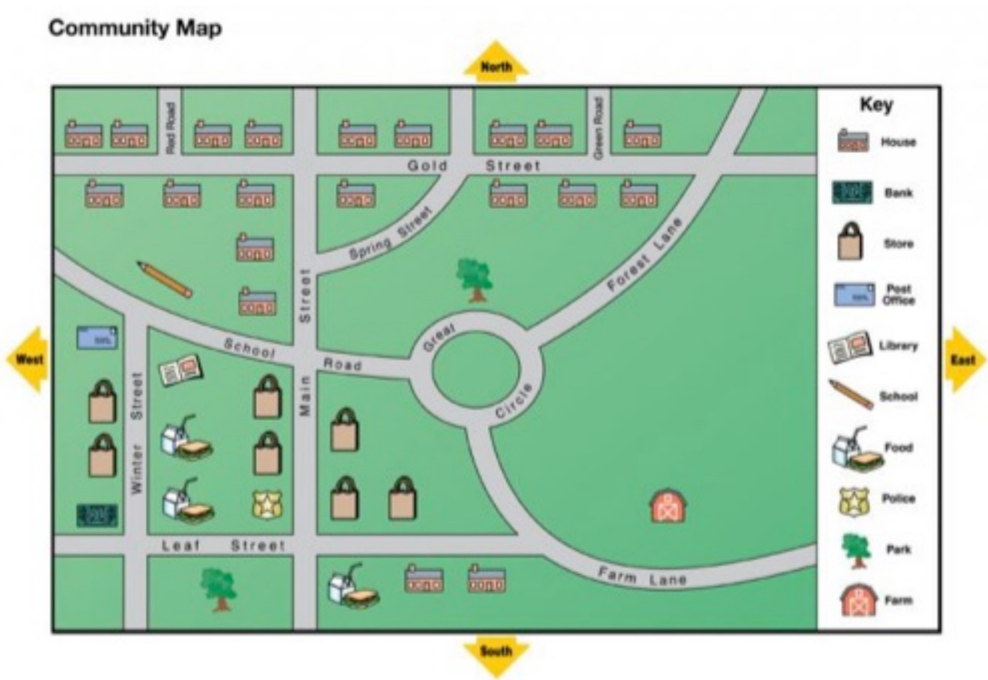
Attachment A

National Geographic Society and the Lawrence Hall of Science

This survey asks questions about maps, geography and how you use this information to make decisions. Your responses to these questions will help us understand what you know about maps and how to use them. Thank you for taking our survey.

DIRECTIONS: Use this map to answer the questions that follow.



1. If you start at the police station and walk north on Main Street, what street will you cross first?

- O A. Winter Street
- O B. Gold Street
- O C. School Road
- O D. Farm Lane

[ITEM Q2 is recommended for modification.]

2. What streets could you take from the post office to the farm?

- O A. School Street to Main Street to Farm Lane.
- O B. Winter Street to Leaf Street to Farm Lane.

This material is based upon work supported by the National Science Foundation under Grant No. DRL-1010749. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

O C. Farm Lane to Forest Lane to Winter Street

O D. School Road to Spring Street to Farm Lane.

3. What direction will you need to walk on Leaf Street to get from the Bank to the Police Station?

O A. North

O B. South

O C. East

O D. West

4. What is on the west side of the street when you walk north from the police station on Main Street, and cross through School Road?

O A. House

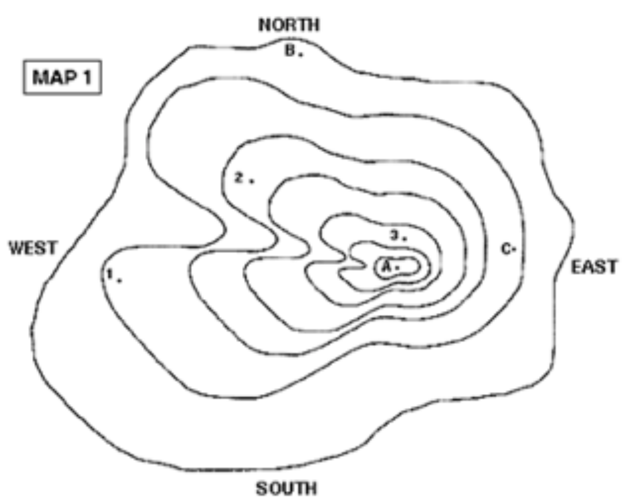
O B. Post Office

O C. Park

O D. Farm

[ITEM Q5 is recommended for removal]

DIRECTIONS: The map below is a topographical map of a hill surrounded by water. Point B is at an elevation of 10 feet. Each line represents an increase in elevation of an additional 10 feet. Use the map below to answer the questions that follow.



5.[5] Which side of the hill is the steepest?

- O *A. North*
- O *B. South*
- O *C. East*
- O *D. West*

6. Which point is at the highest elevation?

- O A. A
- O B. B
- O C. C
- O D. All the same elevation.

Nadje is studying human impact on the local ecosystems around Detroit Michigan. Below is a map of the Detroit area. What additional maps or layers may help her understand human impact in the area?

7. Select the best map or layer to help Nadje understand human impact in the Detroit area.

[5] Question from Ellen P. Metzger, Building A Topographic Model, available at: http://www.ucmp.berkeley.edu/fosrec/Metzger1.html

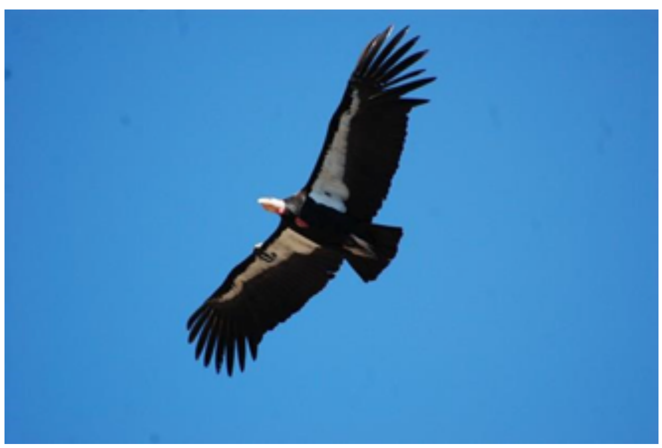
O A. Population Density

O C. Human Footprint

O B. Major Religions

O D. Lights at Night

You are trying to determine what is causing the decline of the condor population in a particular region of California. You think that the increased number of people living in the region is responsible for the decline. How would you collect information to answer this question?



8. How would you begin to collect information to answer this question?

O A. Record the number of people in places where the number of condors has stayed the same.

O B. Identify where in the region the number of people has changed the most over time.

O C. Compare the number of condors in places where the number of people has increased and where they have stayed the same.

O D. Measure the rate at which the number of condors has decreased in the region.

You are trying to determine what is causing the decline of the condor population in a particular region of California. You think that the increased number of people living in the region since 1970 is responsible for the decline.

9. Which of the following sources of information is relevant to the question being asked?

A map that shows:

O A. The areas in California at the elevation where condors live

O B. How many people lived in different parts of California in 1970

O C. Where in California the number of people is the highest this year

O D. Where in California the number of people has increased since 1970

Saraya is planting an orange grove in California's San Joaquin Valley. Below is a map of California and the San Joaquin Valley.

10. **Oranges cannot tolerate temperatures below 30 degrees. What additional map or layer may help her determine the best part of the Valley to plant oranges?**

O A. Minimum Temperature Map

O B. Average Temperature Map

O C. Maximum Temperature Map

O D. Today's Temperature Map

[ITEM Q11 is recommended for modification.]

11. **You are trying to determine what is causing flooding in one neighborhood in your town. You think that the amount of paved surface in that neighborhood causes the flooding. How would you collect information to answer this question?**

O A. Record the number of square miles of paved surface in the flooded neighborhoo

O B. Compare the amount of paved surfaces in the neighborhood to neighborhoods that have less flooding.

O C. Record the highest depth of water over the paved surfaces.

O D. Compare the highest depth of water over the paved surfaces in the flooded neighborhood to the depth in neighborhoods that have less flooding.

Use the following information to answer the next series of items:

- Average rainfall is the amount of water that falls as rain, snow, hail, or sleet in a specified area and time interval (in this case inches per year).
- Latitude is the vertical distance from the equator.

Forest	Distance to Equator	Mountains	Hemisphere	Avg. Rainfall (inches/year)
1	Far	No	Northern	40
2	Far	No	Northern	17
3	Far	No	Southern	280
4	Close	Yes	Southern	40
5	Close	Yes	Northern	63

12. How are the distance from the equator of the forest's location related to if the forest is in the mountains?

O A. The distance from the equator of the forest and if the forest is in the mountains are unrelated.

O B. Forests far from the equator tend to not be in the mountains.

O C. Forests far from the equator tend to be in the mountains.

O D. Forests in the Northern hemisphere tend to be in the mountains more than forests in the Southern hemisphere.

[ITEM Q13 is recommended for modification.]

13. How is the amount of rainfall related to forests being in the mountains?

O A. The amount of rainfall and the forest being in the mountains are unrelated.

O B. Forests far from the equator tend to have less rainfall than forests near the equator.

O C. Forests with less rainfall tend to be in the mountains.

O D. Forests with more rainfall tend to be in the mountains.

[ITEM Q14 is recommended for modification.]

Ajay and Julian are in Mrs. Armstrong's class. Mrs. Armstrong asked Ajay and Julian to compare arguments to see who used evidence drawn from the table above.

- Julian's Argument: The forests close to the equator are in the mountains. Measurements at the forests 4 and 5 show they are near the equator and all of them are in the mountains. These forests show that forests near the equator are in the mountains.
- Ajay's Argument: The forests close to the equator are in the mountains. Forests 1 and 2 are far from the equator and are not in the mountains. These provide more evidence that forests near the equator are at high altitudes.

14. Based on the information provided in the table above, which student, Ajay or Julian, better supports their argument? Why?

O A. Ajay, because he provides examples of forests far from the equator that are not in the mountains.

O B. Ajay, because he uses examples of forests from two different continents.

O C. Julian, because he provides examples of forests near the equator that are in the mountains.

O D. Julian, because he uses examples of forests from two different continents.

15. Julian is thinking of adding more evidence to his argument. Which piece of evidence below best supports his claim?

O A. Two forests in Europe that have 30 inches of rain fall.

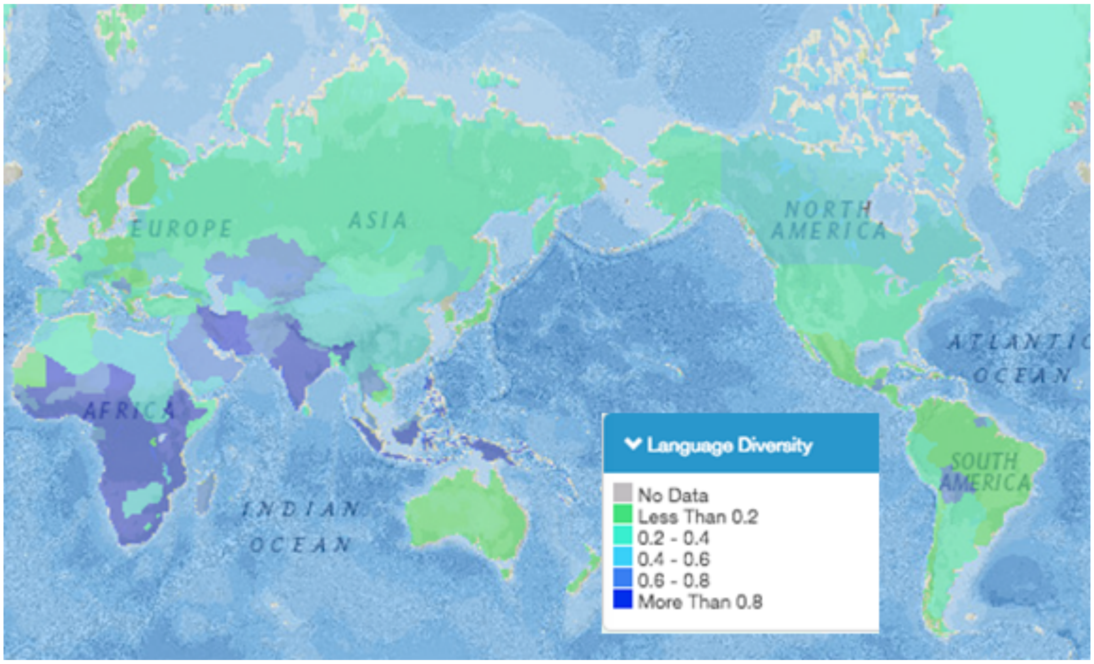
O B. A forest in Bolivia is near the equator and is in the mountains.

O C. The forests in Costa Rica are examples of forests near the equator.

O D. Hawaii is near the equator, but the forest there is not in the mountains.

This map shows the world's language diversity. The Linguistic Diversity Index measures the diversity of languages spoken in a country. The index ranges from 0 to 1. An index of 0 represents no language

diversity, meaning that everyone speaks the same language. An index of 1 represents total diversity, meaning that no two people speak the same language. No country in the world has an index value of exactly 0 or 1. Learn more about language diversity and the data in this map on our site. -
Source: Used by permission, (c) SIL International, Ethnologue: Languages of the World, 2009.



16. Based on this map what continent has the greatest language diversity?

- O A. Europe / Asia
- O B. North America
- O C. Africa
- O D. South America

Hispaniola is a Caribbean island that is the home of two countries, Haiti and the Dominican Republic. Below are four maps of the island of Hispaniola. The next three questions ask you to compare the maps and determine which map you might use to determine different information about this island.

17. Which map would you use to plan a driving trip around the island?

- O A
- O B
- O C
- O D

18. Which map best indicates the border between the two countries?

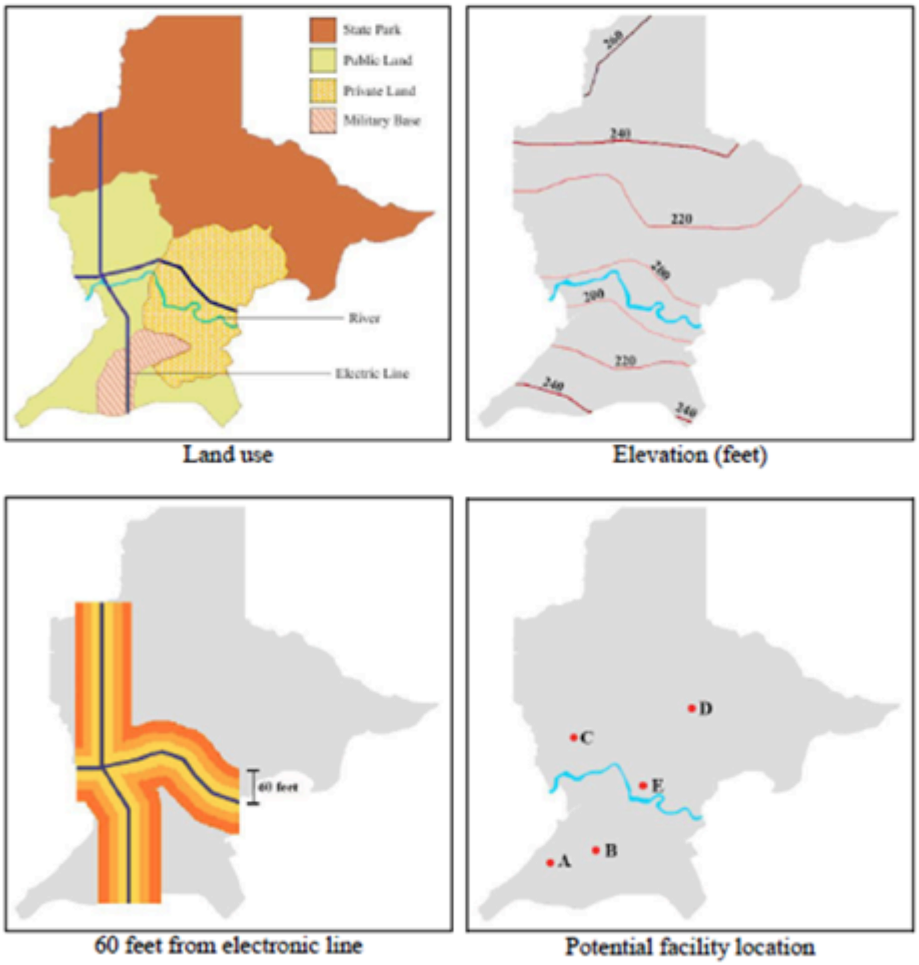
- O A
- O B
- O C
- O D

19. Which map best indicates where the mountain ranges are on the island?

- O A
- O B
- O C
- O D

[ITEM Q20 is recommended for modification.]

DIRECTIONS: Find the best location for a flood management facility based on the following conditions. First, a possible site for a flood management facility should be within 60 feet of an existing electric line. Second, a possible site for a flood management facility should be located at less than 220 feet in elevation. And last, a possible site for a flood management facility should be located in a State Park or Public Land.



20.[6] Which is the best site (A~E) for the flood management facility on the map above?

- O A
- O B
- O C
- O D
- O E

Real world objects can be represented explicitly by point, line (arc), and area (polygon). Here are some examples:[7]

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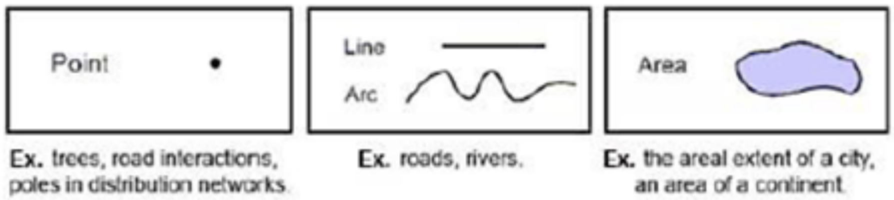
[6] Items 20, 21, 22 and 23 are from the STAT: Lee, J., & Bednarz, R. (2012). Components of spatial thinking: Evidence from a spatial thinking ability test. *Journal of Geography*, *111*(1), 15-26.



Based on the examples above, classify the following spatial data.

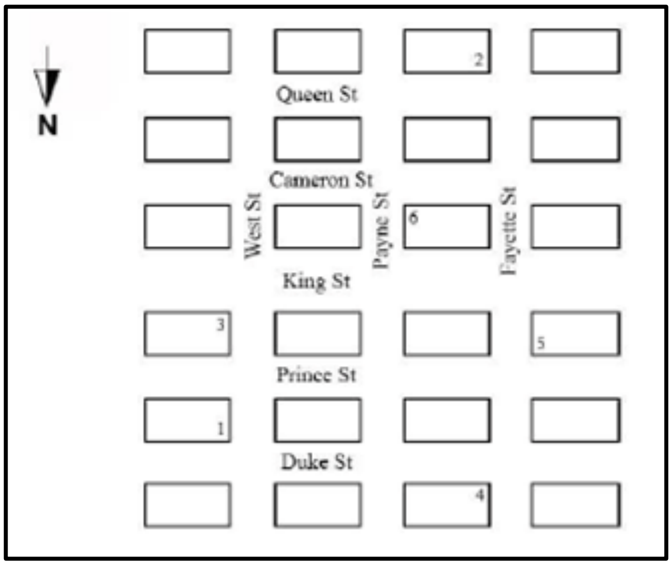


Figure A

21. Locations of fire hydrants in the town.

- O A. Lines
- O B. Area
- O C. Points
- O D. Points and Lines

22. (Based on Figure A) Path from Point 1 to Point 2.

- O A. Points
- O B. Area
- O C. Lines
- O D. Points and Area

[ITEM Q23 is recommended for removal.]

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[7] Wording for the introduction to this set of questions from AAG's Spatial Thinking Ability Test, introduction to questions 13-16. © 2006 Association of American Geographers. http://people.rit.edu/~bmtski/rw_stat/STAT_baseline_July_2013.pdf

23. **(Based on Figure A) Starting at point 6, the places that can be reached by car in five minutes or less.**

- O A. Points
- O B. Lines
- O C. Area
- O D. Points and Lines

Demographics

24. **What is your sex?**

- O Female
- O Male
- O Other [ ]
- O Prefer not to answer

25. **Tell us about your experience (past or current) with citizen science (crowd-sourced or volunteered science projects).**

- O I have not collected data or been involved in any citizen science projects.
- O I have collected data for one citizen science project.
- O I have collected data for two or more citizen science projects.
- O I have been involved with a citizen science organization but do not collect data.
- O I am a professional scientist collecting or working with data.

26. **How old are you?**

- O 21 years old or Greater
- O Under 21 years old

CORRECT RESPONSES

Q1 C	Q2 B	Q3 C	Q4 A
Q5 B	Q6 A	Q7 C	Q8 C
Q9 D	Q10 A	Q11 B	Q12 B
Q13 A	Q14 C	Q15 B	Q16 C
Q17 7	Q18 A	Q19 B	Q20 C
Q21 C	Q22 C	Q23 C	